Mondrian 3.0.4
Technical Guide

Developing OLAP solutions with Mondrian/JasperAnalysis

March 2009

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Introduction

This document summarizes in one place the available documentation from the Mondrian open source project, version 3.0.4. The contents are derived from documentation in the Mondrian code distribution.

The aim of this document is to provide a guide to the use of Mondrian, covering:

- Mondrian overview and architecture
- Developing OLAP schemas
- Querying cubes with MDX
- Tools and techniques for managing data and tuning query performance
- Integrating Mondrian into applications

The audience of this document is intended to be people creating and managing Mondrian based OLAP environments and developers who are integrating Mondrian into their applications.

JasperAnalysis and Mondrian

JasperAnalysis in JasperServer 3.5 is based on Mondrian 3.0.4 and the corresponding version of JPivot (the OLAP slice and dice user interface). JasperAnalysis modifies these base open source projects in the following ways:

Extensive changes to the JPivot user interface

- Revised Look and feel
- Expand and Collapse All
- Additonal display and output options
- Performance improvements for drillthrough against Mondrian cubes
- Fully internationalized text
- Save/Save As View to the JasperServer repository

Mondrian Integration with JasperServer

- Integration with the JasperServer repository
    - Schemas, Data Source definitions in JasperServer Repository
    - Access to resources controlled by repository permissions for users and roles
- Maintenance screens for Mondrian and XML/A configuration
- Mondrian and XML/A data sources for JasperReports
- Configuration of JasperAnalysis as an XML/A server, providing services to XML/A client such as Excel Pivot tables (Jaspersoft ODBO Connect) and other JasperAnalysis web clients
- Display of current Mondrian configuration settings

JasperAnalysis Professional Features

JasperAnalysis Professional Edition has additional features beyond what is provided in JasperAnalysis Community Edition.

- Performance Profiling Analysis and reports for SQL and MDX queries
- Data level security: user profile based fitering of OLAP results beyond simple roles
- Editing of current Mondrian configuration settings through the browser
- Excel Pivot Table ODBO driver: connects to JasperAnalysis and Mondrian to display and interact with JasperAnalysis hosted cubes

JasperAnalysis is documented in separate User and Administration Guides. In this guide, there are specific notes on where JasperAnalysis differs from standard Mondrian features.

Mondrian and OLAP

Mondrian is an OLAP engine written in Java. It executes queries written in the MDX language, reading data from a relational database (RDBMS), and presents the results in a multidimensional format via a Java API. Let's go into what that means.

Online Analytical Processing

OLAP (Online Analytical Processing) means analysing large quantities of data in real-time. Unlike Online Transaction Processing (OLTP), where typical operations read and modify individual and small numbers of records, OLAP deals with data in bulk, and operations are generally read-only. The term 'online' implies that even though huge quantities of data are involved — typically many millions of records, occupying several gigabytes — the system must respond to queries fast enough to allow an interactive exploration of the data. As we shall see, that presents considerable technical challenges.

OLAP employs a technique called Multidimensional Analysis. Whereas a relational database stores all data in the form of rows and columns, a multidimensional dataset consists of axes and cells. Consider the dataset

Year		**2000**		**2001**		**Growth**
Product	**Dollar sales**	**Unit sales**	**Dollar sales**	**Unit sales**	**Dollar sales**	**Unit sales**
Total	$7,073	2,693	$7,636	3,008	8%	12%
— Books	$2,753	824	$3,331	966	21%	17%
—— Fiction	$1,341	424	$1,202	380	-10%	-10%
—— Non-fiction	$1,412	400	$2,129	586	51%	47%
— Magazines	$2,753	824	$2,426	766	-12%	-7%
— Greetings cards	$1,567	1,045	$1,879	1,276	20%	22%

The rows axis consists of the members 'All products', 'Books', 'Fiction', and so forth, and the columns axis consists of the cartesian product of the years '2000' and '2001', and the calculation 'Growth', and the measures 'Unit sales' and 'Dollar sales'. Each cell represents the sales of a product category in a particular year; for example, the dollar sales of Magazines in 2001 were $2,426.

This is a richer view of the data than would be presented by a relational database. The members of a multidimensional dataset are not always values from a relational column. 'Total', 'Books' and 'Fiction' are members at successive levels in a hierarchy, each of which is rolled up to the next. And even though it is alongside the years '2000' and '2001', 'Growth' is a calculated member, which introduces a formula for computing cells from other cells.

The dimensions used here — products, time, and measures — are just three of many dimensions by which the dataset can be categorized and filtered. The collection of dimensions, hierarchies and measures is called a cube.

Conclusion

I hope I have demonstrated that multidimensional is above all a way of presenting data. Although some multidimensional databases store the data in multidimensional format, I shall argue that it is simpler to store the data in relational format.

Now it's time to look at the architecture of an OLAP system. See Mondrian architecture.

Mondrian Architecture

Layers of a Mondrian system

A Mondrian OLAP System consists of four layers; working from the eyes of the end-user to the bowels of the data center, these are as follows: the presentation layer, the dimensional layer, the star layer, and the storage layer. (See figure 1.)

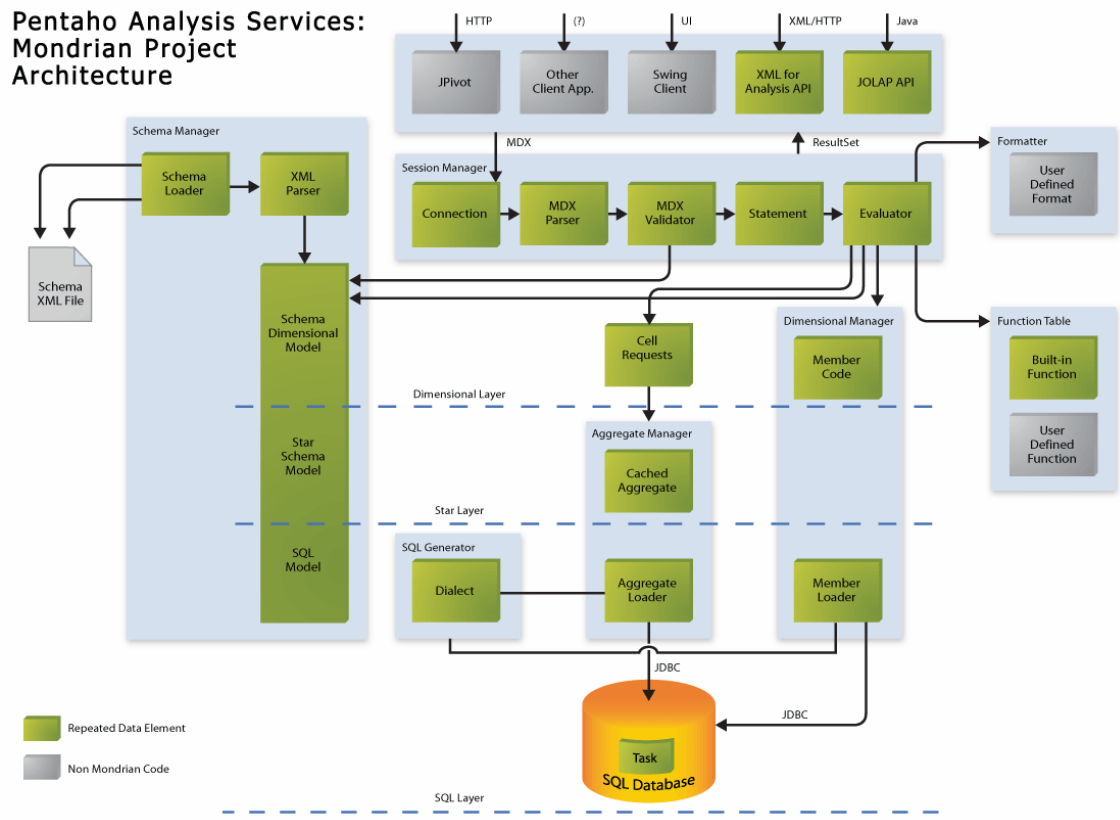
The presentation layer determines what the end-user sees on his or her monitor, and how he or she can interact to ask new questions. There are many ways to present multidimensional datasets, including pivot tables (an interactive version of the table shown above), pie, line and bar charts, and advanced visualization tools such as clickable maps and dynamic graphics. These might be written in Swing or JSP, charts rendered in JPEG or GIF format, or transmitted to a remote application via XML. What all of these forms of presentation have in common is the multidimensional 'grammar' of dimensions, measures and cells in which the presentation layer asks the question is asked, and OLAP server returns the answer.

The second layer is the dimensional layer. The dimensional layer parses, validates and executes MDX queries. A query is evaluted in multiple phases. The axes are computed first, then the values of the cells within the axes. For efficiency, the dimensional layer sends cell-requests to the aggregation layer in batches. A query transformer allows the application to manipulate existing queries, rather than building an MDX statement from scratch for each request. And metadata describes the the dimensional model, and how it maps onto the relational model.

The third layer is the star layer, and is responsible for maintaining an aggregate cache. An aggregation is a set of measure values ('cells') in memory, qualified by a set of dimension column values. The dimensional layer sends requests for sets of cells. If the requested cells are not in the cache, or derivable by rolling up an aggregation in the cache, the aggregation manager sends a request to the storage layer.

The storage layer is an RDBMS. It is responsible for providing aggregated cell data, and members from dimension tables. I describe below why I decided to use the features of the RDBMS rather than developing a storage system optimized for multidimensional data.

These components can all exist on the same machine, or can be distributed between machines. Layers 2 and 3, which comprise the Mondrian server, must be on the same machine. The storage layer could be on another machine, accessed via remote JDBC connection. In a multi-user system, the presentation layer would exist on each end-user's machine (except in the case of JSP pages generated on the server).



Storage and aggregation strategies

OLAP Servers are generally categorized according to how they store their data:

- A MOLAP (multidimensional OLAP) server stores all of its data on disk in structures optimized for multidimensional access. Typically, data is stored in dense arrays, requiring only 4 or 8 bytes per cell value.
- A ROLAP (relational OLAP) server stores its data in a relational database. Each row in a fact table has a column for each dimension and measure.

Three kinds of data need to be stored: fact table data (the transactional records), aggregates, and dimensions.

MOLAP databases store fact data in multidimensional format, but if there are more than a few dimensions, this data will be sparse, and the multidimensional format does not perform well. A HOLAP (hybrid OLAP) system solves this problem by leaving the most granular data in the relational database, but stores aggregates in multidimensional format.

Pre-computed aggregates are necessary for large data sets, otherwise certain queries could not be answered without reading the entire contents of the fact table. MOLAP aggregates are often an image of the in-memory data structure, broken up into pages and stored on disk. ROLAP aggregates are stored in tables. In some ROLAP systems these are explicitly managed by the OLAP server; in other systems, the tables are declared as materialized views, and they are

implicitly used when the OLAP server issues a query with the right combination of columns in the group by clause.

The final component of the aggregation strategy is the cache. The cache holds pre-computed aggregations in memory so subsequent queries can access cell values without going to disk. If the cache holds the required data set at a lower level of aggregation, it can compute the required data set by rolling up.

The cache is arguably the most important part of the aggregation strategy because it is adaptive. It is difficult to choose a set of aggregations to pre-compute which speed up the system without using huge amounts of disk, particularly those with a high dimensionality or if the users are submitting unpredictable queries. And in a system where data is changing in real-time, it is impractical to maintain pre-computed aggregates. A reasonably sized cache can allow a system to perform adequately in the face of unpredictable queries, with few or no pre-computed aggregates.

Mondrian's aggregation strategy is as follows:

- Fact data is stored in the RDBMS. Why develop a storage manager when the RDBMS already has one?
- Read aggregate data into the cache by submitting group by queries. Again, why develop an aggregator when the RDBMS has one?
- If the RDBMS supports materialized views, and the database administrator chooses to create materialized views for particular aggregations, then Mondrian will use them implicitly. Ideally, Mondrian's aggregation manager should be aware that these materialized views exist and that those particular aggregations are cheap to compute. If should even offer tuning suggestings to the database administrator.

The general idea is to delegate unto the database what is the database's. This places additional burden on the database, but once those features are added to the database, all clients of the database will benefit from them. Multidimensional storage would reduce I/O and result in faster operation in some circumstances, but I don't think it warrants the complexity at this stage.

A wonderful side-effect is that because Mondrian requires no storage of its own, it can be installed by adding a JAR file to the class path and be up and running immediately. Because there are no redundant data sets to manage, the data-loading process is easier, and Mondrian is ideally suited to do OLAP on data sets which change in real time.

API

Mondrian provides an API for client applications to execute queries.

Since there is no widely universally accepted API for executing OLAP queries, Mondrian's primary API proprietary; however, anyone who has used JDBC should find it familiar. The main difference is the query language: Mondrian uses a language called MDX ('**M**ulti-**D**imensional e**X**pressions') to specify queries, where JDBC would use SQL. MDX is described in more detail below.

The following Java fragment connects to Mondrian, executes a query, and prints the results:

```
import mondrian.olap.*;
import java.io.PrintWriter;

Connection connection = DriverManager.getConnection(
    "Provider=mondrian;" +
    "Jdbc=jdbc:odbc:MondrianFoodMart;" +
    "Catalog=/WEB-INF/FoodMart.xml;",
    null,
    false);
Query query = connection.parseQuery(
    "SELECT {[Measures].[Unit Sales], [Measures].[Store Sales]} on columns," +
    " {[Product].children} on rows " +
    "FROM [Sales] " +
    "WHERE ([Time].[1997].[Q1], [Store].[CA].[San Francisco])");
Result result = connection.execute(query);
result.print(new PrintWriter(System.out));
```

A Connection is created via a DriverManager, in a similar way to JDBC. A Query is analogous to a JDBC Statement, and is created by parsing an MDX string. A Result is analogous to a JDBC ResultSet; since we are dealing with multi-dimensional data, it consists of axes and cells, rather than rows and columns. Since OLAP is intended for data exploration, you can modify the parse tree contained in a query by operations such as drillDown and sort, then re-execute the query.

The API also presents the database schema as a set of objects: Schema, Cube, Dimension, Hierarchy, Level, Member. For more information about the Mondrian API, see the javadoc.

To comply with emerging standards, we are adding two APIs to Mondrian:

- JOLAP is a standard emerging from the JSR process, and it will become part of J2EE sometime in 2003. We have a few simple JOLAP queries running in class mondrian.test.JolapTest.
- XML for Analysis is a standard for accessing OLAP servers via SOAP (Simple Object Access Protocol). This will allow non-Java components like Microsoft Excel to run queries against Mondrian.

How to Design a Mondrian Schema

What is a schema?

A schema defines a multi-dimensional database. It contains a logical model, consisting of cubes, hierarchies, and members, and a mapping of this model onto a physical model.

The logical model consists of the constructs used to write queries in MDX language: cubes, dimensions, hierarchies, levels, and members.

The physical model is the source of the data which is presented through the logical model. It is typically a star schema, which is a set of tables in a relational database; later, we shall see examples of other kinds of mappings.

Schema files

Mondrian schemas are represented in an XML file. An example schema, containing almost all of the constructs we discuss here, is supplied as `demo/FoodMart.xml` in the mondrian distribution. The dataset to populate this schema is also in the distribution.

Currently, the only way to create a schema is to edit a schema XML file in a text editor. The XML syntax is not too complicated, so this is not as difficult as it sounds, particularly if you use the FoodMart schema as a guiding example.

NOTE: The order of XML elements is important. For example, `<UserDefinedFunction>` element has to occur inside the `<Schema>` element after all collections of `<Cube>`, `<VirtualCube>`, `<NamedSet>` and `<Role>` elements. If you include it before the first `<Cube>` element, the rest of the schema will be ignored.

Logical model

The most important components of a schema are cubes, measures, and dimensions:

- A *cube* is a collection of dimensions and measures in a particular subject area.
- A *measure* is a quantity that you are interested in measuring, for example, unit sales of a product, or cost price of inventory items.
- A *dimension* is an attribute, or set of attributes, by which you can divide measures into sub-categories. For example, you might wish to break down product sales by their color, the gender of the customer, and the store in which the product was sold; color, gender, and store are all dimensions.

Let's look at the XML definition of a simple schema.

```
<Schema>
 <Cube name="Sales">
  <Table name="sales_fact_1997"/>
```

```
   <Dimension name="Gender" foreignKey="customer_id">

    <Hierarchy hasAll="true" allMemberName="All Genders"
primaryKey="customer_id">
     <Table name="customer"/>
      <Level name="Gender" column="gender" uniqueMembers="true"/>
    </Hierarchy>
   </Dimension>
   <Dimension name="Time" foreignKey="time_id">
    <Hierarchy hasAll="false" primaryKey="time_id">
     <Table name="time_by_day"/>
      <Level name="Year" column="the_year" type="Numeric"
uniqueMembers="true"/>
      <Level name="Quarter" column="quarter" uniqueMembers="false"/>
      <Level name="Month" column="month_of_year" type="Numeric"
uniqueMembers="false"/>
     </Hierarchy>
    </Dimension>
    <Measure name="Unit Sales" column="unit_sales" aggregator="sum"
formatString="#,###"/>
    <Measure name="Store Sales" column="store_sales" aggregator="sum"
formatString="#,###.##"/>
   <Measure name="Store Cost" column="store_cost" aggregator="sum"
formatString="#,###.00"/>
   <CalculatedMember name="Profit" dimension="Measures"
formula="[Measures].
 [Store Sales]-[Measures].[Store Cost]">
    <CalculatedMemberProperty name="FORMAT_STRING" value="$#,##0.00"/>
  </CalculatedMember>
 </Cube>
</Schema>
```

This schema contains a single cube, called "Sales". The Sales cube has two dimensions, "Time", and "Gender", and two measures, "Unit Sales" and "Store Sales".

We can write an MDX query on this schema:

```
SELECT {[Measures].[Unit Sales], [Measures].[Store Sales]} ON COLUMNS,
  {descendants([Time].[1997].[Q1])} ON ROWS
FROM [Sales]
WHERE [Gender].[F]
```

This query refers to the Sales cube (`[Sales]`), each of the dimensions `[Measures]`, `[Time]`, `[Gender]`, and various members of those dimensions. The results are as follows:

```
[Time]           [Measures].[Unit Sales] [Measures].[Store Sales]
[1997].[Q1]      0                       0
[1997].[Q1].[Jan] 0                      0
[1997].[Q1].[Feb] 0                      0
[1997].[Q1].[Mar] 0                      0
```

Now let's look at the schema definition in more detail.

Cube

A cube (see <Cube>) is a named collection of measures and dimensions. The one thing the measures and dimensions have in common is the fact table, here "sales_fact_1997". As we shall see, the fact table holds the columns from which measures are calculated, and contains references to the tables which hold the dimensions.

```
<Cube name="Sales">
<Table name="sales_fact_1997"/>
...
</Cube>
```

The fact table is defined using the <Table> element. If the fact table is not in the default schema, you can provide an explicit schema using the "schema" attribute, for example

```
<Table schema=" dmart" name="sales_fact_1997"/>
```

You can also use the <View> and <Join> constructs to build more complicated SQL statements.

Measures

The Sales cube defines several measures, including "Unit Sales" and "Store Sales".

```
<Measure name="Unit Sales" column="unit_sales"
aggregator="sum" datatype="Integer" formatString="#,###"/>
<Measure name="Store Sales" column="store_sales"
aggregator="sum" datatype="Numeric" formatString="#,###.00"/>
```

Each measure (see <Measure>) has a name, a column in the fact table, and an aggregator. The aggregator is usually "sum", but "count", "mix", "max", "avg", and "distinct count" are also allowed; "distinct count" has some limitations if your cube contains a parent-child hierarchy.

The optional datatype attribute specifies how cell values are represented in Mondrian's cache, and how they are returned via XML for Analysis. The datatype attribute can have values "String", "Integer", "Numeric" “Boolean”, “Date”, “Time”, and “Timestamp”. The default is "Numeric", except for "count" and "distinct-count" measures, which are "Integer".

An optional formatString attribute specifies how the value is to be printed. Here, we have chosen to output unit sales with no decimal places (since it is an integer), and store sales with two decimal places (since it is a currency value). The ',' and '.' symbols are locale-sensitive, so if you were running in Italian, store sales might appear as "48.123,45". You can achieve even more wild effects using advanced format strings.

A measure can have a caption attribute to be returned by the Member.getCaption() method instead of the name. Defining a specific caption does make sense if special letters (e.g. Σ or Π) are to be displayed:

```
<Measure name="Sum X" column="sum_x" aggregator="sum" caption="&#931;
X"/>
```

Rather than coming from a column, a measure can use a cell reader, or a measure can use a SQL expression to calculate its value. The measure "Promotion Sales" is an example of this.

```
<Measure name="Promotion Sales" aggregator="sum"
formatString="#,###.00">
<MeasureExpression>
<SQL dialect="generic">
(case when sales_fact_1997.promotion_id =
0 then 0 else sales_fact_1997.store_sales end)
</SQL>
</MeasureExpression>
</Measure>
```

In this case, sales are only included in the summation if they correspond to a promotion sales. Arbitrary SQL expressions can be used, including subqueries. However, the underlying database must be able to support that SQL expression in the context of an aggregate. Variations in syntax between different databases is handled by specifying the dialect in the SQL tag.

In order to provide a specific formatting of the cell values, a measure can use a cell formatter.

Dimensions, Hierarchies, Levels

Some more definitions:

- A *member* is a point within a dimension determined by a particular set of attribute values. The gender hierarchy has the two members 'M' and 'F'. 'San Francisco', 'California' and 'USA' are all members of the store hierarchy.
- A *hierarchy* is a set of members organized into a structure for convenient analysis. For example, the store hierarchy consists of the store name, city, state, and nation. The hierarchy allows you form intermediate sub-totals: the sub-total for a state is the sum of the sub-totals of all of the cities in that state, each of which is the sum of the sub-totals of the stores in that city.
- A *level* is a collection of members which have the same distance from the root of the hierarchy.
- A *dimension* is a collection of hierarchies which discriminate on the same fact table attribute (say, the day that a sale occurred).

For reasons of uniformity, measures are treated as members of a special dimension, called 'Measures'.

An example

Let's look at a simple dimension.

```
<Dimension name="Gender" foreignKey="customer_id">
  <Hierarchy hasAll="true" primaryKey="customer_id">
    <Table name="customer"/>
    <Level name="Gender" column="gender" uniqueMembers="true"/>
  </Hierarchy>
</Dimension>
```

This dimension consists of a single hierarchy, which consists of a single level called `Gender`. (As we shall see later, there is also a special level called `[(All)]` containing a grand total.)

The values for the dimension come from the `gender` column in the `customer` table. The "gender" column contains two values, 'F' and 'M', so the Gender dimension contains the members `[Gender].[F]` and `[Gender].[M]`.

For any given sale, the gender dimension is the gender of the customer who made that purchase. This is expressed by joining from the fact table "sales_fact_1997.customer_id" to the dimension table "customer.customer_id".

Mapping dimensions and hierarchies onto tables

A dimension is joined to a cube by means of a pair of columns, one in the fact table, the other in the dimension table. The `<Dimension>` element has a `foreignKey` attribute, which is the name of a column in the fact table; the `<Hierarchy>` element has `primaryKey` attribute.

If the hierarchy has more than one table, you can disambiguate using the `primaryKeyTable` attribute.

The `column` attribute defines the key of the level. It must be the name of a column in the level's table. If the key is an expression, you can instead use the `<KeyExpression>` element inside the Level. The following is equivalent to the above example:

```
<Dimension name="Gender" foreignKey="customer_id">
  <Hierarchy hasAll="true" primaryKey="customer_id">
    <Table name="customer" />
    <Level name="Gender" column="gender" uniqueMembers="true">
      <KeyExpression>
        <SQL dialect="generic">customer.gender</SQL>
      </KeyExpression>
    </Level>
  </Hierarchy>
</Dimension>
```

Other attributes of `<Level>`, `<Measure>` and `<Property>` have corresponding nested elements:

Parent element	Attribute	Equivalent nested element	Description
<Level>	`column`	<KeyExpression>	Key of level.
<Level>	`nameColumn`	<NameExpression>	Expression which defines the name of members of this level. If not specified, the level key is used.
<Level>	`ordinalColumn`	<OrdinalExpression>	Expression which defines the order of members. If not specified, the level key is used.
<Level>	`captionColumn`	<CaptionExpression>	Expression which forms the caption of members. If not specified, the level name is used.

<Level>	parentColumn	<ParentExpression>	Expression by which child members reference their parent member in a parent-child hierarchy. Not specified in a regular hierarchy.
<Measure>	column	<MeasureExpression>	SQL expression to calculate the value of the measure (the argument to the SQL aggregate function).
<Property>	column	<PropertyExpression>	SQL expression to calculate the value of the property.

The uniqueMembers attribute is used to optimize SQL generation. If you know that the values of a given level column in the dimension table are unique across all the other values in that column across the parent levels, then set uniqueMembers="true", otherwise, set to "false". For example, a time dimension like [Year].[Month] will have uniqueMembers="false" at the Month level, as the same month appears in different years. On the other hand, if you had a [Product Class].[Product Name] hierarchy, and you were sure that [Product Name] was unique, then you can set uniqueMembers="true". If you are not sure, then always set uniqueMembers="false". At the top level, this will always be uniqueMembers="true", as there is no parent level.

The highCardinality attribute is used to notify Mondrian there are undefined and very high number of elements for this dimension. Acceptable values are true or false (last one is default value). Actions performed over the whole set of dimension elements cannot be performed when using highCardinality="true".

The 'all' member

By default, every hierarchy contains a top level called '(All)', which contains a single member called '(All {*hierarchyName*})'. This member is parent of all other members of the hierarchy, and thus represents a grand total. It is also the default member of the hierarchy; that is, the member which is used for calculating cell values when the hierarchy is not included on an axis or in the slicer. The allMemberName and allLevelName attributes override the default names of the all level and all member.

If the <Hierarchy> element has hasAll="false", the 'all' level is suppressed. The default member of that dimension will now be the first member of the first level; for example, in a Time hierarchy, it will be the first year in the hierarchy. Changing the default member can be confusing, so you should generally use hasAll="true".

The <Hierarchy> element also has a defaultMember attribute, to override the default member of the hierarchy:

```
<Dimension name="Time" type="TimeDimension" foreignKey="time_id">
  <Hierarchy hasAll="false" primaryKey="time_id"
defaultMember="[Time].[1997].[Q1].[1]"/>
  ...
```

Time dimensions

Time dimensions based on year/month/week/day are coded differently in the Mondrian schema due to the MDX time related functions such as:

- `ParallelPeriod([level[, index[, member]]])`
- `PeriodsToDate([level[, member]])`
- `WTD([member])`
- `MTD([member])`
- `QTD([member])`
- `YTD([member])`
- `LastPeriod(index[, member])`

Time dimensions have `type="TimeDimension"`. The role of a level in a time dimension is indicated by the level's `levelType` attribute, whose allowable values are as follows:

`levelType` value	**Meaning**
TimeYears	Level is a year
TimeQuarters	Level is a quarter
TimeMonths	Level is a month
TimeWeeks	Level is a week
TimeDays	Level represents days

Here is an example of a time dimension:

```
<Dimension name="Time" type="TimeDimension">
  <Hierarchy hasAll="true" allMemberName="All Periods"
primaryKey="dateid">
    <Table name="datehierarchy"/>
     <Level name="Year" column="year" uniqueMembers="true"
levelType="TimeYears" type="Numeric"/>
     <Level name="Quarter" column="quarter"
uniqueMembers="false" levelType="TimeQuarters" />
     <Level name="Month" column="month" uniqueMembers="false"
ordinalColumn="month" nameColumn="month_name"
levelType="TimeMonths" type="Numeric"/>
     <Level name="Week" column="week_in_month"
uniqueMembers="false" levelType="TimeWeeks" />
     <Level name="Day" column="day_in_month"
uniqueMembers="false" ordinalColumn="day_in_month"
nameColumn="day_name" levelType="TimeDays" type="Numeric"/>
  </Hierarchy>
</Dimension>
```

Order and display of levels

Notice that in the time hierarchy example above the `ordinalColumn` and `nameColumn` attributes on the `<Level>` element. These effect how levels are displayed in a result. The

`ordinalColumn` attribute specifies a column in the Hierarchy table that provides the order of the members in a given Level, while the `nameColumn` specifies a column that will be displayed.

For example, in the Month Level above, the `datehierarchy` table has month (1 .. 12) and month_name (January, February, ...) columns. The column value that will be used internally within MDX is the month column, so valid member specifications will be of the form: `[Time].[2005].[Q1].[1]`. Members of the `[Month]` level will displayed in the order January, February, etc.

In a parent-child hierarchy, members are always sorted in hierarchical order. The `ordinalColumn` attribute controls the order that siblings appear within their parent.

Ordinal columns may be of any datatype which can legally be used in an ORDER BY clause. Scope of ordering is per-parent, so in the example above, the day_in_month column should cycle for each month. Values returned by the JDBC driver should be non-null instances of java.lang.Comparable which yield the desired ordering when their Comparable.compareTo method is called.

Levels contain a type attribute, which can have values "`String`", "`Integer`", "`Numeric`", "`Boolean`", "`Date`", "`Time`", and "`Timestamp`". The default value is "`Numeric`" because key columns generally have a numeric type. If it is a different type, Mondrian needs to know this so it can generate SQL statements correctly; for example, string values will be generated enclosed in single quotes:

WHERE productSku = '123-455-AA'

Multiple hierarchies

A dimension can contain more than one hierarchy:

```
<Dimension name="Time" foreignKey="time_id">
  <Hierarchy hasAll="false" primaryKey="time_id">
    <Table name="time_by_day"/>
    <Level name="Year" column="the_year" type="Numeric"
    uniqueMembers="true"/>
    <Level name="Quarter" column="quarter"
    uniqueMembers="false"/>
    <Level name="Month" column="month_of_year"
    type="Numeric" uniqueMembers="false"/>
  </Hierarchy>
  <Hierarchy name="Time Weekly" hasAll="false"
    primaryKey="time_id">
    <Table name="time_by_week"/>
    <Level name="Year" column="the_year" type="Numeric"
    uniqueMembers="true"/>
    <Level name="Week" column="week"
    uniqueMembers="false"/>
    <Level name="Day" column="day_of_week" type="String"
    uniqueMembers="false"/>
  </Hierarchy>
</Dimension>
```

Notice that the first hierarchy doesn't have a name. By default, a hierarchy has the same name as its dimension, so the first hierarchy is called "Time".

These hierarchies don't have much in common — they don't even have the same table! — except that they are joined from the same column in the fact table, `"time_id"`. The main reason to put two hierarchies in the same dimension is because it makes more sense to the end-user: end-users know that it makes no sense to have the "Time" hierarchy on one axis and the "Time Weekly" hierarchy on another axis. If two hierarchies are the same dimension, the MDX language enforces common sense, and does not allow you to use them both in the same query.

Degenerate dimensions

A *degenerate dimension* is a dimension which is so simple that it isn't worth creating its own dimension table. For example, consider following the fact table:

product_id	time_id	payment_method	customer_id	store_id	item_count	dollars
55	20040106	Credit	123	22	3	$3.54
78	20040106	Cash	89	22	1	$20.00
199	20040107	ATM	3	22	2	$2.99
55	20040106	Cash	122	22	1	$1.18

and suppose we created a dimension table for the values in the `payment_method` column:

payment_method
Credit
Cash
ATM

This dimension table is fairly pointless. It only has 3 values, adds no additional information, and incurs the cost of an extra join.

Instead, you can create a degenerate dimension. To do this, declare a dimension without a table, and Mondrian will assume that the columns come from the fact table.

```
<Cube name="Checkout">
  <!-- The fact table is always necessary. -->
  <Table name="checkout">
  <Dimension name="Payment method">
    <Hierarchy hasAll="true">
      <!-- No table element here.
      Fact table is assumed. -->
      <Level name="Payment method"
      column="payment_method" uniqueMembers="true" />
    </Hierarchy>
  </Dimension>
  <!-- other dimensions and measures -->
</Cube>
```

Note that because there is no join, the `foreignKey` attribute of `Dimension` is not necessary, and the `Hierarchy` element has no `<Table>` child element or `primaryKey` attribute.

Inline tables

The <InlineTable> construct allows you to define a dataset in the schema file. You must declare the names of the columns, the column types ("String" or "Numeric"), and a set of rows. As for <Table> and <View>, you must provide a unique alias with which to refer to the dataset.

Here is an example:

```
<Dimension name="Severity">
  <Hierarchy hasAll="true" primaryKey="severity_id">
    <InlineTable alias="severity">
      <ColumnDefs>
        <ColumnDef name="id" type="Numeric"/>
        <ColumnDef name="desc" type="String"/>
      </ColumnDefs>
      <Rows>
        <Row>
          <Value column="id">1</Value>
          <Value column="desc">High</Value>
        </Row>
        <Row>
          <Value column="id">2</Value>
          <Value column="desc">Medium</Value>
        </Row>
        <Row>
          <Value column="id">3</Value>
          <Value column="desc">Low</Value>
        </Row>
      </Rows>
    </InlineTable>
    <Level name="Severity" column="id" nameColumn="desc"
uniqueMembers="true"/>
  </Hierarchy>
</Dimension>
```

This has the same effect as if you had a table called 'severity' in your database:

id	desc
1	High
2	Medium
3	Low

and the declaration

```
<Dimension name="Severity">
  <Hierarchy hasAll="true" primaryKey="severity_id">
    <Table name="severity"/>
    <Level name="Severity" column="id" nameColumn="desc"
uniqueMembers="true"/>
  </Hierarchy>
</Dimension>
```

To specify a NULL value for a column, omit the <Value> for that column, and the column's value will default to NULL.

Member properties and formatters

As we shall see later, a level definition can also define member properties and a member formatter.

Approximate level cardinality

The <Level> element allows specifying the optional attribute "approxRowCount". Specifying approxRowCount can improve performance by reducing the need to determine level, hierarchy, and dimension cardinality. This can have a significant impact when connecting to Mondrian via XMLA.

Star and snowflake schemas

We saw earlier how to build a cube based upon a fact table, and dimensions in the fact table ("Payment method") and in a table joined to the fact table ("Gender"). This is the most common kind of mapping, and is known as a *star schema*.

But a dimension can be based upon more than one table, provided that there is a well-defined path to join these tables to the fact table. This kind of dimension is known as a snowflake, and is defined using the <Join> operator. For example:

```
<Cube name="Sales">
  ...
  <Dimension name="Product" foreignKey="product_id">
    <Hierarchy hasAll="true" primaryKey="product_id"
primaryKeyTable="product">
      <Join leftKey="product_class_key" rightAlias="product_class"
rightKey="product_class_id">
        <Table name="product"/>
        <Join leftKey="product_type_id" rightKey="product_type_id">
          <Table name="product_class"/>
          <Table name="product_type"/>
        </Join>
      </Join>
    <!-- Level declarations ... ->
    </Hierarchy>
  </Dimension>
</Cube>
```

This defines a "Product" dimension consisting of three tables. The fact table joins to "product" (via the foreign key "product_id"), which joins to "product_class" (via the foreign key "product_class_id"), which joins to " product_type" (via the foreign key "product_type_id"). We require a <Join> element nested within a <Join> element because <Join> takes two operands; the operands can be tables, joins, or even queries.

The arrangement of the tables seems complex, the simple rule of thumb is to order the tables by the number of rows they contain. The "product" table has the most rows, so it joins to the fact

table and appears first; "product_class" has fewer rows, and "product_type", at the tip of the snowflake, has least of all.

Note that the outer <Join> element has a rightAlias attribute. This is necessary because the right component of the join (the inner <Join> element) consists of more than one table. No leftAlias attribute is necessary in this case, because the leftKey column unambiguously comes from the "product" table.

Shared dimensions

When generating the SQL for a join, mondrian needs to know which column to join to. If you are joining to a join, then you need to tell it which of the tables in the join that column belongs to (usually it will be the first table in the join).

Because shared dimensions don't belong to a cube, you have to give them an explicit table (or other data source). When you use them in a particular cube, you specify the foreign key. This example shows the Store Type dimension being joined to the Sales cube using the sales_fact_1997.store_id foreign key, and to the Warehouse cube using the warehouse.warehouse_store_id foreign key:

```
<Dimension name="Store Type">
  <Hierarchy hasAll="true" primaryKey="store_id">
    <Table name="store"/>
    <Level name="Store Type" column="store_type" uniqueMembers="true"/>
  </Hierarchy>
</Dimension>

<Cube name="Sales">
  <Table name="sales_fact_1997"/>
  ...
  <DimensionUsage name="Store Type" source="Store Type"
foreignKey="store_id"/>
</Cube>

<Cube name="Warehouse">
  <Table name="warehouse"/>
  ...
  <DimensionUsage name="Store Type" source="Store Type"
foreignKey="warehouse_store_id"/>
</Cube>
```

Join optimization

The table mapping in the schema tells Mondrian how to get the data, but Mondrian is smart enough not to read the schema literally. It applies a number of optimizations when generating queries:

- If a dimension has a small number of members, Mondrian reads it into a cache on first use. See the mondrian.rolap.LargeDimensionThreshold property.
- If a dimension (or, more precisely, the level of the dimension being accessed) is in the fact table, Mondrian does not perform a join.

- If two dimensions access the same table via the same join path, Mondrian only joins them once. For example, `[Gender]` and `[Age]` might both be columns in the `customers` table, joined via `sales_1997.cust_id = customers.cust_id`.

Advanced logical constructs

Virtual cubes

A virtual cube combines two regular cubes. It is defined by the <VirtualCube> element:

```
<VirtualCube name="Warehouse and Sales">
  <CubeUsages>
    <CubeUsage cubeName="Sales" ignoreUnrelatedDimensions="true"/>
    <CubeUsage cubeName="Warehouse"/>
  </CubeUsages>
  <VirtualCubeDimension cubeName="Sales" name="Customers"/>
  <VirtualCubeDimension cubeName="Sales" name="Education Level"/>
  <VirtualCubeDimension cubeName="Sales" name="Gender"/>
  <VirtualCubeDimension cubeName="Sales" name="Marital Status"/>
  <VirtualCubeDimension name="Product"/>
  <VirtualCubeDimension cubeName="Sales" name="Promotion Media"/>
  <VirtualCubeDimension cubeName="Sales" name="Promotions"/>
  <VirtualCubeDimension name="Store"/>
  <VirtualCubeDimension name="Time"/>
  <VirtualCubeDimension cubeName="Sales" name="Yearly Income"/>
  <VirtualCubeDimension cubeName="Warehouse" name="Warehouse"/>
  <VirtualCubeMeasure cubeName="Sales" name="[Measures].[Sales
Count]"/>
  <VirtualCubeMeasure cubeName="Sales" name="[Measures].[Store Cost]"/>
  <VirtualCubeMeasure cubeName="Sales" name="[Measures].[Store
Sales]"/>
  <VirtualCubeMeasure cubeName="Sales" name="[Measures].[Unit Sales]"/>
  <VirtualCubeMeasure cubeName="Sales" name="[Measures].[Profit
Growth]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Store
Invoice]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Supply
Time]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Units
Ordered]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Units
Shipped]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Warehouse
Cost]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Warehouse
Profit]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Warehouse
Sales]"/>
  <VirtualCubeMeasure cubeName="Warehouse" name="[Measures].[Average
Warehouse Sale]"/>
  <CalculatedMember name="Profit Per Unit Shipped" dimension="Measures">
    <Formula>[Measures].[Profit] / [Measures].[Units Shipped]</Formula>
  </CalculatedMember>
</VirtualCube>
```

The <CubeUsages> element is optional. It specifies the cubes that are imported into the virtual cube. Holds CubeUsage elements.

The <CubeUsage> element is optional. It specifies the base cube that is imported into the virtual cube. Currently it is possible to define a VirtualCubeMeasure and similar imports from base cube without defining CubeUsage for the cube. The `cubeName` attribute specifies the base cube being imported. The `ignoreUnrelatedDimensions` attribute specifies that the measures from this base cube will have non joining dimension members pushed to the top level member. This behaviour is currently supported for aggregation. This attribute is by default false. `ignoreUnrelatedDimensions` is an experimental feature similar to the similarly named feature in SSAS 2005. MSDN documentation mentions "When IgnoreUnrelatedDimensions is true, unrelated dimensions are forced to their top level; when the value is false, dimensions are not forced to their top level. This property is similar to the Multidimensional Expressions (MDX) ValidMeasure function". Current mondrian implementation of `ignoreUnrelatedDimensions` depends on use of ValidMeasure. E.g. If we want to apply this behaviour to "Unit Sales" measure in the "Warehouse and Sales" virtual cube then we need to define a CubeUsage entry for "Sales" cube as shown in the example above and also wrap this measure with ValidMeasure.

The `<VirtualCubeDimension>` element imports a dimension from one of the constituent cubes. If you do not specify the cubeName attribute, this means you are importing a shared dimension. (If a shared dimension is used more than once in a cube, there is no way, at present, to disambiguate which usage of the shared dimension you intend to import.)

The `<VirtualCubeDimension>` element imports a measure from one of the constituent cubes. It is imported with the same name. If you want to create a formula, or just to rename a measure as you import it, use the <CalculatedMember> element.

Virtual cubes occur surprisingly frequently in real-world applications. They occur when you have fact tables of different granularities (say one measured at the day level, another at the month level), or fact tables of different dimensionalities (say one on Product, Time and Customer, another on Product, Time and Warehouse), and want to present the results to an end-user who doesn't know or care how the data is structured.

Any common dimensions -- shared dimensions which are used by both constituent cubes -- are automatically synchronized. In this example, `[Time]` and `[Product]` are common dimensions. So if the context is (`[Time].[1997].[Q2]`, `[Product].[Beer].[Miller Lite]`), measures from either cube will relate to this context.

Dimensions which only belong to one cube are called non-conforming dimensions. The `[Gender]` dimension is an example of this: it exists in the Sales cube but not Warehouse. If the context is (`[Gender].[F]`, `[Time].[1997].[Q1]`), it makes sense to ask the value of the `[Unit Sales]` measure (which comes from the `[Sales]` cube) but not the `[Units Ordered]` measure (from `[Warehouse]`). In the context of `[Gender].[F]`, `[Units Ordered]` has value NULL.

Parent-child hierarchies

A conventional hierarchy has a rigid set of levels, and members which adhere to those levels. For example, in the `Product` hierarchy, any member of the `Product Name` level has a parent in the `Brand Name` level, which has a parent in the `Product Subcategory` level, and so forth. This structure is sometimes too rigid to model real-world data.

A *parent-child hierarchy* has only one level (not counting the special 'all' level), but any member can have parents in the same level. A classic example is the reporting structure in the `Employees` hierarchy:

```
<Dimension name="Employees" foreignKey="employee_id">
  <Hierarchy hasAll="true" allMemberName="All Employees"
primaryKey="employee_id">
    <Table name="employee"/>
    <Level name="Employee Id" uniqueMembers="true" type="Numeric"
       column="employee_id" nameColumn="full_name"
       parentColumn="supervisor_id" nullParentValue="0">
      <Property name="Marital Status" column="marital_status"/>
      <Property name="Position Title" column="position_title"/>
      <Property name="Gender" column="gender"/>
      <Property name="Salary" column="salary"/>
      <Property name="Education Level" column="education_level"/>
      <Property name="Management Role" column="management_role"/>
    </Level>
  </Hierarchy>
</Dimension>
```

The important attributes here are `parentColumn` and `nullParentValue`:

- The `parentColumn` attribute is the name of the column which links a member to its parent member; in this case, it is the foreign key column which points to an employee's supervisor. The `<ParentExpression>` child element of `<Level>` is equivalent to the `parentColumn` attribute, but allows you to define an arbitrary SQL expression, just like the `<Expression>` element. The `parentColumn` attribute (or `<ParentExpression>` element) is the only indication to Mondrian that a hierarchy has a parent-child structure.
- The `nullParentValue` attribute is the value which indicates that a member has no parent. The default is `nullParentValue="null"`, but since many database don't index null values, schema designers sometimes use values as the empty string, 0, and -1 instead.

Tuning parent-child hierarchies

There's one serious problem with the parent-child hierarchy defined above, and that is the amount of work Mondrian has to do in order to compute cell-totals. Let's suppose that the employee table contains the following data:

employee

supervisor_id	employee_id	full_name
null	1	Frank
1	2	Bill
2	3	Eric
1	4	Jane
3	5	Mark
2	6	Carla

If we want to compute the total salary budget for Bill, we need to add in the salaries of Eric and Carla (who report to Bill) and Mark (who reports to Eric). Usually Mondrian generates a SQL `GROUP BY` statement to compute these totals, but there is no (generally available) SQL construct

which can traverse hierarchies. So by default, Mondrian generates one SQL statement per supervisor, to retrieve and total all of that supervisor's direct reports.

This approach has a couple of drawbacks. First, the performance is not very good if a hierarchy contains more than a hundred members. Second, because Mondrian implements the "distinct count" aggregator by generating SQL, you cannot define a "distinct count" member in any cube which contains a parent-child hierarchy.

How can we solve these problems? The answer is to enhance the data so that Mondrian is able to retrieve the information it needs using standard SQL. Mondrian supports a mechanism called a *closure table* for this purpose.

Closure tables

A closure table is a SQL table which contains a record for every employee/supervisor relationship, regardless of depth. (In mathematical terms, this is called the 'reflexive transitive closure' of the employee/supervisor relationship. The `distance` column is not strictly required, but it makes it easier to populate the table.)

employee_closure

supervisor_id	employee_id	distance
1	1	0
1	2	1
1	3	2
1	4	1
1	5	3
1	6	2
2	2	0
2	3	1
2	5	2
2	6	1
3	3	0
3	5	1
4	4	0
5	5	0
6	6	0

In the catalog XML, the <Closure> element maps the level onto a <Table>:

```
<Dimension name="Employees" foreignKey="employee_id">
  <Hierarchy hasAll="true" allMemberName="All Employees"
primaryKey="employee_id">
    <Table name="employee"/>
    <Level name="Employee Id" uniqueMembers="true" type="Numeric"
        column="employee_id" nameColumn="full_name"
        parentColumn="supervisor_id" nullParentValue="0">
      <Closure parentColumn="supervisor_id" childColumn="employee_id">
        <Table name="employee_closure"/>
      </Closure>
      <Property name="Marital Status" column="marital_status"/>
      <Property name="Position Title" column="position_title"/>
      <Property name="Gender" column="gender"/>
```

```
      <Property name="Salary" column="salary"/>
      <Property name="Education Level" column="education_level"/>
      <Property name="Management Role" column="management_role"/>
   </Hierarchy>
</Dimension>
```

This table allows totals to be evaluated in pure SQL. Even though this introduces an extra able into the query, database optimizers are very good at handling joins. I recommend that you declare both `supervisor_id` and `employee_id` NOT NULL, and index them as follows:

```
CREATE UNIQUE INDEX employee_closure_pk ON employee_closure (
   supervisor_id,
   employee_id
);
CREATE INDEX employee_closure_emp ON employee_closure (
   employee_id
);
```

The table needs to be re-populated whenever the hierarchy changes, and it is the application's responsibility to do so -- Mondrian does not do this! Here is an example of a stored procedure that computes a closure table.

```
CREATE PROCEDURE close_employee()
BEGIN
  DECLARE distance int;
  TRUNCATE TABLE employee_closure;
  SET distance = 0;
  -- seed closure with self-pairs (distance 0)
  INSERT INTO employee_closure (supervisor_id, employee_id, distance)
    SELECT employee_id, employee_id, distance
      FROM employee;

  -- for each pair (root, leaf) in the closure,
  -- add (root, leaf->child) from the base table
  REPEAT
    SET distance = distance + 1;
    INSERT INTO employee_closure (supervisor_id, employee_id, distance)
      SELECT employee_closure.supervisor_id, employee.employee_id,
distance
        FROM employee_closure, employee
          WHERE employee_closure.employee_id = employee.supervisor_id
          AND employee_closure.distance = distance - 1;
  UNTIL (ROW_COUNT() == 0))
  END REPEAT
END
```

Member properties

Member properties are defined by the <Property> element within a <Level>, like this:

```
<Level name="MyLevel" column="LevelColumn" uniqueMembers="true"/>
<Property name="MyProp" column="PropColumn"
formatter="com.acme.MyPropertyFormatter"/>
<Level/>
```

The `formatter` attribute defines a property formatter, which is explained later.

Once properties have been defined in the schema, you can use them in MDX statements via the *`member`*`.Properties("`*`propertyName`*`")` function, for example:

```
SELECT {[Store Sales]} ON COLUMNS,
  TopCount(Filter([Store].[Store Name].Members,
                  [Store].CurrentMember.Properties("Store Type") =
"Supermarket"),
           10,
           [Store Sales]) ON ROWS
FROM [Sales]
```

Mondrian deduces the type of the property expression, if it can. If the property name is a constant string, the type is based upon the type attribute ("String", "Numeric" or "Boolean") of the property definition. If the property name is an expression (for example `CurrentMember.Properties("Store " + "Type")`), Mondrian will return an untyped value.

Calculated members

Suppose you want to create a measure whose value comes not from a column of the fact table, but from an MDX formula. One way to do this is to use a `WITH MEMBER` clause, like this:

```
WITH MEMBER [Measures].[Profit] AS '[Measures].[Store Sales]-
[Measures].[Store Cost]',
   FORMAT_STRING = '$#,###'
SELECT {[Measures].[Store Sales], [Measures].[Profit]} ON COLUMNS,
  {[Product].Children} ON ROWS
FROM [Sales]
WHERE [Time].[1997]
```

But rather than including this clause in every MDX query of your application, you can define the member in your schema, as part of your cube definition:

```
<CalculatedMember name="Profit" dimension="Measures">
  <Formula>[Measures].[Store Sales] - [Measures].[Store Cost]</Formula>
  <CalculatedMemberProperty name="FORMAT_STRING" value="$#,##0.00"/>
</CalculatedMember>
```

You can also declare the formula as an XML attribute, if you prefer. The effect is just the same.

```
<CalculatedMember name="Profit" dimension="Measures"
    formula="[Measures].[Store Sales]-[Measures].[Store Cost]">
  <CalculatedMemberProperty name="FORMAT_STRING" value="$#,##0.00"/>
</CalculatedMember>
```

Note that the <`CalculatedMemberProperty` > (not <`Property`>) element corresponds to the `FORMAT_STRING = '$#,###'` fragment of the MDX statement. You can define other properties here too, but `FORMAT_STRING` is by far the most useful in practice.

The FORMAT_STRING property value can also be evaluated using an expression. When formatting a particular cell, first the expression is evaluated to yield a format string, then the format string is applied to the cell value. Here is the same property with a conditional format string:

```
  <CalculatedMemberProperty name="FORMAT_STRING" expression="Iif(Value
< 0, '|($#,##0.00)|style=red', '|$#,##0.00|style=green')"/>
```

For more details about format strings, see the MDX specification.

One additional calculated member property that is worth mentioning is DATATYPE. As with measures, setting datatype specifies how the calculated member is returned via XML for Analysis. The DATATYPE property of a calculated member can have values "String", "Integer", or "Numeric":

```
    <CalculatedMemberProperty name="DATATYPE" value="Numeric"/>
```

You can make a calculated member or a measure invisible. If you specify visible="false" (the default is "true") in the <Measure> or <CalculatedMember> element, user-interfaces such as JPivot will notice this property and hide the member. This is useful if you want to perform calculations in a number of steps, and hide intermediate steps from end-users. For example, here only "Margin per Sqft" is visible, and its factors "Store Cost", "Margin" and "Store Sqft" are hidden:

```
<Measure
    name="Store Cost"
    column="store_cost"
    aggregator="sum"
    formatString="#,###.00"
    visible="false"/>
<CalculatedMember
    name="Margin"
    dimension="Measures"
    visible="false">
  <Formula>([Measures].[Store Sales] - [Measures].[Store Cost]) /
[Measures].[Store Cost]</Formula>
<CalculatedMember
    name="Store Sqft"
    dimension="Measures"
    visible="false">
  <Formula>[Store].Properties("Sqft")</Formula>
<CalculatedMember
    name="Margin per Sqft"
    dimension="Measures"
    visible="true">
  <Formula>[Measures].[Margin] / [Measures].[Store Cost]</Formula>
  <CalculatedMemberProperty name="FORMAT_STRING" value="$#,##0.00"/>
</CalculatedMember>
```

Named sets

The `WITH SET` clause of an MDX statement allows you to declare a set expression which can be used throughout that query. For example,

```
WITH SET [Top Sellers] AS
    'TopCount([Warehouse].[Warehouse Name].MEMBERS, 5,
[Measures].[Warehouse Sales])'
SELECT
    {[Measures].[Warehouse Sales]} ON COLUMNS,
    {[Top Sellers]} ON ROWS
FROM [Warehouse]
WHERE [Time].[Year].[1997]
```

The `WITH SET` clause is very similar to the `WITH MEMBER` clause, and as you might expect, it has a construct in schema analogous to < `CalculatedMember`>. The <`NamedSet`> element allows you to define a named set in your schema as part of a cube definition. It is implicitly available for any query against that cube:

```
<Cube name="Warehouse">
  ...
  <NamedSet name="Top Sellers">
    <Formula>TopCount([Warehouse].[Warehouse Name].MEMBERS, 5,
[Measures].[Warehouse Sales])</Formula>
  </NamedSet>
</Cube>
SELECT
    {[Measures].[Warehouse Sales]} ON COLUMNS,
    {[Top Sellers]} ON ROWS
FROM [Warehouse]
WHERE [Time].[Year].[1997]
```

Warehouse	Warehouse Sales
Treehouse Distribution	31,116.37
Jorge Garcia, Inc.	30,743.77
Artesia Warehousing, Inc.	29,207.96
Jorgensen Service Storage	22,869.79
Destination, Inc.	22,187.42

A named set defined against a cube is not inherited by a virtual cubes defined against that cube. (But you can define a named set against a virtual cube.)

You can also define a named set as global to a schema:

```
<Schema>
  <Cube name="Sales" ... />
  <Cube name="Warehouse" ... />
  <VirtualCube name="Warehouse and Sales" .../>
  <NamedSet name="CA Cities" formula="{[Store].[USA].[CA].Children}"/>
  <NamedSet name="Top CA Cities">
    <Formula>TopCount([CA Cities], 2, [Measures].[Unit
Sales])</Formula>
```

```
  </NamedSet>
</Schema>
```

A named set defined against a schema is available in all cubes and virtual cubes in that schema. However, it is only valid if the cube contains dimensions with the names required to make the formula valid. For example, it would be valid to use `[CA Cities]` in queries against the `[Sales]` and `[Warehouse and Sales]` cubes, but if you used it in a query against the `[Warehouse]` cube you would get an error, because `[Warehouse]` does not have a `[Store]` dimension.

Plug-ins

Sometimes Mondrian's schema language isn't flexible enough, or the MDX language isn't powerful enough, to solve the problem at hand. What you want to do is add a little of your own Java code into the Mondrian application, and a *plug-in* is a way to do this.

Each of Mondrian's extensions is technically a Service Provider Interface (SPI); in short, a Java interface which you write code to implement, and which Mondrian will call at runtime. You also need to register an extension (usually somewhere in your schema.xml file) and to ensure that it appears on the classpath.

Plug-ins include user-defined functions; cell, member and property formatters; dynamic schema processors and Data source change listener. There is incomplete support for member readers and cell readers, and in future we may support pluggable SQL dialects.

Other extenstions include Dynamic datasource xmla servlet

User-defined function

A user-defined function must have a public constructor and implement the mondrian.spi.UserDefinedFunction interface. For example,

```
package com.acme;

import mondrian.olap.*;
import mondrian.olap.type.*;
import mondrian.spi.UserDefinedFunction;

/**
 * A simple user-defined function which adds one to its argument.
 */
public class PlusOneUdf implements UserDefinedFunction {
    // public constructor
    public PlusOneUdf() {
    }

    public String getName() {
        return "PlusOne";
    }

    public String getDescription() {
        return "Returns its argument plus one";
```

```
    }

    public Syntax getSyntax() {
        return Syntax.Function;
    }

    public Type getReturnType(Type[] parameterTypes) {
        return new NumericType();
    }

    public Type[] getParameterTypes() {
        return new Type[] {new NumericType()};
    }

    public Object execute(Evaluator evaluator, Exp[] arguments) {
        final Object argValue = arguments[0].evaluateScalar(evaluator);
        if (argValue instanceof Number) {
            return new Double(((Number) argValue).doubleValue() + 1);
        } else {
            // Argument might be a RuntimeException indicating that
            // the cache does not yet have the required cell value. The
            // function will be called again when the cache is loaded.
            return null;
        }
    }

    public String[] getReservedWords() {
        return null;
    }
}
```

Declare it in your schema:

```
<Schema>
  ...
  <UserDefinedFunction name="PlusOne" class="com.acme.PlusOneUdf">
</Schema>
```

And use it in any MDX statement:

```
WITH MEMBER [Measures].[Unit Sales Plus One]
    AS 'PlusOne([Measures].[Unit Sales])'
SELECT
    {[Measures].[Unit Sales]} ON COLUMNS,
    {[Gender].MEMBERS} ON ROWS
FROM [Sales]
```

If a user-defined function has a public constructor with one string argument, Mondrian will pass in the function's name. Why? This allows you to define two or more user-defined functions using the same class:

```
package com.acme;

import mondrian.olap.*;
import mondrian.olap.type.*;
```

```
import mondrian.spi.UserDefinedFunction;

/**
 * A user-defined function which either adds one to or
 * subtracts one from its argument.
 */
public class PlusOrMinusOneUdf implements UserDefinedFunction {
    private final name;
    private final isPlus;

    // public constructor with one argument
    public PlusOneUdf(String name) {
        this.name = name;
        if (name.equals("PlusOne")) {
            isPlus = true;
        } else if (name.equals("MinusOne")) {
            isPlus = false;
        } else {
            throw new IllegalArgumentException("Unexpected name " +
name);
        }
    }

    public String getName() {
        return name;
    }

    public String getDescription() {
        return "Returns its argument plus or minus one";
    }

    public Syntax getSyntax() {
        return Syntax.Function;
    }

    public Type getReturnType(Type[] parameterTypes) {
        return new NumericType();
    }

    public Type[] getParameterTypes() {
        return new Type[] {new NumericType()};
    }

    public Object execute(Evaluator evaluator, Exp[] arguments) {
        final Object argValue = arguments[0].evaluateScalar(evaluator);
        if (argValue instanceof Number) {
            if (isPlus) {
                return new Double(((Number) argValue).doubleValue() +
1);
            } else {
                return new Double(((Number) argValue).doubleValue() -
1);
            }
        } else {
            // Argument might be a RuntimeException indicating that
            // the cache does not yet have the required cell value. The
            // function will be called again when the cache is loaded.
```

```
            return null;
        }
    }

    public String[] getReservedWords() {
        return null;
    }
}
```

and register two the functions in your schema:

```
<Schema>
  ...
  <UserDefinedFunction name="PlusOne"
class="com.acme.PlusOrMinusOneUdf">
  <UserDefinedFunction name="MinusOne"
class="com.acme.PlusOrMinusOneUdf">
</Schema>
```

If you're tired of writing duplicated User-defined Function declarations in schema files, you can pack your User-defined Function implemention classes into a jar file with a embedded resource file META-INF/services/mondrian.spi.UserDefinedFunction. This resource file contains class names of implementations of interface mondrian.spi.UserDefinedFunction, one name per line. For more details, you may look into src/main/META-INF/services/mondrian.spi.UserDefinedFunction in source ball and Service Provider. User-defined Functions declared by this means are available to all mondrian schema in one JVM.

Caution: you can't define more than one User-defined Function implementations in one class when you declare User-defined Functions in this way.

Member reader

A *member reader* is a means of accessing members. Hierarchies are usually based upon a dimension table (an 'arm' of a star schema), and are therefore populated using SQL. But even if your data doesn't reside in an RDBMS, you can make it appear as a hierarchy by writing a Java class called a *custom member reader*.

Here are a couple of examples:

1. `DateSource` (to be written) generates a time hierarchy. Conventionally, data warehouse implementors generate a table containing a row for every date their system is ever likely to deal with. But the problem is that this table needs to be loaded, and as time goes by, they will have to remember to add more rows. DateSource generates date members in memory, and on demand.
2. `FileSystemSource` (to be written) presents the file system as a hierarchy of directories and files. Since a directory can have a parent which is itself a directory, it is a parent-child hierarchy. Like the time hierarchy created by DateSource, this is a virtual hierarchy: the member for a particular file is only created when, and if, that file's parent directory is expanded.
3. `ExpressionMemberReader` (to be written) creates a hierarchy based upon an expression.

A custom member reader must implement the mondrian.rolap.MemberSource interface. If you need to implement a larger set of member operations for fine-grained control, implement the derived mondrian.rolap.MemberReader interface; otherwise, Mondrian wrap your reader in a mondrian.rolap.CacheMemberReader object. Your member reader must have a public constructor which takes (`RolapHierarchy`, `Properties`) parameters, and throws no checked exceptions.

Member readers are declared using the `<Hierarchy>` element's `memberReaderClass` attribute; any `<Parameter>` child elements are passed via the `properties` constructor parameter. Here is an example:

```
<Dimension name="Has bought dairy">
  <Hierarchy hasAll="true"
memberReaderClass="mondrian.rolap.HasBoughtDairySource">
    <Level name="Has bought dairy" uniqueMembers="true"/>
    <Parameter name="expression" value="not used"/>
  </Hierarchy>
</Dimension>
```

Cell reader

Not implemented yet. Syntax would be something like

```
<Measure name="name" formatter="com.acme.MyCellFormatter">
  <CalculatedMemberProperty />
</Measure>
```

For a calculated member that belongs to a cube or virtual cube, you can define a formatter by setting the `CELL_FORMATTER` property of the member to the name of the formatter class:

```
<CalculatedMember name="name" formatter="com.acme.MyCellFormatter">
    <CalculatedMemberProperty name="CELL_FORMATTER"
            value="com.acme.MyCellFormatter" />
      </CalculatedMember>
```

For a calculated measure defined in the `WITH MEMBER` clause of an MDX query, you can set the same property in the MDX to achieve the same effect:

```
WITH MEMBER [Measures].[Foo]
  AS '[Measures].[Unit Sales] * 2',
   CELL_FORMATTER='com.acme.MyCellFormatter'
SELECT {[Measures].[Unit Sales], [Measures].[Foo]} ON COLUMNS,
    {[Store].Children} ON ROWS
FROM [Sales]
```

The cell formatter property is ignored if a member does not belong to the `[Measures]` dimension.

Cell formatter

A cell formatter modifies the behavior of `Cell.getFormattedValue()`. The class must implement the `mondrian.olap.CellFormatter` interface, and is specified like this:

```
<Measure name="name" formatter="com.acme.MyCellFormatter"/>
```

Member formatter

A member formatter modifies the behavior of `Member.getCaption()`. The class must implement the `mondrian.olap.MemberFormatter` interface, and is specified like this:

```
<Level column="column" name="name"
formatter="com.acme.MyMemberFormatter"/>
```

Property formatter

A property formatter modifies the behavior of `Property.getPropertyFormattedValue()`. The class must implement the `mondrian.olap.PropertyFormatter` interface, and is specified like this:

```
<Level name="MyLevel" column="LevelColumn" uniqueMembers="true"/>
<Property name="MyProp" column="PropColumn"
formatter="com.acme.MyPropertyFormatter"/>
<Level/>
```

Schema processor

A schema processor implements the `mondrian.rolap.DynamicSchemaProcessor` interface. It is specified as part of the connection string, like this:

```
Jdbc=jdbc:odbc:MondrianFoodMart; JdbcUser=ziggy; JdbcPassword=stardust;
DynamicSchemaProcessor=com.acme.MySchemaProcessor
```

The effect is that when reading the contents of the schema from a URL, Mondrian turns to the schema processor rather than Java's default URL handler. This gives the schema reader the opportunity to run a schema through a filter, or even generate an entire schema on the fly.

When DynamicSchemaProcessor is specified, schema would be processed and reloaded on every ROLAP connection request. Property UseContentChecksum should be used along with a schema processor to enable caching of the schema:

```
DataSource=java:/jdbc/MyWarehouse;
DynamicSchemaProcessor=com.acme.MySchemaProcessor;
UseContentChecksum=true
```

In this case once loaded schema would be cached until it's change. If schema content has changed, it would be reloaded (and processed).

Dynamic schemas are a very powerful construct. As we shall see, an important application for them is internationalization.

Data source change listener

A data source change listener implements the mondrian.spi.DataSourceChangeListener interface. It is specified as part of the connection string, like this:

```
Jdbc=jdbc:odbc:MondrianFoodMart; JdbcUser=ziggy; JdbcPassword=stardust;
DataSourceChangeListener=com.acme.MyChangeListener;
```

Everytime mondrian has to decide whether it will use data from cache, it will call the change listener. When the change listener tells mondrian the datasource has changed for a dimension, cube, ... then mondrian will flush the cache and read from database again.

This class should be called in mondrian before any data is read, so even before cache is build. This way, the plugin is able to register the first timestamp mondrian tries to read the datasource.

Each time a query is started, aggregate cache is checked to see if it has changed. If so, cache will be flushed and aggregates will be reloaded from the data source.

Here is an example of a data source change listener plugin class :

```
 package com.acme;

 //...
 import javax.sql.DataSource;
 import java.sql.Connection;
 import java.sql.ResultSet;
 import java.sql.SQLException;
 import java.sql.Timestamp;
 //...
 import mondrian.olap.MondrianDef;
 import mondrian.rolap.RolapHierarchy;
 import mondrian.rolap.RolapUtil;
 import mondrian.rolap.agg.Aggregation;
 import mondrian.rolap.RolapStar;
 import mondrian.spi.impl.DataSourceChangeListenerImpl;
 //...

 public class MyChangeListener extends DataSourceChangeListenerImpl {
     public MyChangeListener() {
     }
     public synchronized boolean isHierarchyChanged(RolapHierarchy
hierarchy) {

         // Since this function is called many times, it is a good idea
to not check the database every time
         // And use some sort of time interval...

         // Get name of the table (does not work if based on view)
         String tableName = getTableName(hierarchy);
         Connection jdbcConnection = null;

         DataSource dataSource =
         hierarchy.getRolapSchema().getInternalConnection().getDataSour
ce();
```

```
        try {
            jdbcConnection = dataSource.getConnection();
            if (jdbcConnection != null) {
                // Check database whether hierarchy data source has
changed
                // ...
            }
        }
    }

    public synchronized boolean isAggregationChanged(Aggregation
aggregation) {

        // The first time, register star and bitKey and remember first
time of access...
        RolapStar star = aggregation.getStar();
        BitKey bitKey = aggregation.getConstrainedColumnsBitKey();

        // The first time this function is called, only the bitKey is
set,
        // the columns are not filled up yet.
        RolapStar.Column[] columns = aggregation.getColumns();
        if (columns != null) {
            // Check database...
        }
    }
 }
```

Dynamic datasource xmla servlet

Note that JaspeAnalysis has its own implementation of a servlet to manage XML/A requests, and does not use DynamicDatasourceXmlaServlet. Data sources and other catalog information are stored in the JasperServer repository.

The DynamicDatasourceXmlaServlet Extends DefaultXmlaServlet to add dynamic datasource loading capability. For every client request that it receives, it checks for updates to datasources.xml content. It selectively clears cache for catalogs that have changed or no longer exist in the datasources.xml. It considers a catalog as changed when either of its properties (DataSourceInfo, definition properties on DataSourcesConfig.Catalog) are different. It identifies catalog by name.

This servlet complements the dynamic catalog loading capability based on UseContentChecksum. It does not check the catalog content for updates. There is no overlap in the functionality. Both together will give full dynamic datasource and catalog configuration capability

Following change needs to be done in web.xml in the MondrianXmlaServlet configuration entry:

```
<servlet>
<servlet-name>MondrianXmlaServlet</servlet-name>
<servlet-
class>mondrian.xmla.impl.DynamicDatasourceXmlaServlet</servlet-class>
.
```

.
</servlet>

This implementation has a limitation. It requires catalog name to be unique across the datasources and may not work correctly otherwise

Internationalization

JasperAnalysis does not allow this approach for dynamic internationalization of schemas. You will need a schema per language.

An internationalized Mondrian application would have a schema for each language, where the caption of each object appears in the local language. For example, the `[Product]` dimension would have the caption "Product" in English and "Produit" in French.

It is unwise to translate the actual names of the schema objects, because then the MDX statements would need to be changed also. All that you need to change is the caption. Every schema object (schema, cube, dimension, level, measure) has a caption attribute, and user interfaces such as JPivot display the caption rather than the real name. Additionally:

- A hierarchy can have an `allMemberCaption` attribute as display value of the "All" member.
- For the schema we can set a display value of the "measures" dimension by the `measuresCaption` attribute.

One way to create an internationalized application is to create a copy of the schema file for each language, but these are difficult to maintain. A better way is to use the LocalizingDynamicSchemaProcessor class to perform dynamic substitution on a single schema file.

Localizing schema processor

First, write your schema using variables as values for `caption`, `allMemberCaption` and `measuresCaption` attributes as follows:

```
<Schema measuresCaption="%{foodmart.measures.caption}">

  <Dimension name="Store"
caption="%{foodmart.dimension.store.caption}">
    <Hierarchy hasAll="true" allMemberName="All Stores"
allMemberCaption ="%{foodmart.dimension.store.allmember.caption =All
Stores}" primaryKey="store_id">
    <Table name="store"/>
      <Level name="Store Country" column="store_country"
uniqueMembers="true" caption=
"%{foodmart.dimension.store.country.caption}"/>
      <Level name="Store State" column="store_state"
uniqueMembers="true" caption=
"%{foodmart.dimension.store.state.caption}"/>
      <Level name="Store City" column="store_city"
uniqueMembers="false" caption=
```

```
"%{foodmart.dimension.store.city.caption}"/>
      <Level name="Store Name" column="store_name" uniqueMembers="true"
caption= "%{foodmart.dimension.store.name.caption}">
        <Property name="Store Type" column="store_type" caption=
"%{foodmart.dimension.store. name.property_type.caption}"/>
        <Property name="Store Manager" column="store_manager" caption=
"%{foodmart.dimension.store. name.property_manager.caption}"/>
        <Property name="Store Sqft" column="store_sqft" type="Numeric"
caption= "%{foodmart.dimension.store.
name.property_storesqft.caption}"/>
        <Property name="Grocery Sqft" column="grocery_sqft"
type="Numeric"/>
        <Property name="Frozen Sqft" column="frozen_sqft"
type="Numeric"/>
        <Property name="Meat Sqft" column="meat_sqft" type="Numeric"/>
        <Property name="Has coffee bar" column="coffee_bar"
type="Boolean"/>
        <Property name="Street address" column="store_street_address"
type="String"/>
      </Level>
    </Hierarchy>
  </Dimension>

  <Cube name="Sales" caption="%{foodmart.cube.sales.caption}">
    ...
    <DimensionUsage name="Store" source="Store" foreignKey="store_id"/>
    ...
    <Measure name="Unit Sales" column="unit_sales"
caption="%{foodmart.cube.sales.measure.unitsales}">
```

As usual, the default caption for any cube, measure, dimension or level without a `caption` attribute is the name of the element. A hierarchy's default caption is the caption of its dimension; for example, the `[Store]` hierarchy has no `caption` defined, so it inherits the `caption` attribute from its parent, the `[Store]` dimension.

Next, add the dynamic schema processor and locale to your connect string. For example,

```
Provider=mondrian; Locale=en_US; DynamicSchemaProcessor=
mondrian.i18n.LocalizingDynamicSchemaProcessor; Jdbc=
jdbc:odbc:MondrianFoodMart; Catalog= /WEB-INF/FoodMart.xml
```

Now, for each locale you wish to support, provide a resource file named `locale_{locale}.properties`. For example,

```
# locale.properties: Default resources
foodmart.measures.caption=Measures
foodmart.dimension.store.country.caption=Store Country
foodmart.dimension.store.name.property_type.column= store_type
foodmart.dimension.store.country.member.caption= store_country
foodmart.dimension.store.name.property_type.caption =Store Type
foodmart.dimension.store.name.caption =Store Name
foodmart.dimension.store.state.caption =Store State
foodmart.dimension.store.name.property_manager.caption =Store Manager
foodmart.dimension.store.name.property_storesqft.caption =Store Sq. Ft.
foodmart.dimension.store.allmember.caption =All Stores
```

```
foodmart.dimension.store.caption =Store
foodmart.cube.sales.caption =Sales
foodmart.dimension.store.city.caption =Store City
foodmart.cube.sales.measure.unitsales =Unit Sales
```

and

```
# locale_hu.properties: Resources for the 'hu' locale.
foodmart.measures.caption=Hungarian Measures
foodmart.dimension.store.country.caption=Orsz\u00E1g
foodmart.dimension.store.name.property_manager.caption
=\u00C1ruh\u00E1z vezet\u0151
foodmart.dimension.store.country.member.caption
=store_country_caption_hu
foodmart.dimension.store.name.property_type.caption =Tipusa
foodmart.dimension.store.name.caption =Megnevez\u00E9s
foodmart.dimension.store.state.caption =\u00C1llam/Megye
foodmart.dimension.store.name.property_type.column
=store_type_caption_hu
foodmart.dimension.store.name.property_storesqft.caption =M\u00E9ret
n.l\u00E1b
foodmart.dimension.store.allmember.caption =Minden \u00C1ruh\u00E1z
foodmart.dimension.store.caption =\u00C1ruh\u00E1z
foodmart.cube.sales.caption =Forgalom
foodmart.dimension.store.city.caption =V\u00E1ros
foodmart.cube.sales.measure.unitsales =Eladott db
```

Aggregate tables

Aggregate tables are a way to improve Mondrian's performance when the fact table contains a huge number of rows: a million or more. An aggregate table is essentially a pre-computed summary of the data in the fact table.

Let's look at a simple aggregate table.

```
<Cube name="Sales">
  <Table name="sales_fact_1997">
    <AggName name="agg_c_special_sales_fact_1997">
      <AggFactCount column="FACT_COUNT"/>
      <AggMeasure name="[Measures].[Store Cost]"
column="STORE_COST_SUM"/>
      <AggMeasure name="[Measures].[Store Sales]"
column="STORE_SALES_SUM"/>
      <AggLevel name="[Product].[Product Family]"
column="PRODUCT_FAMILY"/>
      <AggLevel name="[Time].[Quarter]" column="TIME_QUARTER"/>
      <AggLevel name="[Time].[Year]" column="TIME_YEAR"/>
      <AggLevel name="[Time].[Quarter]" column="TIME_QUARTER"/>
      <AggLevel name="[Time].[Month]" column="TIME_MONTH"/>
    </AggName>
  </Table>

  <!-- Rest of the cube definition -->
</Cube>
```

The <AggForeignKey> element, not shown here, allows you to reference a dimension table directly, without including its columns in the aggregate table. It is described in the aggregate tables guide.

In practice, a cube which is based upon a very large fact table may have several aggregate tables. It is inconvenient to declare each aggregate table explicitly in the schema XML file, and luckily there is a better way. In the following example, Mondrian locates aggregate tables by pattern-matching.

```
Cube name="Sales">
  <Table name="sales_fact_1997">
    <AggPattern pattern="agg_.*_sales_fact_1997"/>
      <AggFactCount column="FACT_COUNT"/>
      <AggMeasure name="[Measures].[Store Cost]"
column="STORE_COST_SUM"/>
      <AAggMeasure name="[Measures].[Store Sales]"
column="STORE_SALES_SUM"/>
      <AggLevel name="[Product].[Product Family]"
column="PRODUCT_FAMILY"/>
      <AggLevel name="[Time].[Quarter]" column="TIME_QUARTER"/>
      <AggLevel name="[Time].[Year]" column="TIME_YEAR"/>
      <AggLevel name="[Time].[Quarter]" column="TIME_QUARTER"/>
      <AggLevel name="[Time].[Month]" column="TIME_MONTH"/>
       <AggExclude name="agg_c_14_sales_fact_1997"/>
    <AggExclude name="agg_lc_100_sales_fact_1997"/>
  </Table> </AggPattern>
  </Table
</Cube>
```

It tells Mondrian to treat all tables which match the pattern `"agg_.*_sales_fact_1997"` as aggregate tables, except `"agg_c_14_sales_fact_1997"` and `"agg_lc_100_sales_fact_1997"`. Mondrian uses rules to deduce the roles of the columns in those tables, so it's important to adhere to strict naming conventions. The naming conventions are described in the aggregate tables guide.

The performance guide has advice on choosing aggregate tables.

Access-control

Note that in JasperAnalysis Community Edition, roles are not set when connecting to Mondrian and so roles as defined here are not operational.

In JasperAnalysis Professional, roles are dynamically defined based on the user profile and role definitions. This goers beyond the simple role approach of standard Mondrian. See the JasperAnalysis Professional User and Adminsitration Guides for more details.

OK, so now you've got all this great data, but you don't everyone to be able to read all of it. To solve this, you can define an access-control profile, called a *Role*, as part of the schema, and set this role when establishing a connection.

Defining a role

Roles are defined by `<Role>` elements, which occur as direct children of the `<Schema>` element, after the last `<Cube>`. Here is an example of a role:

```
<Role name="California manager">
  <SchemaGrant access="none">
    <CubeGrant cube="Sales" access="all">
      <HierarchyGrant hierarchy="[Store]" access="custom"
topLevel="[Store].[Store Country]">
        <MemberGrant member="[Store].[USA].[CA]" access="all"/>
        <MemberGrant member="[Store].[USA].[CA].[Los Angeles]"
access="none"/>
      </HierarchyGrant>
      <HierarchyGrant hierarchy="[Customers]" access="custom"
topLevel="[Customers].[State Province]"
bottomLevel="[Customers].[City]">
        <MemberGrant member="[Customers].[USA].[CA]" access="all"/>
        <MemberGrant member="[Customers].[USA].[CA].[Los Angeles]"
access="none"/>
      </HierarchyGrant>
      <HierarchyGrant hierarchy="[Gender]" access="none"/>
    </CubeGrant>
  </SchemaGrant>
</Role>
```

A `<SchemaGrant>` defines the default access for objects in a schema. The `access` attribute can be "all" or "none"; this access can be overridden for specific objects. In this case, because `access="none"`, a user would only be able to browse the "Sales" cube, because it is explicitly granted.

A `<CubeGrant>` defines the access to a particular cube. As for `<SchemaGrant>`, the access attribute can be "all" or "none", and can be overridden for specific sub-objects in the cube.

A `<HierarchyGrant>` defines access to a hierarchy. The access attribute can be "all", meaning all members are visible; "none", meaning the hierarchy's very existence is hidden from the user; and "custom". With custom access, you can use the `topLevel` attribute to define the top level which is visible (preventing users from seeing too much of the 'big picture', such as viewing revenues rolled up to the `Store Country` level); or use the `bottomLevel` attribute to define the bottom level which is visible (here, preventing users from invading looking at individual customers' details); or control which sets of members the user can see, by defining nested `<MemberGrant>` elements.

You can only define a `<MemberGrant>` element if its enclosing `<HierarchyGrant>` has `access="custom"`. Member grants give (or remove) access to a given member, and all of its children. Here are the rules:

1. **Members inherit access from their parents**. If you deny access to California, you won't be able to see San Francisco.
2. **Grants are order-dependent**. If you grant access to USA, then deny access to Oregon, then you won't be able to see Oregon, or Portland. But if you were to deny access to Oregon, then grant access to USA, you can effectively see everything.
3. **A member is visible if any of its children are visible**. Suppose you deny access to USA, then grant access to California. You will be able to see USA, and California, but none of the other states. The totals against USA will still reflect all states, however.
4. **Member grants don't override the hierarchy grant's top- and bottom-levels**. If you set `topLevel="[Store].[Store State]"`, and grant access to California, you won't be able to see USA.

In the example, the user will have access to California, and all of the cities in California except Los Angeles. They will be able to see USA (because its child, California, is visible), but no other nations, and not All Stores (because it is above the top level, `Store Country`).

Rollup policy

A *rollup policy* determines how Mondrian computes a member's total if the current role cannot see all of that member's children. Under the default rollup policy, called 'full', the total for that member includes contributions from the children that are not visible. For example, suppose that Fred belongs to a role that can see `[USA].[CA]` and `[USA].[OR]` but not `[USA].[WA]`. If Fred runs the query

```
SELECT {[Measures].[Unit Sales]} ON COLUMNS,
    {[[Store].[USA], Store].[USA].Children} ON ROWS
FROM [Sales]
```

the query returns

[Customer]	[Measures].[Unit Sales]
[USA]	266,773
[USA].[CA]	74,748
[USA].[OR]	67,659

Note that `[USA].[WA]` is not returned, per the access-control policy, but the total includes the total from Washington (124,366) that Fred cannot see. For some applications, this is not appropriate. In particular, if the dimension has a small number of members, the end-user may be able to deduce the values of the members which they do not have access to.

To remedy this, a role can apply a different rollup policy to a hierarchy. The policy describes how a total is calculated for a particular member if the current role can only see some of that member's children:

- **Full**. The total for that member includes all children. This is the default policy if you don't specify the `rollupPolicy` attribute.
- **Partial**. The total for that member includes only accessible children.
- **Hidden**. If any of the children are inaccessible, the total is hidden.

Note that the default rollup policy in JasperAnalysis is **Partial**.

Under the 'partial' policy, the [USA] total is the sum of the accessible children [CA] and [OR]:

[Customer]	[Measures].[Unit Sales]
[USA]	142,407
[USA].[CA]	74,748
[USA].[OR]	67,659

Under 'hidden' policy, the [USA] total is hidden because one of its children is not accessible:

[Customer]	[Measures].[Unit Sales]
[USA]	-
[USA].[CA]	74,748
[USA].[OR]	67,659

The policy is specified per role and hierarchy. In the following example, the role sees partial totals for the [Store] hierarchy but full totals for [Product].

```
<Role name="South Pacific manager">
    <SchemaGrant access="none">
        <CubeGrant cube="Sales" access="all">
            <HierarchyGrant hierarchy="[Store]" access="custom"
rollupPolicy="partial" topLevel="[Store].[Store Country]">
                <MemberGrant member="[Store].[USA].[CA]" access="all"/>
                <MemberGrant member="[Store].[USA].[CA].[Los Angeles]"
access="none"/>
            </HierarchyGrant>
            <HierarchyGrant hierarchy="[Customers]" access="custom"
rollupPolicy="full" topLevel="[Customers].[State Province]"
bottomLevel="[Customers].[City]">
                <MemberGrant member="[Customers].[USA].[CA]"
access="all"/>
                <MemberGrant member="[Customers].[USA].[CA].[Los
Angeles]" access="none"/>
            </HierarchyGrant>
            <HierarchyGrant hierarchy="[Gender]" access="none"/>
        </CubeGrant>
    </SchemaGrant>
</Role>
```

This example also shows existing features, such as how hierarchy grants can be restricted using topLevel and/or bottomLevel attributes, and how a role can be prevented from seeing a hierarchy using access="none".

Union roles

A union role combines several roles, and has the sum of their privileges.

A union role can see a particular schema object if one or more of its constituent roles can see it. Similarly, the rollup policy of a union role with respect to a particular hierarchy is the least restrictive of all of the roles' rollup policies.

Here is an example showing the syntax of a union role.

```
<Role name="Coastal manager">
  <Union>
    <RoleUsage roleName="California manager" />
    <RoleUsage roleName="Eastern sales manager" />
  </Union>
</Role>
```

The constituent roles "California manager" and "Eastern sales manager" may be regular roles, user-defined roles or union roles, but they must be declared earlier in the schema file. The "Coastal manager" role will be able to see any member that or a "California manager" and "Eastern sales manager". It will be able to see all the cells at the intersection of these members, plus it will be able to see cells that neither role can see: for example, if only "California manager" can see `[USA].[CA].[Fresno]`, and only "Eastern sales manager" see the `[Sales Target]` measure, then "Coastal manager" will be able to see the sales target for Fresno, which neither of the constituent roles have access to.

Setting a connection's role

A role only has effect when it is associated with a connection. By default, connections have a role which gives them access to every cube in that connection's schema.

Most databases associate roles (or 'groups') with users, and automatically assign them when users log in. However, Mondrian doesn't have the notion of users, so you have to establish the role in a different way. There are two ways of doing this:

1. **In the connect string**. If you specify the Role keyword in the connect string, the connection will adopt that role. You can specify multiple role names separated by commas, and a union role will be created; if a role name contains a comma, escape it with an extra comma. See class DriverManager for examples of connect string syntax.
2. **Programmatically**. Once your application has established a connection, call the method Connection.setRole(Role). You can create a Role programmatically (see interface Role and the developer's note link for more details), or look one up using the method Schema.lookupRole(String).

XML elements

Element	Description
<Schema>	Collection of Cubes, Virtual cubes, Shared dimensions, and Roles.
Logical elements	
<Cube>	A collection of dimensions and measures, all centered on a fact table.
<VirtualCube>	A cube defined by combining the dimensions and measures of one or more cubes. A measure

	originating from another cube can be a <CalculatedMember>.
<VirtualCubeDimension>	Usage of a dimension by a virtual cube.
<VirtualCubeMeasure>	Usage of a measure by a virtual cube.
<Dimension>	
<DimensionUsage>	Usage of a shared dimension by a cube.
<Hierarchy>	Hierarchy.
<Level>	Level of a hierarchy.
<KeyExpression>	SQL expression used as key of the level, in lieu of a column.
<NameExpression>	SQL expression used to compute the name of a member, in lieu of Level.nameColumn.
<CaptionExpression>	SQL expression used to compute the caption of a member, in lieu ofLevel.captionColumn.
<OrdinalExpression>	SQL expression used to sort members of a level, in lieu of Level.ordinalColumn.
<ParentExpression>	SQL expression used to compute a measure, in lieu of Level.parentColumn.
<Property>	Member property. The definition is against a hierarchy or level, but the property will be available to all members.
<PropertyExpression>	SQL expression used to compute the value of a property, in lieu of Property.column.
<Measure>	
<CalculatedMember>	A member whose value is derived using a formula, defined as part of a cube.
<NamedSet>	A set whose value is derived using a formula, defined as part of a cube.
Physical elements	
<Table>	Fact or dimension table.
<View>	Defines a 'table' using a SQL query, which can have different variants for different underlying databases.
<Join>	Defines a 'table' by joining a set of queries.
<InlineTable>	Defines a table using an inline dataset.
<Closure>	Maps a parent-child hierarchy onto a closure table.
Aggregate Tables	
<AggExclude>	Exclude a candidate aggregate table by name or pattern matching.
<AggName>	Declares an aggregate table to be matched by name.
<AggPattern>	Declares a set of aggregate tables by regular expression pattern.
<AggFactCount>	Specifies name of the column in the candidate aggregate table which contains the number of fact table rows.
<AggIgnoreColumn>	Tells Mondrian to ignore a column in an

	aggregate table.
<AggForeignKey>	Maps foreign key in the fact table to a foreign key column in the candidate aggregate table.
<AggMeasure>	Maps a measure to a column in the candidate aggregate table.
<AggLevel>	Maps a level to a column in the candidate aggregate table.
Access control	
<Role>	An access-control profile.
<SchemaGrant>	A set of rights to a schema.
<CubeGrant>	A set of rights to a cube.
<CubeUsages>	Base cubes that are imported into a virtual cube
<CubeUsage>	Usage of a base cube by a virtual cube.
<HierarchyGrant>	A set of rights to a hierarchy and levels within that hierarchy.
<MemberGrant>	A set of rights to a member and its children.
<Union>	Definition of a set of rights as the union of a set of roles.
Extensions	
<UserDefinedFunction>	Imports a user-defined function.
Miscellaneous	
<Parameter>	Part of the definition of a Hierarchy; passed to a MemberReader, if present.
<CalculatedMemberProperty>	Property of a calculated member.
<Formula>	Holds the formula text within a <NamedSet> or <CalculatedMember>.
<ColumnDefs>	Holder for <ColumnDef> elements.
<ColumnDef>	Definition of a column in an <InlineTable> dataset.
<Rows>	Holder for <Row> elements.
<Row>	Row in an <InlineTable> dataset.
<Value>	Value of a column in an <InlineTable> dataset.
<MeasureExpression>	SQL expression used to compute a measure, in lieu of a column.
<SQL>	The SQL expression for a particular database dialect.

MDX Specification

What is MDX?

MDX stands for 'multi-dimensional expressions'. It is the main query language implemented by Mondrian.

MDX was introduced by Microsoft with Microsoft SQL Server OLAP Services in around 1998, as the language component of the OLE DB for OLAP API. More recently, MDX has appeared as part of the XML for Analysis API. Microsoft proposed MDX as a standard, and its adoption among application writers and other OLAP providers is steadily increasing.

What is the syntax of MDX?

A basic MDX query looks like this:

```
SELECT {[Measures].[Unit Sales], [Measures].[Store Sales]} ON
COLUMNS,{[Product].members} ON ROWS
    FROM [Sales] WHERE [Time].[1997].[Q2]
```

It looks a little like SQL, but don't be deceived! The structure of an MDX query is quite different from SQL.

Since MDX is a standard language, we don't cover its syntax here. (The Microsoft SQL Server site has an MDX specification; there's also a good tutorial in Database Journal.) This specification describes the differences between Mondrian's dialect and the standard dialect of MDX.

Mondrian-specific MDX

StrToSet and StrToTuple

The StrToSet() and StrToTuple() functions take an extra parameter:

Parsing

Parsing is case-sensitive.

Parameters

Pseudo-functions Param() and ParamRef() allow you to create parameterized MDX statements.

Cast operator

The Cast operator converts scalar expressions to other types. The syntax is

```
Cast(<Expression> AS <Type>)
```

where <Type> is one of:

- BOOLEAN
- NUMERIC
- DECIMAL
- STRING

For example,

```
Cast([Store].CurrentMember.[Store Sqft], INTEGER)
```

returns the value of the `[Store Sqft]` property as an integer value.

`IN` and `NOT IN`

`IN` and `NOT IN` are Mondrian-specific functions. For example:

```
SELECT {[Measures].[Unit Sales]} ON COLUMNS,
   FILTER([Product].[Product Family].MEMBERS,
          [Product].[Product Family].CurrentMember NOT IN
              {[Product].[All Products].firstChild,
               [Product].[All Products].lastChild}) ON ROWS
FROM [Sales]
```

`MATCHES` and `NOT MATCHES`

`MATCHES` and `NOT MATCHES` are Mondrian-specific functions which compare a string with a Java regular expression. For example, the following query finds all employees whose name starts with 'sam' (case-insensitive):

```
SELECT {[Measures].[Org Salary]} ON COLUMNS,
   Filter({[Employees].MEMBERS},
          [Employees].CurrentMember.Name MATCHES '(?i)sam.*') ON ROWS
FROM [HR]
```

Visual Basic for Applications (VBA) functions

Since the first implementation of MDX was as part of Microsoft SQL Server OLAP Services, the language inherited the built-in functions available in that environment, namely the Visual Basic for Applications (VBA) specification. This specification includes functions for conversion (CBool, CInt, IsNumber), arithmetic (Tan, Exp), finance (NPer, NPV), and date/time (DatePart, Now). Even though Mondrian cannot interface with Visual Basic, it includes a large number of VBA functions to allow MDX queries written in a Microsoft environment to run unchanged.

This document describes which VBA functions are available in Mondrian; for more detailed descriptions of all VBA functions, see Visual Basic Functions. Note that that document includes some VBA functions which are not implemented in Mondrian.

Comments

MDX statements can contain comments. There are 3 syntactic forms for comments:

// End-of-line comment

-- End-of-line comment

/* Multi-line
comment */

Comments can be nested, for example

/* Multi-line
comment /* Comment within a comment */
*/

Format Strings

Every member has a FORMAT_STRING property, which affects how its raw value is rendered into text in the user interface. For example, the query

```
WITH MEMBER [Measures].[Profit] AS '([Measures].[Store Sales] -
[Measures].[Store Cost])',
FORMAT_STRING = "$#,###.00"
SELECT {[Measures].[Store Sales], [Measures].[Profit]} ON COLUMNS,
{[Product].CurrentMember.Children} ON ROWS
FROM [Sales]
```

yields cells formatted in dollar and cent amounts.

Members defined in a schema file can also have format strings. Measures use the formatString attribute:

```
<Measure name="Store Sales" column="store_sales" aggregator="sum"
formatString="#,###.00"/>
```

and calculated members use the <CalculatedMemberProperty> sub-element:

```
<CalculatedMember name="Profit" dimension="Measures"
formula="[Measures].[Store Sales] - [Measures].[Store Cost]">
  <CalculatedMemberProperty name="FORMAT_STRING" value="$#,##0.00"/>
</CalculatedMember>
```

Format strings use Visual Basic formatting syntax; see class mondrian.olap.Format for more details.

A measure's format string is usually a fixed string, but is really an expression, which is evaluated in the same context as the cell. You can therefore change the formatting of a cell depending upon the cell's value.

The format string can even contain 'style' attributes which are interpreted specially by JPivot. If present, JPivot will render cells in color.

The following example combines a dynamic formula with style attributes. The result is that cells are displayed with green background if they are less than $100,000, or a red background if they are greater than $100,000:

```
WITH MEMBER [Measures].[Profit] AS
   '([Measures].[Store Sales] - [Measures].[Store Cost])',
  FORMAT_STRING = Iif([Measures].[Profit] < 100000, '|#|style=green',
'|#|style=red')
SELECT {[Measures].[Store Sales], [Measures].[Profit]} ON COLUMNS,
  {[Product].CurrentMember.Children} ON ROWS
FROM [Sales]
```

Order of sets

MDX sets are ordered and may contain duplicates. (Both of these properties are at odds with the mathematical definition of 'set', so it would have been better if they were called 'lists', but we're stuck with the term 'set'.)

For most functions that return sets, Microsoft's documentation for SQL Server Analysis Services 2008 (the *de facto* MDX standard) does not specify the order of elements in the result set, and one might assume that MDX server could return the results in any order and still comply with the standard. However, Mondrian's implementation of MDX gives stronger guarantees: a function's result set will be in the obvious order.

For most functions, the definition of 'obvious' is obvious, so we won't spell it out in detail. For example, `Filter` returns elements in the same order as the set expression; `Crossjoin` returns the results in the order of the first set expression, then within that, by the second second expression. Similarly `Generate`, `Union`, `Except`. The sorting functions (`Order`, `TopCount`, `BottomCount`, `TopPercent`, `Hierarchize`, etc.) use a stable sorting algorithm. Metadata methods such as `<Hierarchy>.Members` return their results in natural order.

If you do not care about the order of results of a set expression (say because you are sorting the results later), wrap the expression the `Unorder` function, and mondrian may be able to use a more efficient algorithm that does not guarantee order.

Configuration Guide

Properties

Mondrian has a properties file to allow you to configure how it executes. The mondrian.properties file is loaded when the executing Mondrian JAR detects it needs properties, but can also be done explicitly in your code. It looks in several places, in the following order:

1. In the directory where you started your JVM (Current working directory for JVM process, java.exe on Win32, java on *nix).

2. If there isn't mondrian.properties under current working directory of JVM process, Class MondrianProperties's classloader will try to locate mondrian.properties in all of its classpaths. So you may put mondrian.properties under `/WEB-INF/classes` when you pack Mondrian into a Java web application. The demonstration web applications have this configuration.

These properties are stored as system properties, so they can be set during JVM startup via `-D<property>=<value>`.

Property list

The following properties in `mondrian.properties` effect the operations of Mondrian.

Not all of the properties in this table are of interest to the end-user. For example, those in the 'Testing' are only applicable if are running Mondrian's suite of regression tests.

Property	Type	Default value	Description
Miscellaneous			
mondrian.foodmart .jdbcURL	string	"jdbc:odbc: Mondrian FoodMart"	Property containing the JDBC URL of the FoodMart database. The default value is to connect to an ODBC data source called "MondrianFoodMart".
mondrian.query. limit	int	40	Maximum number of simultaneous queries the system will allow. Oracle fails if you try to run more than the 'processes' parameter in init.ora, typically 150. The throughput of Oracle and other databases will probably reduce long before you get to their limit.
mondrian. jdbcDrivers	string	See Description	A list of JDBC drivers to load automatically. Must be a comma-separated list of class names, and the classes must be on the class path.
mondrian.result .limit	int	0	If a query exceeds the limit, you will get an error such as: Mondrian result limit exceeded: Mondrian Error: Size of CrossJoin result (53,463) exceeded limit (50,000) or Number of members to be read exceeded limit 50,000 and Mondrian throws a mondrian.olap.ResourceLimitExceededException. See also limit properties.

mondrian.rolap. CachePool.costLimit	int	10,000	Obsolete.
mondrian.rolap. evaluate. MaxEvalDepth	int	10	Maximum number of passes allowable while evaluating an MDX expression. If evaluation exceeds this depth (for example, while evaluating a very complex calculated member), Mondrian will throw an error.
mondrian.rolap. LargeDimension Threshold	int	100	Determines when a dimension is considered "large". If a dimension has more than this number of members, Mondrian uses a smart member reader.
mondrian.rolap. SparseSegment ValueThreshold	int	1,000	The values of the mondrian.rolap. SparseSegment ValueThreshold (*countThreshold*) and mondrian.rolap. SparseSegment DensityThreshold (*densityThreshold*) properties determine whether to choose a sparse or dense representation when storing collections of cell values in memory. When storing collections of cell values in memory, Mondrian has to choose between a sparse and a dense representation, based upon the *possible* and *actual* number of values. The *density* is defined by the formula *density = actual / possible* Mondrian uses a sparse representation if possible - (countThreshold * actual) > densityThreshold For example, at the default values (*countThreshold* = 1000 and *densityThreshold* = 0.5), Mondrian use a dense representation for • (1000 possible, 0 actual), or • (2000 possible, 500 actual), or • (3000 possible, 1000 actual). Any fewer actual values, or any more possible values, and Mondrian will use a sparse representation.
mondrian.rolap. SparseSegment DensityThreshold	double	0.5	See mondrian.rolap. SparseSegment ValueThreshold.
mondrian.olap. triggers.enable	boolean	true	Whether to notify the Mondrian system when a property value changes.

			This allows objects dependent on Mondrian properties to react (that is, reload), when a given property changes via, say,
			
			`MondrianProperties .instance() .populate(null);`
			
			or
			
			`MondrianProperties .instance() .QueryLimit.set(50);`

mondrian.olap. case.sensitive	boolean	false	Controls whether the MDX parser resolves uses case-sensitive matching when looking up identifiers.
mondrian.rolap. localePropFile	string	null	Name of locale property file. Used for the LocalizingDynamicSchemaProcessor; see Internationalization for more details.
mondrian.rolap.queryTimeout	int	0	If set to a value greater than zero, limits the number of seconds a query executes before it is aborted.
mondrian.rolap.nonempty	boolean	false	If true, each query axis implicit has the NON EMPTY option set (and in fact there is no way to display empty cells).
mondrian.rolap.ignoreInvalidMembers	boolean	false	If set to true, during schema load, invalid members are ignored and will be treated as a null member if they are later referenced in a query.
Testing			
mondrian.test. Name	string	null	Property which determines which tests are run. This is a Java regular expression. If this property is specified, only tests whose names match the pattern in its entirety will be run.
mondrian.test. Class	string	-	Property which determines which test class to run. This is the name of the class which either implements interface junit .framework.Test or has a method `public static junit.framework.Test suite()`.
mondrian.test .connectString	string	-	Property containing the connect string which regresssion tests should use to connect to the database. See the connect string specification for more details.
mondrian.test .QueryFilePattern	string	-	(not documented)

mondrian.test .QueryFileDirectory	string	-	(not documented)
mondrian.test .Iterations	int	1	(not documented)
mondrian.test .VUsers	int	1	(not documented)
mondrian.test .TimeLimit	int	0	The time limit for the test run in seconds. If the test is running after that time, it is terminated.
mondrian.test .Warmup	boolean	false	Whether this is a "warmup test".
mondrian. catalogURL	string	-	The URL of the catalog to be used by CmdRunner and XML/A Test.
mondrian.test .ExpDependencies	int	0	Whether to test operators' dependencies, and how much time to spend doing it. If this property is positive, Mondrian's test framework allocates an expression evaluator which evaluates each expression several times, and makes sure that the results of the expression are independent of dimensions which the expression claims to be independent of.
mondrian.test .random.seed	int	1234	Seed for random number generator used by some of the tests. Any value besides 0 or -1 gives deterministic behavior. The default value is 1234: most users should use this. Setting the seed to a different value can increase coverage, and therefore may uncover new bugs. If you set the value to 0, the system will generate its own pseudo-random seed. If you set the value to -1, Mondrian uses the next seed from an internal random-number generator. This is a little more deterministic than setting the value to 0. public final IntegerProperty TestSeed = new IntegerProperty(this, "", 1234);
mondrian.test. jdbcURL	string	-	Property containing the JDBC URL of a test database. It does not default.
mondrian.test .jdbcUser	string	-	Property containing the JDBC user of a test database. The default value is null, to cope with DBMSs that don't need this.
mondrian.test .jdbcPassword	string	-	Property containing the JDBC password of a test database. The default value is null, to cope with DBMSs that don't need this.
Aggregate tables			
mondrian.rolap	boolean	False,	Whether to use aggregate tables.

.aggregates.Use		True in JasperAnalysis	If true, then Mondrian uses aggregate tables. This property is queried prior to each aggregate query so that changing the value of this property dynamically (not just at startup) is meaningful. Aggregates can be read from the database using the mondrian.rolap.aggregates.Read property but will not be used unless this property is set to true.
mondrian.rolap.aggregates.Read	boolean	False, True in JasperAnalysis	Whether to read aggregate tables. If set to true, then Mondrian scans the database for aggregate tables. Unless mondrian.rolap. aggregates.Use is set to true, the aggregates found will not be used.
mondrian.rolap. aggregates.ChooseByVolume	boolean	False	Whether to choose an aggregate tables based volume or row count. If true, Mondrian uses the aggregate table with the smallest volume (number of rows multiplied by number of columns); if false, Mondrian uses the aggregate table with the fewest rows.
mondrian.rolap.aggregates.rules	string	See Description	Name of the file which defines the rules for recognizing an aggregate table. Can be either a resource in the Mondrian jar or a URL. See aggregate table rules for details. Normally, this property is not set by a user. Default: "/DefaultRules.xml" (which is in the mondrian.rolap.aggmatcher package in mondrian.jar)
mondrian.rolap.aggregates.rule.tag	string	default	The AggRule element's tag value. Normally, this property is not set by a user.
mondrian.rolap. aggregates.generateSql	boolean	false	Whether to print the SQL code generated for aggregate tables. If set, then as each aggregate request is processed, both the lost and collapsed dimension create and insert sql code is printed. This is for use in the CmdRunner allowing one to create aggregate table generation sql.

Caching			
mondrian.rolap.star.disable Caching	boolean	false	Whether to clear a RolapStar's data cache after each query. If true, RolapStar does not cache aggregate data from one query to the next: the cache is cleared after each query.
mondrian.expCache .enable	boolean	true	Controls whether to use a cache for the results of frequently evaluated expressions. With the cache disabled, an expression like: `Rank([Product]. CurrentMember, Order([Product] .MEMBERS, [Measures].[Unit Sales]))` would perform many redundant sorts.
mondrian.rolap.RolapResult. flushAfterEachQuery	boolean	false	Obsolete.
SQL generation			
mondrian.native.crossjoin.enable	boolean	true	If enabled, some NON EMPTY `CrossJoin` MDX statements will be computed in the database and not within Mondrian/Java
mondrian.native.topcount.enable	boolean	false	If enabled, some `TopCount` MDX statements will be computed in the database and not within Mondrian/Java
mondrian.native.filter.enable	boolean	false	If enabled, some `Filter()` MDX statements will be computed in the database and not within Mondrian/Java
mondrian.native.nonempty.enable	boolean	true	If enabled, some NON EMPTY MDX set operations like `member.children`, `level.members` and `member.descendants` will be computed in the database and not within Mondrian/Java
mondrian.rolap.generate.formatted .sql	boolean	false	Whether to pretty-print SQL generated statements. If true, Mondrian generates SQL strings are generated in the log or output in pretty-print mode, formatted for ease of reading.
mondrian.rolap.maxConstraints	int	1,000	Max number of constraints in a single `IN' SQL clause. This value may be variant among database products and their runtime settings. Oracle, for example, gives the error "ORA-01795: maximum number of expressions in a list is 1000".

			Recommended values: • Oracle: 1,000 • DB2: 2,500 • Other: 10,000
XML/A			
mondrian.xmla. drillthroughTotalCount.enable	boolean	true	If enabled, first row in the result of an XML/A drill-through request will be filled with the total count of rows in underlying database.
mondrian.xmla. drillthroughMaxRows	int	1,000	Limit on the number of rows returned by XML/A drill through request.

Connect strings

Connect string syntax

Mondrian connect strings are a connection of property/value pairs, of the form 'property=value;property=value;...'.

Values can be enclosed in single-quotes, which allows them to contain spaces and punctuation. See the the OLE DB connect string syntax specification.

The supported properties are described below.

Connect string properties

Name	Required?	Description
Provider	Yes	Must have the value "Mondrian".
Jdbc	Exactly one	The URL of the JDBC database where the data is stored. You must specify either `DataSource` or `Jdbc`.
DataSource		The name of a data source class. The class must implement the javax.sql.DataSource interface. You must specify either `DataSource` or `Jdbc`.
JdbcDrivers	Yes	Comma-separated list of JDBC driver classes, for example, `JdbcDrivers=sun.jdbc.odbc.JdbcOdbcDriver,oracle.jdbc.OracleDriver`
JdbcUser	No	The name of the user to log on to the JDBC database. (If your JDBC driver allows you to specify the user name in the JDBC URL, you don't need to set this property.)
JdbcPassword	No	The name of the password to log on to the JDBC database. (If your JDBC driver allows you to specify the password in the JDBC URL, you don't need to set this property.)
Catalog	Exactly one	The URL of the catalog, an XML file which describes the schema: cubes, hierarchies, and so forth. For example, `Catalog=file:demo/FoodMart.xml` Catalogs are described in the Schema Guide. See also `CatalogContent`.
CatalogContent		An XML string representing the schema: cubes, hierarchies, and so forth. For example, `CatalogContent=<Schema name="MySchema"><Cube name="Cube1"> ... </Schema>` Catalogs are described in the Schema Guide. See also `Catalog`.
CatalogName	No	Not used. If, in future, Mondrian supports multiple catalogs, this

		property will specify which catalog to use. See also `Catalog`.
PoolNeeded	No	Tells Mondrian whether to add a layer of connection pooling. If the value "true" is specified, or no value is specified, Mondrian assumes that: • connections created via the `Jdbc` property are not pooled, and therefore need to be pooled; • connections created via the `DataSource` are already pooled. If the value "false" is specified, Mondrian does not apply connection-pooling to any connection.
Role	No	The name of the role to adopt for access-control purposes. If not specified, the connection uses a role which has access to every object in the schema.
jdbc.*	No	Any property whose name begins with "jdbc." will be added to the JDBC connection properties, after removing this prefix. This allows you to specify connection properties without a URL. For example, given the properties jdbc.Timeout=50; jdbc.CacheSize=1m Mondrian will create a JDBC connection using the properties {Timeout="50", CacheSize="1m"}.
UseContentChecksum	No	Allows mondrian to work with dynamically changing schema. If this property is set to true and schema content has changed (previous checksum doesn't equal with current), schema would be reloaded. The default is false. Could be used in combination with DynamicSchemaProcessor property.
UseSchemaPool	No	Controls whether a new connection use a schema from the schema cache. If true, the default, a connection shares a schema definition (and hence also a cache of aggregate data retrieved by previous queries) with other connections which have a textually identical schema definition. If false, the connection has a private schema definition and cache.
DynamicSchemaProcessor	No	The name of a class which is called at runtime in order to modify the schema content. The class must implement the mondrian.rolap.DynamicSchemaProcessor interface. For example, `DynamicSchemaProcessor = mondrian.i18n.LocalizingDynamicSchemaProcessor` uses the builtin schema processor class mondrian.i18n.LocalizingDynamicSchemaProcessor to replace variables in the schema file, according to resource files and the

		current locale (see the `Locale` property).
Locale	No	The requested Locale for the current session. The locale determines the formatting of numbers and date/time values, and Mondrian's error messages. Example values are "en" (English), "en_US" (United States English), "hu" (Hungarian). If Locale is not specified, then the name of system's default will be used, as per java.util.Locale#getDefault().

Connect string properties are also documented in the RolapConnectionProperties class.

Cache management

Schema cache

To flush all schema definitions, use the mondrian.olap.MondrianServer.flushSchemaCache() method:

```
import mondrian.olap.*;

Connection connection;
MondrianServer.forConnection(connection).flushSchemaCache();
```

The cache is only used when creating new connections; existing connections retain their schemas.

Memory management

Out Of Memory

Java `OutOfMemoryErrors` have always been an issue with applications. When the JVM throws an `Error` as opposed to an `Exception` it is telling the application that its world has ended and it has no recourse but to die. Prior to Java5 there was not much one could do other than buy 64-bit machines with lots of RAM and hope for the best. For a multi-user, Mondrian environment with potentially very large data-sets and clients that can generate queries requesting arbitrarily large amounts of that data, this can be an issue. This is especially the case when Mondrian is being hosted on some corporate web-server; applications that kill web-servers are not looked upon favorably by IT.

With Java5 (and Java6, etc.) there is alternative. An application cay take advantage of a new feature in Java5 allowing the application to be notified when memory starts running low. This allows the application to take preemptive action prior to an `OutOfMemoryError` being generated by the Java runtime.

Mondrian takes advantage of this new feature. Rather than passing an `OutOfMemoryError` to its client, it will now stop processing the present query, free up data structures associated with the present query and return a `MemoryLimitExceededException` to the client. The `MemoryLimitExceededException` is one of Mondrian's `ResultLimitExceededException`

which are used to communicate with clients that a limit has been exceeded, in this case, memory usage.

By default, for Mondrian running under Java5, this feature is enabled and the "safety limit" is set at 90 percent, when memory usage gets to with 90 percent of the maximum possible, the the processing of the current query is stopped and a `MemoryLimitExceededException` is return to the client. See the Memory monitoring properties above on this page for additional information.

Lastly, the gorilla in the closet. Java5 in its wisdom only allows for one memory threshold notification level to be registered with the JVM. What this means is if within the same JVM, some code registers one level, say, at 80% (here I use percentages for ease of presentation rather than number of bytes which is what the Java5 API actually supports) and some other code later on registers a level of 90%, then it is the 90% that the JVM knows about - it knows nothing of the previously registered 80%. What this means is that the code expecting to be notified when the memory level crosses 80%, won't be notified!

For many applications that don't share their JVM with other applications, this is not a problem, but for Mondrian is it potentially an issue. Mondrian can be running in a Webserver and Webservers can have more than one independent applications. Each such application can register a different memory threshold notification level. In general, application-containing applications such as web-servers or application-servers are a problem with the current Java5 memory threshold notification approach. At the current time, I do not know a way around this problem.

Logging

Mondrian uses log4j for all information and debug logging. When running within an application server, Mondrian's log4j configuration is determined by the server's or web application's log4j configuration. Please see log4j's documentation for a additional details.

Configuring log4j within Mondrian's test environment

When running outside an application server, log4j determines the location of the log4j.xml file via the log4j.configuration java system property. log4j treats this string as a URL, so to have it detect the log4j file on the file system, you must use the syntax "file:DIR/log4j.xml". Relative paths are acceptible, so if you have your log4j.xml file in the root directory of mondrian, "file:log4j.xml" will load the correct file. You may specify the log4j.configuration property in mondrian.properties, because Mondrian's ant build file explicitly sets the property as a JVM system property when running JUnit tests.

MDX and SQL Statement Logging

The default log4j.xml file is configured so that a separate log file is created for both MDX and SQL statement logging. In the code, the MDX and SQL strings are logged at the debug level, so to disable them you can set the log level to INFO or any other level above debug. Statement logging occurs within the log4j categories "mondrian.mdx" ,"mondrian.sql" and “jasperanalysis.drillThroughSQL”. These categories log the statements and how long they took to execute. The SQL log also records the number of results returned in the result set.

Optimizing Mondrian Performance

Introduction

As with any data warehouse project, dealing with volumes is always the make or break issue. Mondrian has its own issues, based on its architecture and goals of being cross platform. Here are some experiences and comments.

From the Mondrian developer's mailing list in February, 2005 - an example of unoptimized performance:

When Mondrian initializes and starts to process the first queries, it makes SQL calls to get member lists and determine cardinality, and then to load segments into the cache. When Mondrian is closed and restarted, it has to do that work again. This can be a significant chunk of time depending on the cube size. For example in one test an 8GB cube (55M row fact table) took 15 minutes (mostly doing a group by) before it returned results from its first query, and absent any caching on the database server would take another 15 minutes if you closed it and reopened the application. Now, this cube was just one month of data; imagine the time if there was 5 years worth.

Since this time, Mondrian has been extended to use aggregate tables and materialized views, which have a lot of performance benefits that address the above issue.

From Julian:

I'm surprised that people can run 10m+ row fact tables on Mondrian at all, without using aggregate tables or materialized views.

From Sherman:

Our largest site has a cube with currently ~6M facts on a single low end Linux box running our application with Mondrian and Postgres (not an ideal configuration), without aggregate tables, and gets sub second response times for the user interface (JPivot). This was achieved by tuning the database to support the queries being executed, modifying the OS configuration to best support Postgres execution (thanks Josh!) and adding as much RAM as possible.

A generalized tuning process for Mondrian

The process for addressing performance of Mondrian is a combination of design, hardware, database and other configuration tuning. For really large cubes, the performance issues are driven more by the hardware, operating system and database tuning than anything Mondrian can do.

- Have a reasonable physical design for requirements, such as a data warehouse and specific data marts
- Architect the application effectively
    - Separate the environment where Mondrian is executing from the DBMS

    - If possible: separate UI processing from the environment where Mondrian is caching
- Have adequate hardware for the DBMS
- Tune the operating system for the DBMS
- Add materialized views or aggregate tables to support specific MDX queries (see Aggregate Tables and AggGen below)
- Tune the DBMS for the specific SQL queries being executed: that is, indexes on both the dimensions and fact table
- Tune the Mondrian cache: the larger the better

Recommendations for database tuning

As part of database tuning process, enable SQL tracing and tail the log file. Run some representative MDX queries and watch which SQL statements take a long time. Tune the database to fix those statements and rerun.

- Indexes on primary and foreign keys
- Consider enabling foreign keys
- Ensure that columns are marked NOT NULL where possible
- If a table has a compound primary key, experiment with indexing subsets of the columns with different leading edges. For example, for columns (a, b, c) create a unique index on (a, b, c) and non-unique indexes on (b, c) and (c, a). Oracle can use such indexes to speed up counts.
- On Oracle, consider using bitmap indexes for low-cardinality columns. (Julian implemented the Oracle's bitmap index feature, and he's rather proud of them!)
- On Oracle, Postgres and other DBMSs, analyze tables, otherwise the cost-based optimizers will not be used

Mondrian currently uses 'count(distinct ...)' queries to determine the cardinality of dimensions and levels as it starts, and for your measures that are counts, that is, `aggregator="count"`. Indexes might speed up those queries -- although performance is likely to vary between databases, because optimizing count-distinct queries is a tricky problem.

Aggregate Tables, Materialized Views and Mondrian

The best way to increase the performance of Mondrian is to build a set of aggregate (summary) tables that coexist with the base fact table. These aggregate tables contain pre-aggregated measures build from the fact table.

Some databases, particularly Oracle, can automatically create these aggregations through materialized views, which are tables created and synchronized from views. Otherwise, you will have to maintain the aggregation tables through your data warehouse load processes, usually by clearing them and rerunning aggregating INSERTs.

Aggregate tables are introduced in the Schema Guide.

Choosing aggregate tables

It isn't easy to choose the right aggregate tables. For one thing, there are so many to choose from: even a modest cube with six dimensions each with three levels has $6^4 = 1296$ possible aggregate tables! And aggregate tables interfere with each other. If you add a new aggregate table, Mondrian may use an existing aggregate table less frequently.

Missing aggregate tables may not even be the problem. Choosing aggregate tables is part of a wider performance tuning process, where finding the problem is more than half of the battle. The real cause may be a missing index on your fact table, your cache isn't large enough, or (if you're running Oracle) the fact that you forgot to compute statistics. (See recommendations, above.)

Performance tuning is an iterative process. The steps are something like this:

1. Choose a few queries which are typical for those the end-users will be executing.
2. Run your set of sample queries, and note how long they take. Now the cache has been primed, run the queries again: has performance improved?
3. Is the performance good enough? If it is, stop tuning now! If your data set isn't very large, you probably don't need any aggregate tables.
4. Decide which aggregate tables to create. If you turn on SQL tracing, looking at the GROUP BY clauses of the long-running SQL statements will be a big clue here.
5. Register the aggregate tables in your catalog, create the tables in the database, populate the tables, and add indexes.
6. Restart Mondrian, to flush the cache and re-read the schema, then go to step 2 to see if things have improved.

AggGen

AggGen is a tool that generates SQL to support the creation and maintenance of aggregate tables, and would give a template for the creation of materialized views for databases that support those. Given an MDX query, the generated create/insert SQL is optimal for the given query. The generated SQL covers both the "lost" and "collapsed" dimensions. For usage, see the documentation for CmdRunner.

Optimizing Calculations with the Expression Cache

Mondrian may have performance issues if your schema makes intensive use of calculations. Mondrian executes calculations very efficiently, so usually the time spent calculating expressions is insignificant compared to the time spent executing SQL, but if you have many layers of calculated members and sets, in particular set-oriented constructs like the Aggregate function, it is possible that many thousands of calculations will be required for each cell.

To see whether calculations are causing your performance problem, turn on SQL tracing and measure what proportion of the time is spent executing SQL. If SQL is less than 50% of the time, it is possible that excessive calculations are responsible for the rest. (If the result set is very large, and if you are using JPivot or XML/A, the cost of generating HTML or XML is also worth investigating.)

It caches cell values retrieved from the database, but it does not generally cache the results of calculations. (The sole case where mondrian caches expression results automatically is for the

second argument of the `Rank(<Member>, <Set>[, <Expression>])` function, since this function is typically evaluated many times for different members over the same set.)

Since calculations are very efficient, this is generally the best policy: it is better for mondrian to use the available memory to cache values retrieved from the database, which are much slower to re-create.

The expression cache only caches expression results for the duration of a single statement. The results are not available for other statements. The expression cache also takes into account the evaluation context, and the known dependencies of particular functions and operators. For example, the expression

```
Filter([Store].[City].Members, ([Store].CurrentMember.Parent,
[Time].[1997].[Q1])) > 100)
```

depends on all dimensions besides [Store] and [Time], because the expression overrides the value of the [Store] and [Time] dimensions inherited from the context, but the implicit evaluation of a cell pulls in all other dimensions. If the expression result has been cached for the contexts `([Store].[USA], [Time].[1997].[Q2], [Gender].[M])`, the cache knows that it will return the same value for **`([Store].[USA].[CA], [Time].[1997].[Q3], [Gender].[M]`**); however, ([**`Store].[USA], [Time].[1997].[Q2], [Gender].[F])`** will require a new cache value, because the dependent dimension [Gender] has a different value.

However, if your application is very calculation intensive, you can use the **`Cache(<Expression>)`** function to tell mondrian to store the results of the expression in the expression cache. The first time this function is called, it evaluates its argument and stores it in the expression cache; subsequent calls within the an equivalent context will retrieve the value from the cache. We recommend that you use this function sparingly. If you have cached a frequently evaluated expression, then it will not be necessary to cache sub-expressions or super-expressions; the sub-expressions will be evaluated less frequently, and the super-expressions will evaluate more quickly because their expensive argument has been cached.

Aggregate Tables

Introduction

Unlike many OLAP servers, Mondrian does not store data on disk: it just works on the data in the RDBMS, and once it has read a piece of data once, it stores that data in its cache. This greatly simplifies the process of installing Mondrian, but it puts limits on Mondrian's performance when Mondrian is applied to a huge dataset.

Consider what happens when the CEO runs her Sales Report first thing on a Monday morning. This report contains a single number: the total sales of all products, in all regions, this year. In order to get this number, Mondrian generates a query something like this:

```
SELECT sum(store_sales)
FROM sales_fact,
    time
WHERE sales_fact.time_id = time.time_id
AND time.year = 2005
```

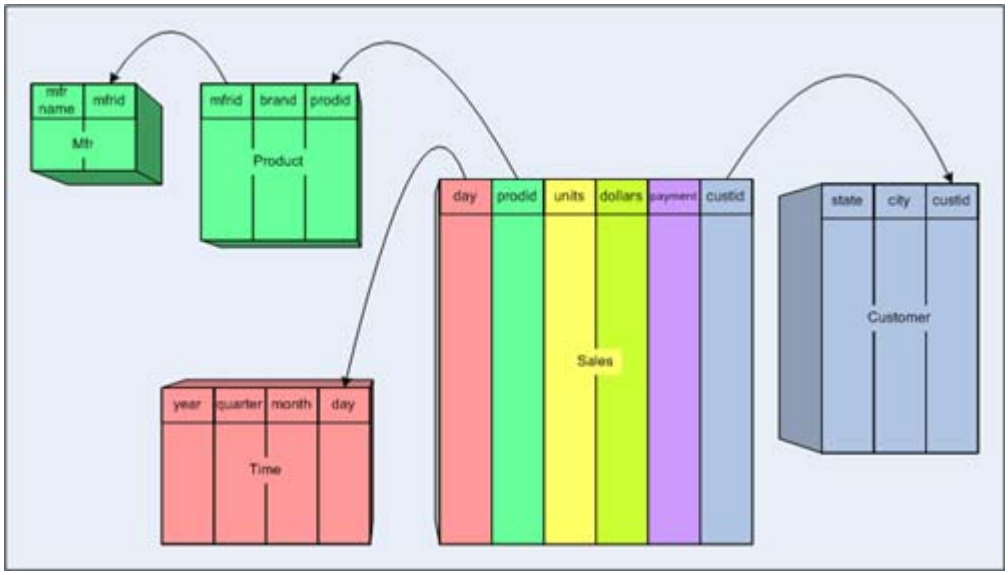
and sends it to the DBMS. The DBMS takes several minutes to execute it: which is understandable because the DBMS has to read all of this year's records in the fact table (a few million sales, say) and aggregate them into a single total. Clearly, what is needed in this case, and in others like it, is a pre-computed summary of the data: an aggregate table.

An *aggregate table* coexists with the base fact table, and contains pre-aggregated measures build from the fact table. It is registered in Mondrian's schema, so that Mondrian can choose to use whether to use the aggregate table rather than the fact table, if it is applicable for a particular query.

Designing aggregate tables is a fine art. There is extensive research, both empirical and theoretical, available on the web concerning different ways to structure aggregate tables and we will not attempt to duplicate any of it here.

What are aggregate tables?

To explain what aggregate tables are, let's consider a simple star schema.



The star schema has a single fact table `Sales`, two measure columns (`units` and `dollars`) and four dimension tables (`Product`, `Mfr`, `Customer`, `Time`, and `Customer`).

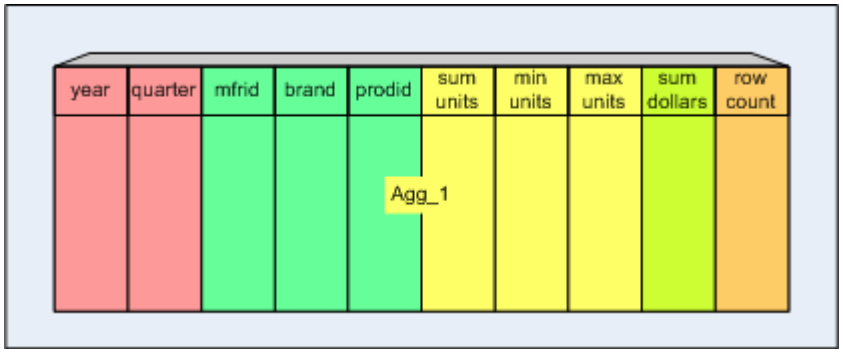
On top of this star schema, we create the following multidimensional model:

- Cube `[Sales]` has two measures `[Unit sales]` and `[Dollar sales]`
- Dimension `[Product]` has levels `[All Products]`, `[Manufacturer]`, `[Brand]`, `[Prodid]`
- Dimension `[Time]` has levels `[All Time]`, `[Year]`, `[Quarter]`, `[Month]`, `[Day]`
- Dimension `[Customer]` has levels `[All Customers]`, `[State]`, `[City]`, `[Custid]`
- Dimension `[Payment Method]` has levels `[All Payment Methods]`, `[Payment Method]`

Most of the dimensions have a corresponding dimension table, but there are two exceptions. The `[Product]` dimension is a *snowflake dimension*, which means that it is spread across more than one table (in this case `Product` and `Mfr`). The `[Payment Method]` dimension is a *degenerate dimension*; its sole attribute is the `payment` column in the fact table, and so it does not need a dimension table.

A simple aggregate table

Now let's create an aggregate table, `Agg_1`:



See how the original star schema columns have been combined into the table:

- The `Time` dimension has been "collapsed" into the aggregate table, omitting the `month` and `day` columns.
- The two tables of the `Product` dimension has been "collapsed" into the aggregate table.
- The Customer dimension has been "lost".
- For each measure column in the fact table (`units`, `dollars`), there are one or more measure columns in the aggregate table (`sum units`, `min units`, `max units`, `sum dollars`).
- There is also a measure column, `row count`, representing the "count" measure.

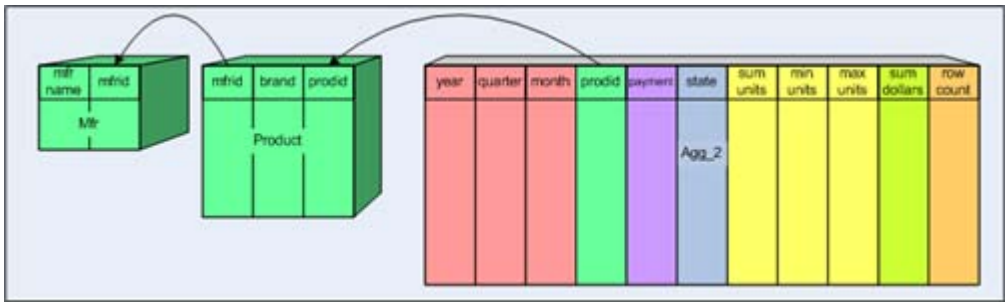
`Agg_1` would be declared like this:

```
<Cube name="Sales">
  <Table name="sales">
    <AggName name="agg_1">
      <AggFactCount column="row count"/>
      <AggMeasure name="[Measures].[Unit Sales]" column="sum units"/>
      <AggMeasure name="[Measures].[Min Units]" column="min units"/>
      <AggMeasure name="[Measures].[Max Units]" column="max units"/>
      <AggMeasure name="[Measures].[Dollar Sales]" column="sum
dollars"/>
      <AggLevel name="[Time].[Year]" column="year"/>
      <AggLevel name="[Time].[Quarter]" column="quarter"/>
      <AggLevel name="[Product].[Mfrid]" column="mfrid"/>
      <AggLevel name="[Product].[Brand]" column="brand"/>
      <AggLevel name="[Product].[Prodid]" column="prodid"/>
    </AggName>
  </Table>

  <!-- Rest of the cube definition -->
</Cube>
```

Another aggregate table

Another aggregate table, Agg_2:



and the corresponding XML:

```
<Cube name="Sales">
  <Table name="sales">
    <AggName name="agg_1" ... />
    <AggName name="agg_2">
      <AggFactCount column="row count"/>
      <AggForeignKey factColumn="prodid" aggColumn="prodid"/>
      <AggMeasure name="[Measures].[Unit Sales]" column="sum units"/>
      <AggMeasure name="[Measures].[Min Units]" column="min units"/>
      <AggMeasure name="[Measures].[Max Units]" column="max units"/>
      <AggMeasure name="[Measures].[Dollar Sales]" column="sum
dollars"/>
      <AggLevel name="[Time].[Year]" column="year"/>
      <AggLevel name="[Time].[Quarter]" column="quarter"/>
      <AggLevel name="[Time].[Month]" column="month"/>
      <AggLevel name="[Payment Method].[Payment Method]"
column="payment"/>
      <AggLevel name="[Customer].[State]" column="state"/>
    </AggName>
  </Table>

  <Dimension name="Product">
    <Hierarchy hasAll="true" primaryKey="prodid"
primaryKeyTable="Product">
      <Join leftKey="mfrid" rightKey="mfrid">
        <Table name="Product"/>
        <Table name="Mfr"/>
      </Join>
      <Level name="Manufacturer" table="Mfr" column="mfrid"/>
      <Level name="Brand" table="Product" column="brand"/>
      <Level name="Name" table="Product" column="prodid"/>
    </Hierarchy>
  </Dimension>

  <!-- Rest of the cube definition -->
</Cube>
```

Several dimensions have been collapsed: `[Time]` at the `[Quarter]` level; `[Customer]` at the `[State]` level; and `[Payment Method]` at the `[Payment Method]` level. But the `[Product]` dimension has been retained in its original snowflake form.

The <AggForeignKey> element is used to declare that the column `prodid` links to the dimension table, but all other columns remain in the `Product` and `Mfr` dimension tables.

Defining aggregate tables

A fact table can have zero or more aggregate tables. Every aggregate table is associated with just one fact table. It aggregates the fact table measures over one or more of the dimensions. As an example, if a particular column in the fact table represents the number of sales of some product on a given day by a given store, then an aggregate table might be created that sums the information so that applies at a month level rather than by day. Such an aggregate might reasonably be 1/30th the size of the fact table (assuming comparable sales for every day of a month). Now, if one were to execute a MDX query that needed sales information at a month (or quarter or year) level, running the query against the aggregate table is faster but yields the same answer as if it were run against the base fact table.

Further, one might create an aggregate that not only aggregates at the month level but also, rather than at the individual store level, aggregates at the state level. If there were, say, 20 stores per state, then this aggregate table would be 1/600th the size of the original fact table. MDX queries interested only at the month or above and state or above levels would use this table.

When a MDX query runs, what aggregate should be used? This comes down to what measures are needed and with which dimension levels. The base fact table always has the correct measures and dimension levels. But, it might also be true that there is one or more aggregate tables that also have the measures and levels. Of these, the aggregate table with the lowest cost to read, the smallest number of rows, should be the table used to fulfill the query.

Mondrian supports two aggregation techniques which are called "lost" dimension and "collapsed" dimension. For the creation of any given aggregate table these can be applied independently to any number of different dimensions.

A "lost" dimension is one which is completely missing from the aggregate table. The measures that appear in the table have been aggregated across all values of the lost dimension. As an example, in a fact table with dimensions of time, location, and product and measure sales, for an aggregate table that did not have the location dimension that dimension would be "lost". Here, the sales measure would be the aggregation over all locations. An aggregate table where all of the dimensions are lost is possible - it would have a single row with the measure aggregated over everything - sales for all time, all locations and all products.

```
fact table
    time_id
    product_id
    location_id
    measure

lost (time_id) dimension table
    product_id
    location_id
```

```
    measure (aggregated over time)
    fact_count

fully lost dimension table
    measure (aggregated over everything)
    fact_count
```

Note the "fact_count" column in the aggregate table. This additional column is a general feature of aggregate tables. It is a count of how many fact table columns were aggregated into the one aggregate table row. As an example, if for a particular choice of product_id and location_id, the time_id occurred 5 times in the fact table, then in the aggregate table the fact_count column would contain 5 for that product_id/location_id pair (a given product was sold at a given location at 5 different times).

The second supported aggregation technique provides a finer level of control, the "collapsed" dimension technique. Recall that the dimension key in the fact table refers (more or less) to the lowest level in the dimension hierarchy. For a collapsed dimension, the dimension key in the aggregate table is replaced with a set of dimension levels; the dimension key column is replaced with a set of columns; a fully denormalized summary table for that dimension. As an example, if the time dimension with base fact table foreign key time_id had the levels: day, month, quarter and year, and in an aggregate it was collapsed to the month level, then the aggregate table would not have a time_id column but rather columns for month, quarter and year. The SQL generated for a MDX query for which this aggregate table can be used, would no longer refer to the time dimension's table but rather all time related information would be gotten from the aggregate table.

```
time dimension table
    time_id
    day
    month
    quarter
    year

fact table
    time_id
    measure

collapsed dimension table
    month
    quarter
    year
    measure (aggregated to month level)
    fact_count
```

In the literature, there are other ways of creating aggregate tables but they are not supported by Mondrian at this time.

Building aggregate tables

Aggregate tables must be built. Generally, they not real-time; they are rebuilt, for example, every night for use the following day by the analysts. Considering the lost and collapsed dimension technique for aggregate table definition, one can estimate that for a dimension with N levels, there are N+1 possible aggregate tables (N collapsed and 1 lost). Also, dimensions (with different

dimension tables) can be aggregated independently. For the FoodMart Sales cube there are 1400 different possible aggregate tables.

Clearly, one does not want to create all possible aggregate tables. Which ones to create depends upon two considerations. The first consideration is application dependent: the nature of the MDX queries that will be executed. If many of the queries deal with per month and per state questions, then an aggregate at those levels might be created. The second consideration is application independent: per dimension aggregating from the lowest level to the next lowest generally gives greater bang for the buck than aggregating from the N to the N+1 (N>1) level. This is because 1) a first level aggregation can be used for all queries at that level and above and 2) dimension fan-out tends to increase for the lower levels. Of course, your mileage may vary.

In a sense, picking which aggregate tables to build is analogous to picking which indexes to build on a table; it is application dependent and experience helps.

The hardest part about the actually creation and population of aggregate tables is figuring out how to create the first couple; what the SQL looks like. After that they are pretty much all the same.

Four examples will be given. They all concern building aggregate tables for the sales_fact_1997 fact table. As a reminder, the sales_fact_1997 fact table looks like:

```
sales_fact_1997
    product_id
    time_id
    customer_id
    promotion_id
    store_id
    store_sales
    store_cost
    unit_sales
```

The first example is a lost time dimension aggregate table, the time_id foreign key is missing.

```
CREATE TABLE agg_l_05_sales_fact_1997 (
    product_id INTEGER NOT NULL,
    customer_id INTEGER NOT NULL,
    promotion_id INTEGER NOT NULL,
    store_id INTEGER NOT NULL,
    store_sales DECIMAL(10,4) NOT NULL,
    store_cost DECIMAL(10,4) NOT NULL,
    unit_sales DECIMAL(10,4) NOT NULL,
    fact_count INTEGER NOT NULL);

CREATE INDEX i_sls_97_cust_id ON agg_l_05_sales_fact_1997
(customer_id);
CREATE INDEX i_sls_97_prod_id ON agg_l_05_sales_fact_1997 (product_id);
CREATE INDEX i_sls_97_promo_id ON agg_l_05_sales_fact_1997
(promotion_id);
CREATE INDEX i_sls_97_store_id ON agg_l_05_sales_fact_1997 (store_id);

INSERT INTO agg_l_05_sales_fact_1997 (
    product_id,
    customer_id,
```

```
    promotion_id,
    store_id,
    store_sales,
    store_cost,
    unit_sales,
    fact_count)
SELECT
    product_id,
    customer_id,
    promotion_id,
    store_id,
    SUM(store_sales) AS store_sales,
    SUM(store_cost) AS store_cost,
    SUM(unit_sales) AS unit_sales,
    COUNT(*) AS fact_count
FROM
    sales_fact_1997
GROUP BY
    product_id,
    customer_id,
    promotion_id,
    store_id;
```

A couple of things to note here.

The above is in MySQL's dialect of SQL, and may not work for your database - but I hope the general idea is clear. The aggregate table "looks like" the base fact table except the time_id column is missing and there is a new fact_count column. The insert statement populates the aggregate table from the base fact table summing the measure columns and counting to populate the fact_count column. This done while grouping by the remaining foreign keys to the remaining dimension tables.

Next, some databases recognize star joins - Oracle for instance. For such database one should not create indexes, not on the fact table and not on the aggregate tables. On the other hand, databases that do not recognize star joins will require indexes on both the fact table and the aggregate tables.

For our purposes here, the exact name of the aggregate table is not important; the "agg_l_05_" preceding the base fact table's name sales_fact_1997. First, the aggregate table name must be different from the base fact table name. Next, the aggregate table name ought to be related to the base fact table name both for human eyeballing of what aggregate is associated with which fact table, but also, as described below, Mondrian employs mechanism to automagically recognize which tables are aggregates of others.

The following example is a collapsed dimension aggregate table where the time dimension has been rolled up to the month level.

```
CREATE TABLE agg_c_14_sales_fact_1997 (
    product_id INTEGER NOT NULL,
    customer_id INTEGER NOT NULL,
    promotion_id INTEGER NOT NULL,
    store_id INTEGER NOT NULL,
    month_of_year SMALLINT(6) NOT NULL,
    quarter VARCHAR(30) NOT NULL,
```

```
    the_year SMALLINT(6) NOT NULL,
    store_sales DECIMAL(10,4) NOT NULL,
    store_cost DECIMAL(10,4) NOT NULL,
    unit_sales DECIMAL(10,4) NOT NULL,
    fact_count INTEGER NOT NULL);

CREATE INDEX i_sls_97_cust_id ON agg_c_14_sales_fact_1997
(customer_id);
CREATE INDEX i_sls_97_prod_id ON agg_c_14_sales_fact_1997 (product_id);
CREATE INDEX i_sls_97_promo_id ON agg_c_14_sales_fact_1997
(promotion_id);
CREATE INDEX i_sls_97_store_id ON agg_c_14_sales_fact_1997 (store_id);

INSERT INTO agg_c_14_sales_fact_1997 (
    product_id,
    customer_id,
    promotion_id,
    store_id,
    month_of_year,
    quarter,
    the_year,
    store_sales,
    store_cost,
    unit_sales,
    fact_count)
SELECT
    BASE.product_id,
    BASE.customer_id,
    BASE.promotion_id,
    BASE.store_id,
    DIM.month_of_year,
    DIM.quarter,
    DIM.the_year,
    SUM(BASE.store_sales) AS store_sales,
    SUM(BASE.store_cost) AS store_cost,
    SUM(BASE.unit_sales) AS unit_sales,
    COUNT(*) AS fact_count
FROM
    sales_fact_1997 AS BASE, time_by_day AS DIM
WHERE
    BASE.time_id = DIM.time_id
GROUP BY
    BASE.product_id,
    BASE.customer_id,
    BASE.promotion_id,
    BASE.store_id,
    DIM.month_of_year,
    DIM.quarter,
    DIM.the_year;
```

In this case, one can see that the time_id foreign key in the base fact table has been replaced with the columns: month_of_year, quarter, and the_year in the aggregate table. There is, as always, the fact_count column. The measures are inserted as sums. And, the group by clause is over the remaining foreign keys as well as the imported time dimension levels.

When creating a collapsed dimension aggregate one might consider creating indexes for the columns imported from the dimension that was collapsed.

Below is another aggregate table. This one has two lost dimensions (`store_id` and `promotion_id`) as well as collapsed dimension on time to the quarter level. This shows how aggregate techniques can be mixed.

```
CREATE TABLE agg_lc_100_sales_fact_1997 (
    product_id INTEGER NOT NULL,
    customer_id INTEGER NOT NULL,
    quarter VARCHAR(30) NOT NULL,
    the_year SMALLINT(6) NOT NULL,
    store_sales DECIMAL(10,4) NOT NULL,
    store_cost DECIMAL(10,4) NOT NULL,
    unit_sales DECIMAL(10,4) NOT NULL,
    fact_count INTEGER NOT NULL);

CREATE INDEX i_sls_97_cust_id ON agg_lc_100_sales_fact_1997
(customer_id);
CREATE INDEX i_sls_97_prod_id ON agg_lc_100_sales_fact_1997
(product_id);

INSERT INTO agg_lc_100_sales_fact_1997 (
    product_id,
    customer_id,
    quarter,
    the_year,
    store_sales,
    store_cost,
    unit_sales,
    fact_count)
SELECT
    BASE.product_id,
    BASE.customer_id,
    DIM.quarter,
    DIM.the_year,
    SUM(BASE.store_sales) AS store_sales,
    SUM(BASE.store_cost) AS store_cost,
    SUM(BASE.unit_sales) AS unit_sales,
    COUNT(*) AS fact_count
FROM sales_fact_1997 AS BASE,
    time_by_day AS DIM
WHERE
    BASE.time_id = DIM.time_id
GROUP BY
    BASE.product_id,
    BASE.customer_id,
    DIM.quarter,
    DIM.the_year;
```

In the above three examples, for the most part the column names in the aggregate are the same column names that appear in the fact table and dimension tables. These tables would all be recognized by the Mondrian default aggregate recognizer. It is possible to create an aggregate table and name the columns arbitrarily. For such an aggregate, an explicit Mondrian recognizer must be specified.

```
CREATE TABLE agg_c_special_sales_fact_1997 (
    PRODUCT_ID INTEGER NOT NULL,
    CUSTOMER_ID INTEGER NOT NULL,
    PROMOTION_ID INTEGER NOT NULL,
    STORE_ID INTEGER NOT NULL,
    TIME_MONTH SMALLINT(6) NOT NULL,
    TIME_QUARTER VARCHAR(30) NOT NULL,
    TIME_YEAR SMALLINT(6) NOT NULL,
    STORE_SALES_SUM DECIMAL(10,4) NOT NULL,
    STORE_COST_SUM DECIMAL(10,4) NOT NULL,
    UNIT_SALES_SUM DECIMAL(10,4) NOT NULL,
    FACT_COUNT INTEGER NOT NULL);

CREATE INDEX i_sls_97_cust_id ON agg_c_special_sales_fact_1997
(CUSTOMER_ID);
CREATE INDEX i_sls_97_prod_id ON agg_c_special_sales_fact_1997
(PRODUCT_ID);
CREATE INDEX i_sls_97_promo_id ON agg_c_special_sales_fact_1997
(PROMOTION_ID);
CREATE INDEX i_sls_97_store_id ON agg_c_special_sales_fact_1997
(STORE_ID);

INSERT INTO agg_c_special_sales_fact_1997 (
    PRODUCT_ID,
    CUSTOMER_ID,
    PROMOTION_ID,
    STORE_ID,
    TIME_MONTH,
    TIME_QUARTER,
    TIME_YEAR,
    STORE_SALES_SUM,
    STORE_COST_SUM,
    UNIT_SALES_SUM,
    FACT_COUNT)
SELECT
    BASE.product_id,
    BASE.customer_id,
    BASE.promotion_id,
    BASE.store_id,
    DIM.month_of_year,
    DIM.quarter,
    DIM.the_year,
    SUM(BASE.store_sales) AS STORE_SALES_SUM,
    SUM(BASE.store_cost) AS STORE_COST_SUM,
    SUM(BASE.unit_sales) AS UNIT_SALES_SUM,
    COUNT(*) AS FACT_COUNT
FROM
    sales_fact_1997 BASE, time_by_day DIM
WHERE
    BASE.time_id = DIM.time_id
GROUP BY
    BASE.product_id,
    BASE.customer_id,
    BASE.promotion_id,
    BASE.store_id,
    DIM.month_of_year,
```

```
    DIM.quarter,
    DIM.the_year;
```

This aggregate table has column names that are not identical to those found in the base fact table and dimension table. It is still a valid aggregate but Mondrian has to be told how to map its columns into those of the base fact table.

Sometimes with multiple aggregate tables, one aggregate table is an aggregate of not only the base fact table but also another aggregate table; an aggregate table with lost time and product dimensions (no time_id and product_id foreign keys) is an aggregate of the base fact table and an aggregate which only has a lost time dimension (no time_id foreign key). In this case, one might first build the aggregate with only the lost time dimension and then build the aggregate with both lost time and product dimensions from that first aggregate - it will be faster (in some cases, much faster) to populate the second aggregate from the first rather than from the base fact table.

One last note, when creating aggregate tables from the base fact table pay attention to the size of the numeric columns - what might be big enough in the base fact table might not be big enough in an aggregate.

How Mondrian recognizes Aggregate Tables

Mondrian has to know about the aggregate tables in order to use them. You can either define an aggregate explicitly, or set up rules to recognize several aggregate tables at the same time.

How Mondrian recognizes aggregate table names and columns pretty much dictates how one must name those table names and columns when creating them in the first place!

Rules

Rules are templates, designed to work for all fact table names and their column names. These rules are templates of regular expressions that are instantiated with the names of a fact table and its columns. In order to describe the rule templates, a name that instantiate a rule are represented in a rule by have the name bracketed by "${" and "}". As an example, "abc_${name}_xyz" is a rule parameterized by "name". When name is "john" the template becomes "abc_john_xyz".

The regular expression engine used here and a definition of the allowed regular expression grammar is found in the Java regular expression Pattern class: java.util.regex.Pattern.

In order that a table be recognized as an aggregate table, Mondrian must be able to map from the fact table foreign key columns and measure columns and those in the aggregate table. In addition, Mondrian must identify the fact count column in the aggregate and possible level columns (which would appear in an aggregate table if it had a "collapsed" dimension). What follows is a description of the steps taken in the identification of aggregate tables by the default recognizer. If at any step, a match fails, the table is rejected as an aggregate table.

Starting off, the candidate aggregate table's name must comply with the aggregate table name rule. Represented as a template regular expression the rule is:

```
agg_.+_${fact_table_name}
```

which is parameterized with the fact table's name. (In addition, this rule is applied in "ignore case" mode.) This means that an aggregate table's name must start with "agg_" (ignoring character case), followed by at least one character, then the '_' character and, lastly, the name of the fact table. The ".+" in the template has special meaning in a regular expression - it matches one or more characters.

As an example of applying the aggregate table name rule, let the fact table be called `sales_fact_1997`, the `Sales` cube's fact table from the FoodMart schema. Applying the specific fact table name to the regular expression template creates the following regular expression:

```
agg_.+_sales_fact_1997
```

This will match the following table names:

- `agg_l_05_sales_fact_1997`
- `agg_c_14_sales_fact_1997`
- `agg_lc_100_sales_fact_1997`
- `agg_c_special_sales_fact_1997`
- `AGG_45_SALES_FACT_1997`
- `AGG_drop_time_id_sales_fact_1997`

The aggregate table name recognition mechanism has one additional programatic feature, one can specify that only a portion of the base fact table name be used as the basis of template name. For instance, if the DBA demanded that all fact tables begin with the string "fact_", e.g., "fact_sales_fact_1997", one would certainly not want that string to have to be part of each aggregate table's name. The aggregate table name recognition mechanism allows one to specify a regular expression with one and only one group clause (a group clause is a pattern bracketed by '(' and ')'). Whatever is matched by the contents of the group clause is taken to be the part of the fact table name to be used in the matching template. This regular expression containing the group clause is specified as the "basename" attribute. The default Mondrian aggregate table recognizer does not use this feature. For more information see the associated developer's note link.

After the default recognizer determines that a table's name matches the aggregate table template regular expression for a given fact table, it then attempts to match columns. The first column tested for is the "fact count" column. Here the candidate aggregate table must have a column called "fact_count" (ignoring case) and this column's type must be numeric. The following examples would match as "fact count" columns.

```
fact_count
FACT_COUNT
fact_COUNT
```

Following matching the "fact count" column, the candidate aggregate table's columns are examined for possible foreign key matches. For each of the foreign key column names in the fact table it is determined if there are any character case independent matches of the aggregate table's columns. Those columns that match are noted. It is alright if no columns match; the aggregate might be a "collapsed" dimension aggregate with no fact table foreign keys remaining.

If the fact table had foreign key columns "store_id" and "time_id", then the following aggregate table columns (for example) would match:

- time_id
- store_id
- TIME_ID
- STORE_ID
- time_ID
- STORE_id

At this point, matches are looked for the level and measure columns. Both of these matching rules are multi-part - has sub rules; each rule has more than one possible regular expression that might match where a match on any one is a match.

There are three sub rules for matching level columns. Each is a template which is parameterized with 1) the fact table's cube's dimension hierarchy's name, "hierarchy_name", 2) the fact table's cube's dimension hierarchy's level name, "level_name", 3) the dimension table's level column name, "level_column_name", and 4) a usage prefix, "usage_prefix", which in most cases is null":

- ${hierarchy_name}_${level_name}
- ${hierarchy_name}_${level_column_name}
- ${usage_prefix}${level_column_name}
- ${level_column_name}

The "usage_prefix" is the value of the DimensionUsage's or private Dimension's optional usagePrefix attribute. It can be the case that a "level_column_name", the name of a dimension's level column, is the same for more than one dimension. During aggregate recognition for collapsed dimension aggregates where the base fact table has two or more dimensions with common column names, the attempted recognition will fail unless in the schema catalog the usagePrefix attribute is used to disambiguate those column names. Of course, one must also remember to prefix the the column in the aggregate table with the same prefix.

As an example of usagePrefix, consider a fact table named ORDERS which has two DimensionUsages, one for the CUSTOMER dimension and the other for the WHOLESALER dimension where each dimension has a level column named CUST_NM. In this case, a collapsed aggregate table could not include a column named CUST_NM because there would be no way to tell which dimension to associate it with. But if in the CUSTOMER' DimensionUsage the usagePrefix had the value "CU_", while the WHOLESALER's usagePrefix had the value "WS_", and the aggregate table column was named WS_CUST_NM, then the recognizer could associate the column with the WHOLESALER dimension.

In the case of a private Dimension, a usagePrefix need only be used if there is a public, shared Dimension that has the same name and has a "level_column_name" that is also the same. Without the usagePrefix there would be no way of disambiguating collapsed dimension aggregate tables.

If any of these parameters have space characters, ' ', these are mapped to underscore characters, '_', and, similarly, dot characters, '.', are also mapped to underscores. So, if the hierarchy_name is "Time", level_name is "Month" and level_column_name is month_of_year, the possible aggregate table column names are:

- `time_month`
- `time_month_of_year`
- `month_of_year`

For this rule, the "hierarchy_name" and "level_name" are converted to lower case while the "level_column_name" must match exactly.

Lastly, there is the rule for measures. There are three parameters to matching aggregate columns to measures: 1) the fact table's cube's measure name, "measure_name", 2) the fact table's cube's measure column name, "measure_column_name", and 3) the fact table's cube's measure's aggregator (sum, avg, max, etc.), "aggregate_name".

- `${measure_name}`
- `${measure_column_name}`
- `${measure_column_name}_${aggregate_name}`

where the measure name is converted to lower case and both the measure column name and aggregate name are matched as they appear. If the fact table's cube's measure name was, "Avg Unit Sales", the fact table's measure column name is "unit_sales", and, lastly, the fact table's cube's measure's aggregate name is "avg", then possible aggregate table column names that would match are:

- `avg_unit_sales`
- `unit_sales`
- `unit_sales_avg`

For Mondrian developers there are additional notes describing the default rule recognition schema.

Explicit aggregates

On a per cube basis, in a schema file a user can both include and exclude aggregate tables. A table that would have been include as an aggregate by the default rules can be explicitly excluded. A table that would not be include by the default rules can be explicitly included. A table that would have only been partially recognized by the default rules and, therefore, resulted in a warning or error message, can be explicitly include in rules specified in the cube's definition.

Below is an example for the FoodMart `Sales` cube with fact table `sales_fact_1997`. There are child elements of the `Table` element that deal with aggregate table recognition.

```
<Cube name="Sales">
  <Table name="sales_fact_1997">
    <AggExclude name="agg_c_14_sales_fact_1997" />
```

```
    <AggExclude name="agg_lc_10_sales_fact_1997" />
    <AggExclude name="agg_pc_10_sales_fact_1997" />

    <AggName name="agg_c_special_sales_fact_1997">
        <AggFactCount column="FACT_COUNT"/>
        <AggIgnoreColumn column="admin_one"/>
        <AggIgnoreColumn column="admin_two"/>
        <AggForeignKey factColumn="product_id" aggColumn="PRODUCT_ID"
/>
        <AggForeignKey factColumn="customer_id" aggColumn="CUSTOMER_ID"
/>

        <AggForeignKey factColumn="promotion_id"
aggColumn="PROMOTION_ID" />
        <AggForeignKey factColumn="store_id" aggColumn="STORE_ID" />
        <AggMeasure name="[Measures].[Unit Sales]"
column="UNIT_SALES_SUM" />
        <AggMeasure name="[Measures].[Store Cost]"
column="STORE_COST_SUM" />
        <AggMeasure name="[Measures].[Store Sales]"
column="STORE_SALES_SUM" />
        <AggLevel name="[Time].[Year]" column="TIME_YEAR" />

        <AggLevel name="[Time].[Quarter]" column="TIME_QUARTER" />
        <AggLevel name="[Time].[Month]" column="TIME_MONTH" />
    </AggName>
    <AggPattern pattern="agg_sales_fact_1997_.*">
    ....
    <AggExclude name="agg_sales_fact_1997_olddata" />
    <AggExclude pattern="agg_sales_fact_1997_test.*" />

     </AggPattern>

  </Table>
....
</Cube>
```

The `AggExclude` elements define tables that should not be considered aggregates of the fact table. In this case Mondrian is instructed to ignore the tables `agg_c_14_sales_fact_1997`, `agg_lc_10_sales_fact_1997` and `agg_pc_10_sales_fact_1997`. Following the excludes is the `AggName` element which identifies the name of an aggregate table table, `agg_c_special_sales_fact_1997`, and rules for mapping names from the fact table and cube to it. The two `AggIgnoreColumn` elements are used to specifically state to Mondrian that the columns `admin_one` and `admin_two` are known and should be ignored. If these columns were not so identified, Mondrian at the end of determining the fitness of the `agg_c_special_sales_fact_1997` table to be an aggregate of the `sales_fact_1997` fact table would complain that there were extra unidentified columns and that the mapping was incomplete. The `AggForeignKey` elements define mappings from the `sales_fact_1997` fact table foreign key column names into the `agg_c_special_sales_fact_1997` aggregate table column names.

Both the `AggMeasure` and `AggLevel` elements map "logical" name, names defined in the cube's schema, to the aggregate table's column names. An aggregate table does not have to have all of the measures that are found in the base fact table, so it is not a requirement that all

of the fact table measures appear as `AggMeasure` mappings, though it will certainly be the most common case. The most notable exception are `distinct-count` measures; such a measure can be aggregated, but one can not in general aggregate further on the measure - the "distinctness" of the measure has been lost during the first aggregation.

The `AggLevel` entries correspond to collapsed dimensions. For each collapsed dimension there is a hierarchy of levels spanning from the top level down to some intermediate level (with no gaps).

The `AggName` element is followed by an `AggPattern` element. This matches candidate aggregate table names using a regular expression. Included as child elements of the `AggPattern` element are two `AggExclude` elements. These specifically state what table names should not be considered by this `AggPattern` element.

In a given `Table` element, all of the `AggExclude` are applied first, followed by the `AggName` element rules and then the `AggPattern` rules. In the case where the same fact table is used by multiple cubes, the above still applies, but its across all of the aggregation rules in all of the multiple cube's `Table` elements. The first "Agg" element, name or pattern, that matches per candidate aggregate table name has its associated rules applied.

Most of the time, the scope of these include/exclude statements apply only to the cube in question, but not always. A cube has a fact table and it is the characteristics of the fact table (like column names) against which some of the aggregate table rules are applied. But, a fact table can actually be the basis of more than one cube. In the FoodMart schema the `sales_fact_1997` fact table applies to both the `Sales` and the `Sales Ragged` cubes. What this means is that any explicit rules defined in the `Sales` cube also applies to the `Sales Ragged` cube and visa versa.

One feature of the explicit recognizer is very useful. With a single line in the cubes definition in the schema file, one can force Mondrian not to recognize any aggregate tables for the cube's fact table. As an example, for the FoodMart Sales cube the following excludes all aggregate tables because the regular expression pattern `".*"` matches all candidate aggregate table names.

```
<Table name="sales_fact_1997" >     <AggExclude pattern=".*" />
</Table>
```

During aggregate table recognition, rather than fail silently, Mondrian is rather noisy about things it can not figure out.

Aggregate tables and parent-child hierarchies

A parent-child hierarchy is a special kind of hierarchy where members can have arbitrary depth. The classic example of a parent-child hierarchy is an employee org-chart.

When dealing with parent-child hierarchies, the challenge is to roll up measures of child members into parent members. For example, when considering an employee Bill who is head of a department, we want to report not Bill's salary, but Bill's salary plus the sum of his direct and indirect reports (Eric, Mark and Carla). It is difficult to generate efficient SQL to do this rollup, so Mondrian provides a special structure called a closure table, which contains the expanded contents of the hierarchy.

A closure table serves a similar purpose to an aggregate table: it contains a redundant copy of the data in the database, organized in such a way that Mondrian can access the data efficiently. An aggregate table speeds up aggregation, whereas a closure table makes it more efficient to compute hierarchical rollups.

Supposing that a schema contains a large fact table, and one of the hierarchies is a parent-child hierarchy. Is is possible to make aggregate tables and closure tables work together, to get better performance? Let's consider a concrete example.

```
Cube:
    [Salary]

Dimensions:
    [Employee], with level [Employee]
    [Time], with levels [Year], [Quarter], [Month], [Day]

Fact table:
    salary (employee_id, time_id, dollars)

Parent-child dimension table:
    employee (employee_id, supervisor_id, name)
```

employee

supervisor_id	employee_id	name
null	1	Frank
1	2	Bill
2	3	Eric
1	4	Jane
3	5	Mark
2	6	Carla

```
Closure table:
    employee_closure (employee_id, supervisor_id, depth)
```

employee_closure

supervisor_id	employee_id	distance
1	1	0
1	2	1
1	3	2
1	4	1
1	5	3
1	6	2
2	2	0
2	3	1
2	5	2
2	6	1
3	3	0
3	5	1
4	4	0
5	5	0
6	6	0

```
Regular dimension table:
    time (year, month, quarter, time_id)
```

Aggregate tables at the leaf level of a parent-child hierarchy

The simplest option is to create an aggregate table which joins at the leaf level of the parent-child hierarchy. The following aggregate table is for leaf members of the `[Employee]` hierarchy, and the `[Year]` level of the `[Time]` hierarchy.

```
Aggregate table:
    agg_salary_Employee_Time_Year (employee_id, time_year, sum_dollars)

INSERT INTO agg_salary_Employee_Time_Year
SELECT
    salary.employee_id,
    time.year AS time_year,
    sum(salary.dollars) AS sum_dollars
FROM salary,
    time
WHERE time.time_id = salary.time_id
GROUP BY salary.employee_id, time.year
```

Mondrian can use the aggregate table to retrieve salaries of leaf employees (without rolling up salaries of child employees). But because the aggregate table has the same foreign key as the `salary` fact table, Mondrian is able to automatically join `salary.employee_id` to either `agg_salary_Employee_Time_Year.employee_id` or `agg_salary_Employee_Time_Year.supervisor_id` to rollup employees efficiently.

Combined closure and aggregate tables

A more advanced option is to combine the closure table and aggregate table into one:

```
Aggregate table:
    agg_salary_Employee$Closure_Time_Year (supervisor_id, time_year,
sum_dollars)

INSERT INTO agg_salary_Employee$Closure_Time_Year
SELECT
    ec.supervisor_id,
    time.year AS time_year,
    sum(salary.dollars) AS sum_dollars
FROM employee_closure AS ec,
    salary,
    time
WHERE ec.supervisor_id = salary.employee_id
AND ec.supervisor_id <> ec.employee_id
AND time.time_id = salary.time_id
GROUP BY ec.employee_id, ec.supervisor_id, time.year
```

The `agg_salary_Employee$Closure_Time_Year` aggregate table contains the salary of every employee, rolled up to include their direct and indirect reports, aggregated to the `[Year]` level of the `[Time]` dimension.

The trick: How combined closure and aggregate tables work

Incidentally, this works based upon a 'trick' in Mondrian's internals. Whenever Mondrian sees a closure table, it creates a auxilliary dimension behind the scenes. In the case of the `[Employee]` hierarchy and its `employee_closure` table, the auxilliary dimension is called `[Employee$Closure]`.

```
Dimension [Employee$Closure], levels [supervisor_id], [employee_id]
```

When an MDX query evaluates a cell which uses a rolled up salary measure, Mondrian translates the coordinates of that cell in the `[Employee]` dimension into a corresponding coordinate in the `[Employee$Closure]` dimension. This translation happens *before* Mondrian starts to search for a suitable aggregate table, so if your aggregate table contains the name of the auxiliary hierarchy (as `agg_salary_Employee$Closure_Time_Year` contains the name of the [Employee$Closure] hierarchy) it find and use the aggregate table in the ordinary way.

How Mondrian uses aggregate tables

Choosing between aggregate tables

If more than one aggregate table matches a particular query, Mondrian needs to choose between them.

If there is an aggregate table of the same granularity as the query, Mondrian will use it. If there is no aggregate table at the desired granularity, Mondrian will pick an aggregate table of lower granularity and roll up from it. In general, Mondrian chooses the aggregate table with the fewest rows, which is typically the aggregate table with the fewest extra dimensions. See property `mondrian.rolap.aggregates.ChooseByVolume`.

Distinct count

There is an important exception for distinct-count measures: they cannot in be rolled up over arbitrary dimensions. To see why, consider the case of a supermarket chain which has two stores in the same city. Suppose that Store A has 1000 visits from 800 distinct customers in the month of July, while Store B has 1500 visits from 900 distinct customers. Clearly the two stores had a total of 2500 customer visits between them, but how many distinct customers? We can say that there were at least 900, and maybe as many as 1700, but assuming that some customers visit both stores, and the real total will be somewhere in between. "Distinct customers" is an example of a distinct-count measure, and cannot be deduced by rolling up subtotals. You have to go back to the raw data in the fact table.

There is a special case where it is acceptable to roll up distinct count measures. Suppose that we know that in July, this city's stores (Store A and B combined) have visits from 600 distinct female customers and 700 distinct male customers. Can we say that the number of distinct customers in July is 1300? Yes we can, because we know that the sets of male and female customers cannot possibly overlap. In technical terms, gender is *functionally dependent on* customer id.

The rule for rolling up distinct measures can be stated as follows:

A distinct count measure over key *k* can be computed by rolling up more granular subtotals only if the attributes which are being rolled up are functionally dependent on *k*.

Even with this special case, it is difficult to create enough aggregate tables to satisfy every possible query. When evaluating a distinct-count measure, Mondrian can only use an aggregate table if it has the same logical/level granularity as the cell being requested, or can be rolled up to that granularity only by dropping functionally dependent attributes. If there is no aggregate table of the desired granularity, Mondrian goes instead against the fact table.

This has implications for aggregate design. If your application makes extensive use of distinct-count measures, you will need to create an aggregate table for each granularity where it is used. That could be a lot of aggregate tables! (We hope to have a better solution for this problem in future releases.)

That said, Mondrian will rollup measures in an aggregate table that contains one or more distinct-count measures if none of the distinct-count measures are requested. In that respect an aggregate table containing distinct-count measures are just like any other aggregate table as long as the distinct-count measures are not needed. And once in memory, distinct-count measures are cached like other measures, and can be used for future queries.

When building an aggregate table that will contain a distinct-count measure, the measure must be rolled up to a logical dimension level, which is to say that the aggregate table must be a collapsed dimension aggregate. If it is rolled up only to the dimension's foreign key, there is no guarantee that the foreign key is at the same granularity as the lowest logical level, which is what is used by MDX requests. So for an aggregate table that only rolls the distinct-count measure to the foreign key granularity, a request of that distinct-count measure may result in further rollup and, therefore, an error.

Consider the following aggregate table that has lost dimensions `customer_id`, `product_id`, `promotion_id` and `store_id`.

```
INSERT INTO "agg_l_04_sales_fact_1997" (
    "time_id",
    "store_sales",
    "store_cost",
    "unit_sales",
    "customer_count",
    "fact_count"
) SELECT
    "time_id",
    SUM("store_sales") AS "store_sales",
    SUM("store_cost") AS "store_cost",
    SUM("unit_sales") AS "unit_sales",
    COUNT(DISTINCT "customer_id") AS "customer_count",
    COUNT(*) AS "fact_count"
FROM "sales_fact_1997"
GROUP BY "time_id";
```

This aggregate table is useless for computing the `"customer_count"` measure. Why? The distinct-count measure is rolled up to the `time_id` granularity, the lowest level granularity of the physical database table `time_by_day`. Even a query against the lowest level in the `Time`

dimension would require a rollup from `time_id` to `month_of_year`, and this is impossible to perform.

Now consider this collapsed `Time` dimension aggregate table that has the same lost dimensions `customer_id`, `product_id`, `promotion_id` and `store_id`. The `time_id` foreign key is no longer present, rather it has been replaced with the logical levels `the_year`, `quarter` and `month_of_year`.

```
INSERT INTO "agg_c_10_sales_fact_1997" (
    "month_of_year",
    "quarter",
    "the_year",
    "store_sales",
    "store_cost",
    "unit_sales",
    "customer_count",
    "fact_count"
) SELECT
    "D"."month_of_year",
    "D"."quarter",
    "D"."the_year",
    SUM("B"."store_sales") AS "store_sales",
    SUM("B"."store_cost") AS "store_cost",
    SUM("B"."unit_sales") AS "unit_sales",
    COUNT(DISTINCT "customer_id") AS "customer_count",
    COUNT(*) AS fact_count
FROM
    "sales_fact_1997" "B",
    "time_by_day" "D"
WHERE
    "B"."time_id" = "D"."time_id"
GROUP BY
    "D"."month_of_year",
    "D"."quarter",
    "D"."the_year";
```

This aggregate table of the distinct-count measure can be used to fulfill a query as long as the query specifies the `Time` dimension down to the `month_of_year` level.

The general rule when building aggregate tables involving distinct-count measures is that there can be NO foreign keys remaining in the aggregate table - for each base table foreign key, it must either be dropped, a lost dimension aggregate, or it must be replaces with levels, a collapsed dimension aggregate. In fact, this rule, though not required, is useful to follow when creating any aggregate table; there is no value in maintaining foreign keys in aggregate tables. They should be replaced by collapsing to levels unless the larger memory used by such aggregate tables is too much for one's database system.

A better design for the aggregate table would include a few attributes which are functionally dependent on `customer_id`, the key for the distinct-count measure:

```
INSERT INTO "agg_c_12_sales_fact_1997" (
    "country",
    "gender",
    "marital_status",
    "month_of_year",
    "quarter",
    "the_year",
    "store_sales",
    "store_cost",
    "unit_sales",
    "customer_count",
    "fact_count"
) SELECT
    "D"."month_of_year",
    "D"."quarter",
    "D"."the_year",
    SUM("B"."store_sales") AS "store_sales",
    SUM("B"."store_cost") AS "store_cost",
    SUM("B"."unit_sales") AS "unit_sales",
    COUNT(DISTINCT "customer_id") AS "customer_count",
    COUNT(*) AS fact_count
FROM
    "sales_fact_1997" "B",
    "time_by_day" "D",
    "customer" "C"
WHERE
    "B"."time_id" = "D"."time_id"
AND "B".customer_id" = "C"."customer_id"
GROUP BY
    "C"."country",
    "C"."gender",
    "C"."marital_status",
    "D"."month_of_year",
    "D"."quarter",
    "D"."the_year";
```

The added attributes are `"country"`, `"gender"` and `"marital_status"`. This table has only appoximately 12x the number of rows of the previous aggregate table (3 values of `country` x 2 values of `gender` x 2 values of `marital_status`) but can answer many more potential queries.

Tools for designing and maintaining aggregate tables

Aggregate tables are difficult to design and maintain. We make no bones about it. But this is the first release in which aggregate tables have been available, and we decided to get the internals right rather than building a toolset to make them easy to use.

Unless your dataset is very large, Mondrian's performance will be just fine without aggregate tables. If Mondrian isn't performing well, you should first check that your DBMS is well-tuned: see our guide to optimizing performance). If decide to build aggregate tables anyway, we don't offer

any tools to help administrators design them, so unless you are blessed with superhuman patience and intuition, using them won't be smooth sailing.

Here are some ideas for tools we'd like to build in the future. I'm thinking of these being utilities, not part of the core runtime engine. There's plenty of room to wrap these utilities in nice graphical interfaces, make them smarter.

AggGen (aggregate generator)

AggGen is a tool that generates SQL to support the creation and maintenance of aggregate tables, and would give a template for the creation of materialized views for databases that support those. Given an MDX query, the generated create/insert SQL is optimal for the given query. The generated SQL covers both the "lost" and "collapsed" dimensions. For usage, see the documentation for CmdRunner.

Aggregate table populater

This utility populates (or generates INSERT statements to populate) the agg tables.

For extra credit: populate the tables in topological order, so that higher level aggregations can be built from lower level aggregations. (See [AAD+96]).

Script generator

This utility generates a script containing CREATE TABLE and CREATE INDEX statements all possible aggregate tables (including indexes), XML for these tables, and comments indicating the estimated number of rows in these tables. Clearly this will be a huge script, and it would be ridiculous to create all of these tables. The person designing the schema could copy/paste from this file to create their own schema.

Recommender

This utility (maybe graphical, maybe text-based) recommends a set of aggregate tables. This is essentially an optimization algorithm, and it is described in the academic literature [AAD+96]. Constraints on the optimization process are the amount of storage required, the estimated time to populate the agg tables.

The algorithm could also take into account usage information. A set of sample queries could be an input to the utility, or the utility could run as a background task, consuming the query log and dynamically making recommendations.

Online/offline control

This utility would allow agg tables to be taken offline/online while Mondrian is still running.

Properties that affect aggregates

Mondrian has properties that control the behavior of its aggregate table sub-system. (You can find the full set of properties in the Configuration Guide.)

Property	Type	Default Value	Description
mondrian.rolap.aggregates.Use	boolean	false	If set to true, then Mondrian uses any aggregate tables that have been read. These tables are then candidates for use in fulfilling MDX queries. If set to false, then no aggregate table related activity takes place in Mondrian.
mondrian.rolap.aggregates.Read	boolean	false	If set to true, then Mondrian reads the database schema and recognizes aggregate tables. These tables are then candidates for use in fulfilling MDX queries. If set to false, then aggregate table will not be read from the database. Of course, after aggregate tables have been read, they are read, so setting this property false after starting with the property being true, has no effect. Mondrian will not actually use the aggregate tables unless the mondrian.rolap.aggregates.Use property is set to true.
mondrian.rolap.aggregates.ChooseByVolume	boolean	false	Currently, Mondrian support to algorithms for selecting which aggregate table to use: the aggregate with smallest row count or the aggregate with smallest volume (row count * row size). If set to false, then row count is used. If true, then volume is used.
mondrian.rolap.aggregates.rules	resource or url	/DefaultRules.xml	This is a developer property, not a user property. Setting this to a url (e.g., file://c:/myrules.xml) allows one to use their own "default" Mondrian aggregate table recognition rules. In general use this should never be changed from the default value.
mondrian.rolap.aggregates.rule.tag	string	default	This is also a developer property. It allows one to pick which named rule in the default rule file to use. In general use this should never be changed from the default value.

Aggregate Table References

[AAD+96]	S. Agarwal, R. Agrawal, P. M. Deshpande, A. Gupta, J. F. Naughton, R. Ramakrishnan, and S. Sarawagi. On the computation of multidimensional aggregates. In Proc. 22nd VLDB, pages 506-521, Mumbai, Sept. 1996. [pdf]
[ABDGHLS99]	J. Albrecht, A. Bauer, O. Deyerling, H. Gunze, W. Hummer, W. Lehner, L. Schlesinger. Management of Multidimensional Aggregates for Efficient Online Analytical Processing. Proceedings of International Database Engineering and Applications Symposium, 1999, pp. 156–164. [pdf]
[GBLP96]	J. Gray, A. Bosworth, A. Layman, and H. Pirahesh. Data cube: A relational aggregation operator generalizing group-by, cross-tab, and sub-totals. In Proc. 12th ICDE, pages 152-159, New Orleans, March 1996. [pdf]
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[Rittman05]	M. Rittman. Compressed Composites (Oracle 10g Compression) Explained. Online article. [html]
[SDNR96]	Amit Shukla, Prasad Deshpande, Jeffrey F. Naughton, Karthikeyan Ramasamy. Storage Estimation for Multidimensional Aggregates in the Presence of Hierarchies. VLDB 1996, pp. 522–531. [pdf]

Cache Control

Note for JasperAnalysis

The Mondrian cache control API is only used in it simplest form in JasperAnalysis 3.5. Only the full cache can be flushed, in keeping with prior versions of Mondrian.

Introduction

One of the strengths of mondrian's design is that you don't need to do any processing to populate special data structures before you start running OLAP queries. More than a few people have observed that this makes mondrian an excellent choice for 'real-time OLAP' -- running multi-dimensional queries on a database which is constantly changing. The problem is that mondrian's cache gets in the way. Usually the cache is a great help, because it ensures that Mondrian only goes to the DBMS once for a given piece of data, but the cache becomes out of date if the underlying database is changing.

This is solved with a set of APIs for cache control. Before I explain the API, let's understand how Mondrian caches data.

How Mondrian's cache works

Mondrian's cache ensures that once a multidimensional cell -- say the Unit Sales of Beer in Texas in Q1, 1997 -- has been retrieved from the DBMS using an SQL query, it is retained in memory for subsequent MDX calculations. That cell may be used later during the execution of the same

MDX query, and by future queries in the same session and in other sessions. The cache is a major factor ensuring that Mondrian is responsive for speed-of-thought analysis.

The cache operates at a lower level of abstraction than access control. If the current role is only permitted to see only sales of Dairy products, and the query asks for all sales in 1997, then the request sent to Mondrian's cache will be for Dairy sales in 1997. This ensures that the cache can safely be shared among users which have different permissions.

If the contents of the DBMS change while Mondrian is running, Mondrian's implementation must overcome some challenges. The end-user expects a speed-of-thought query response time yielding a more or less up-to-date view of the database. Response time necessitates a cache, but this cache will tend to become out of date as the database is modified.

Mondrian cannot deduce when the database is being modified, so we introduce an API so that the container can tell Mondrian which parts of the cache are out of date. Mondrian's implementation must ensure that the changing database state does not yield inconsistent query results.

Until now, control of the cache has been very crude: applications would typically call:

```
mondrian.rolap.RolapSchema.clearCache();
```

to flush the cache which maps connect string URLs to in-memory datasets. The effect of this call is that a future connection will have to re-load metadata by parsing the schema XML file, and then load the data afresh.

There are a few problems with this approach. Flushing all data and metadata is all appropriate if the contents of a schema XML file has changed, but we have thrown out the proverbial baby with the bath-water. If only the data has changed, we would like to use a cheaper operation.

The final problem with the `clearCache()` method is that it affects only new connections. Existing connections will continue to use the same metadata and stale data, and will compete for scarce memory with new connections.

New CacheControl API

The new CacheControl API solves all of the problems described above. It provides fine-grained control over data in the cache, and the changes take place as soon as possible while retaining a consistent view of the data.

When a connection uses the API to notify Mondrian that the database has changed, subsequent queries will see the new state of the database. Queries in other connections which are in progress when the notification is received will see the database state either before or after the notification, but in any case, will see a consistent view of the world.

The cache control API uses the new concept of a cache region, an area of multidimensional space defined by one or more members. To flush the cache, you first define a cache region, then tell Mondrian to flush all cell values which relate to that region. To ensure consistency, Mondrian automatically flushes all rollups of those cells.

A simple example

Suppose that a connection has executed a query:

```
import mondrian.olap.*;

Connection connection;
Query query = connection.parseQuery(
    "SELECT" +
    " {[Time].[1997]," +
    " [Time].[1997].Children} ON COLUMNS," +
    " {[Customer].[USA]," +
    " [Customer].[USA].[OR]," +
    " [Customer].[USA].[WA]} ON ROWS" +
    "FROM [Sales]");
Result result = connection.execute(query);
```

and that this has populated the cache with the following segments:

Segment YN#1	Year Nation Unit Sales 1997 USA xxx Predicates: Year=1997, Nation=USA
Segment YNS#1	Year Nation State Unit Sales 1997 USA OR xxx 1997 USA WA xxx Predicates: Year=1997, Nation=USA, State={OR, WA}
Segment YQN#1	Year Quarter Nation Unit Sales 1997 Q1 USA xxx 1997 Q2 USA xxx Predicates: Year=1997, Quarter=any, Nation=USA
Segment YQNS#1	Year Quarter Nation State Unit Sales 1997 Q1 USA OR xxx 1997 Q1 USA WA xxx 1997 Q2 USA OR xxx 1997 Q2 USA WA xxx Predicates: Year=1997, Quarter=any, Nation=USA, State={OR, WA}

Now suppose that the application knows that batch of rows from Oregon, Q2 have been updated in the fact table. The application notifies Mondrian of the fact by defining a cache region:

```
// Lookup members

Cube salesCube =
    connection.getSchema().lookupCube(
        "Sales", true);
SchemaReader schemaReader =
    salesCube.getSchemaReader(null);
Member memberTimeQ2 =
    schemaReader.getMemberByUniqueName(
        Id.Segment.toList("Time", "1997", "Q2"),
        true);
Member memberCustomerOR =
    schemaReader.getMemberByUniqueName(
        Id.Segment.toList("Customer", "USA", "OR"),
```

```
        true);

// Create an object for managing the cache

CacheControl cacheControl =
      Connection.getCacheControl(null);

// Create a cache region defined by
// [Time].[1997].[Q2] cross join
// [Customer].[USA].[OR].
CacheControl.CellRegion measuresRegion =
    cacheControl.createMeasuresRegion(
        salesCube);
CacheControl.CellRegion regionTimeQ2 =
    cacheControl.createMemberRegion(
        memberTimeQ2, true);
CacheControl.CellRegion regionCustomerOR =
    cacheControl.createMemberRegion(
        memberCustomerOR, true);
CacheControl.CellRegion regionOregonQ2 =
    cacheControl.createCrossjoinRegion(
        measuresRegion,
        regionCustomerOR,
        regionTimeQ2);
```

and flushing that region:

```
cacheControl.flush(regionOregonQ2);
```

Now let's look at what segments are left in memory after the flush.

Segment YNS#1	Year Nation State Unit Sales 1997 USA OR xxx 1997 USA WA xxx Predicates: Year=1997, Nation=USA, State={WA}
Segment YQN#1	Year Quarter Nation Unit Sales 1997 Q1 USA xxx 1997 Q2 USA xxx Predicates: Year=1997, Quarter={any except Q2}, Nation=USA
Segment YQNS#1	Year Quarter Nation State Unit Sales 1997 Q1 USA OR xxx 1997 Q1 USA WA xxx 1997 Q2 USA OR xxx 1997 Q2 USA WA xxx Predicates: Year=1997, Quarter=any, Nation=USA, State={OR, WA}

The effects are:

Segment YN#1 has been deleted. All cells in the segment could contain values in Oregon/1997/Q2.

The constraints in YNS#1 have been strengthened. The constraint on the State column is modified from State={OR, WA} to State={WA} so that future requests for (1997, Q2, USA, OR) will not consider this segment.
The constraints in YQN#1 have been strengthened. The constraint on the Quarter column is modified from Quarter=any to Quarter={any except Q2}.
The constraints in YQNS#1 have been strengthened, similar to YNS#1.

More about cell regions

The previous example showed how to make a cell region consisting of a single member, and how to combine these regions into a two-dimensional region using a crossjoin. The CacheControl API supports several methods of creating regions:

```
createMemberRegion(Member, boolean) creates a region containing a
   single member, optionally including its descendants.
createMemberRegion(boolean lowerInclusive, Member lowerMember, boolean
   upperInclusive, Member upperMember, boolean descendants) creates a
   region containing a range of members, optionally including their
   descendants, and optionally including each endpoint. A range may be
   either closed, or open at one end.
createCrossjoinRegion(CellRegion...) combines several regions into a
   higher dimensionality region. The constituent regions must not have
   any dimensions in common.
createUnionRegion(CellRegion...) unions several regions of the same
   dimensionality.
createMeasuresRegion(Cube) creates a region containing all of the
   measures of a given cube.
```

The second overloading of `createMemberRegion()` is interesting because it allows a range of members to be flushed. Probably the most common use case for cache flush -- flushing all cells since a given point in time -- is expressed as a member range. For example, to flush all cells since February 15th, 2006, you would use the following code:

```
// Lookup members
Cube salesCube =
    connection.getSchema().lookupCube(
        "Sales", true);
SchemaReader schemaReader =
    salesCube.getSchemaReader(null);
Member memberTimeOct15 =
    schemaReader.getMemberByUniqueName(
        Id.Segment.toList("Time", "2006", "Q1"", "2" ,"15”),
        true);

// Create an object for managing the cache
CacheControl cacheControl =
      Connection.getCacheControl(null);

// Create a cache region defined by
// [Time].[1997].[Q1].[2].[15] to +infinity.
CacheControl.CellRegion measuresRegion =
    cacheControl.createMeasuresRegion(
        salesCube);
CacheControl.CellRegion regionTimeFeb15 =
```

```
    cacheControl.createMemberRegion(
        true, memberTimeFeb15, false, null, true);
```

Recall that the cell cache is organized in terms of columns, not members. This makes member ranges difficult for mondrian to implement. A range such as "February 15th 2007 onwards" becomes

```
year > 2007
|| (year = 2007
    && (quarter > 'Q1'
        || (quarter = 'Q1'
            && (month > 2
                || (month = 2
                    && day >= 15)))))
```

The region returned by `createMeasuresRegion(Cube)` effectively encompasses the whole cube. To flush all cubes in the schema, use a loop:

```
Connection connection;
CacheControl cacheControl = connection.getCacheControl(null);
for (Cube cube : connection.getSchema().getCubes()) {
    cacheControl.flush(
        cacheControl.createMeasuresRegion(cube));
}
```

Merging and truncating segments

The current implementation does not actually remove the cells from memory. For instance, in segment YNS#1 in the example above, the cell (1997, USA, OR) is still in the segment, even though it will never be accessed. It doesn't seem worth the effort to rebuild the segment to save a little memory, but we may revisit this decision.

In future, one possible strategy would be to remove a segment if more than a given percentage of its cells are unreachable.

It might also be useful to be able to merge segments which have the same dimensionality, to reduce fragmentation if the cache is flushed repeatedly over slightly different bounds. There are some limitations on when this can be done, since predicates can only constrain one column: it would not be possible to merge the segments `{(State=TX, Quarter=Q2)}` and `{(State=WA, Quarter=Q3)}` into a single segment, for example. An alternative solution to fragmentation would be to simply remove all segments of a particular dimensionality if fragmentation is detected.

Other cache control topics

Flushing the dimension cache

An application might also want to make modifications to a dimension table. Mondrian does not currently allow an application to control the cache of members, but we intend to do so in the future. Here are some notes which will allow this to be implemented.

The main way that Mondrian caches dimensions in memory is via a cache of member children. That is to say, for a given member, the cache holds the list of all children of that member.

If a dimension table row was inserted or deleted, or if its key attributes are updated, its parent's child list would need to be modified, and perhaps other ancestors too. For example, if a customer Zachary William is added in city Oakland, the children list of Oakland will need to be flushed. If Zachary is the first customer in Oakland, California's children list will need to be flushed to accommodate the new member Oakland.

There are a few other ways that members can be cached:
Each hierarchy has a list of root members, an 'all' member (which may or not be visible), and a default member (which may or may not be the 'all' member).
Formulas defined against a cube may reference members.
All other references to members are ephemeral: they are built up during the execution of a query, and are discarded when the query has finished executing and its result set is forgotten.

Possible APIs might be `flushMember(Member, boolean children)` or `flushMembers(CellRegion)`.

Cache consistency

Mondrian's cache implementation must solve several challenges in order to prevent inconsistent query results. Suppose, for example, a connection executes the query

```
SELECT {[Measures].[Unit Sales]} ON COLUMNS,
    {[Gender].Members} ON ROWS
FROM [Sales]
```

It would be unacceptable if, due to updates to the underlying database, the query yielded a result where the total for [All gender] did not equal the sum of [Female] and [Male], such as:

	Unit Sales
All gender	100,000
Female	60,000
Male	55,000

We cannot guarantee that the query result is absolutely up to date, but the query must represent the state of the database at some point in time. To do this, the implementation must ensure that both cache flush and cache population are atomic operations.

First, Mondrian's implementation must provide atomic cache flush so that from the perspective of any clients of the cache. Suppose that while the above query is being executed, another connection issues a cache flush request. Since the flush request and query are simultaneous, it is acceptable for the query to return the state of the database before the flush request or after, but not a mixture of the two.

The query needs to use two aggregates: one containing total sales, and another containing sales sliced by gender. To see a consistent view of the two aggregates, the implementation must ensure that from the perspective of the query, both aggregates are flushed simultaneously. The query evaluator will therefore either see both aggregates, or see none.

Second, Mondrian must provide atomic cache population, so that the database is read consistently. Consider an example.

The end user runs a query asking for the total sales:

	Unit Sales
All gender	100,000

After that query has completed, the cache contains the total sales but not the sales for each gender.

New sales are added to the fact table.

The end user runs a query which shows total sales and sales for male and female customers. The query uses the cached value for total sales, but issues a query to the fact table to find the totals for male and female, and sees different data than when the cache was last populated. As result, the query is inconsistent:

	Unit Sales
All gender	100,000
Female	60,000
Male	55,000

Atomic cache population is difficult to ensure if the database is being modified without Mondrian's knowledge. One solution, not currently implemented, would be for Mondrian to leverage the DBMS' support for read-consistent views of the data. Read-consistent views are expensive for the DBMS to implement (for example, in Oracle they yield the infamous 'Snapshot too old' error), so we would not want Mondrian to use these by default, on a database which is known not to be changing.

Another solution might be to extend the Cache Control API so that the application can say 'this part of the database is currently undergoing modification'.

This scenario has not even considered aggregate tables. We have assumed that aggregate tables do not exist, or if they do, they are updated in sync with the fact table. How to deal with aggregate tables which are maintained asynchronously is still an open question.

Metadata cache control

The CacheControl API tidies up a raft of (mostly equivalent) methods which had grown up for controlling metadata (schema XML files loaded into memory). The methods

```
mondrian.rolap.RolapSchema.clearCache()
mondrian.olap.MondrianServer.flushSchemaCache()
mondrian.rolap.cache.CachePool.flush()
mondrian.rolap.RolapSchema.flushRolapStarCaches(boolean)
mondrian.rolap.RolapSchema.flushAllRolapStarCachedAggregations()
mondrian.rolap.RolapSchema.flushSchema(String,String,String,String)
mondrian.rolap.RolapSchema.flushSchema(DataSource,String)
```

are all deprecated and are superseded by the CacheControl methods:

```
void flushSchemaCache();
```

```
void flushSchema( String catalogUrl, String connectionKey, String
   jdbcUser, String dataSourceStr);
void flushSchema( String catalogUrl, DataSource dataSource);
```

Mondrian CmdRunner

What is CmdRunner?

`CmdRunner` is a command line interpreter for Mondrian. From within the command interpreter or in a command file: properties can be set and values displayed, logging levels changed, built-in function usages displayed, parameter values displayed and set, per-cube attributes displayed and set, results and errors from the previous MDX command displayed and, of course, MDX queries evaluated.

For Mondrian developers new features can be quickly tested with `CmdRunner`. As an example, to test a new user-defined function all one need to is add it to the schema, add the location of the function's java class to the class path, point `CmdRunner` at the schema and execute a MDX query that uses the new function.

For MDX developers, `CmdRunner` lets one test a new MDX query or Mondrian schema without having to run Mondrian in a Webserver using JPivot. Rather, one can have the new MDX query in a file and point `CmdRunner` at it. Granted, the output is a list, possibly long, of row and column entries; but sometimes all one needs from `CmdRunner` is to know that the query runs and other times one can always post process the output into excel or gnuplot, etc.

Building

There are two ways to run the command interpreter. The first is to have a script create a class path with all of the needed mondrian and support jars in it and then have java execute the CmdRunner main method. The second is to build a jar that contains all of the needed classes and simply have java reference the jar using the `-jar` argument.

To build the CmdRunner combined jar from the shell command line execute the following build command:

```
mondrian> ./build.sh cmdrunner
```

This will create the jar `cmdrunner.jar` in the *`MONDRIAN_HOME`*`/lib` directory. For this build to create a jar that can actually be used it is important that the *JDBC* jar for your database be placed in the *`MONDRIAN_HOME`*`/testlib` directory prior to executing the build command.

What is useful about the `cmdrunner.jar` is that it can be executed without having to have the *`MONDRIAN_HOME`* directory around since it bundles up everything that is needed (other than the properties and schema files).

Usage

There are two ways to invoke `CmdRunner`: using the `cmdrunner.jar` or using a script that builds a class path of the required jars and then executes java with that class path. The former is an easy "canned" solution but requires building the `cmdrunner.jar` while the later is quicker if you are in a code, compile and test cycle.

To run CmdRunner using the cmdrunner.jar from the shell prompt execute:

```
somedir> java -jar cmdrunner.jar -p foodmart.properties
```

In the *MONDRIAN_HOME*/bin directory there are the shell scripts cmdrunner.sh and cmdrunner.cmd that can be used duplicating the above command:

```
mondrian> ./bin/cmdrunner.sh -p foodmart.properties
```

To run CmdRunner without first building the cmdrunner.jar there is the run.sh in the *MONDRIAN_HOME*/bin directory. This script creates a class path and includes all jars in the *MONDRIAN_HOME*/testlib directory where the jdbc jars are located.

```
mondrian> ./bin/run.sh -p foodmart.properties
```

Properties File

Below is an example properties file:

```
#############################################################################
#######
#
# Example properties file
#
# $Id: //open/mondrian/doc/cmdrunner.html#10 $
#############################################################################
#######
# Environment
mondrian.catalogURL=file:///home/madonna/mondrian/FoodMartSchema.xml

# mysql
mondrian.test.jdbcURL=jdbc:mysql://localhost/foodmart?user=foodmart&pas
sword=foodmart
# to specify the jdbc username and password:
# mondrian.test.jdbcUser=foodmart
# mondrian.test.jdbcPassword=foodmart
mondrian.jdbcDrivers=com.mysql.jdbc.Driver

# Use MD5 based caching for the RolapSchema instance
mondrian.catalog.content.cache.enabled=true

# both read and use aggregate tables
mondrian.rolap.aggregates.Use=true
mondrian.rolap.aggregates.Read=true

# generate aggregate sql (for every mdx query)
#mondrian.rolap.aggregates.generateSql=true

# pretty print sql (if log level for mondrian.rolap.RolapUtil is DEBUG)
mondrian.rolap.generate.formatted.sql=true

# by default the aggregate table with the smallest number of rows
# (rather than rows times size of each row) is used
#mondrian.rolap.aggregates.ChooseByVolume=true
```

Command line arguments

`CmdRunner` has the following command line options:

Option	Description
`-h`	Print help, the list of command line options.
`-d`	Enable CmdRunner debugging. This does not change this log level.
`-t`	Time each mdx query's execution.
`-nocache`	Regardless of the settings in the Schema file, set each Cube to no in-memory aggregate caching (caching is turned off so each query goes to the database).
`-rc`	Do not reload the connection after each query (the default is to reload the connection. Its safe to just ignore this.
`-p property-file`	Specify the Mondrian property file. This argument is basically required for any but the most trivial command interpreter commands. To execute a MDX query or request information about a function, the property file must be supplied. On the other hand, to have the CmdRunner print out its internal help, then the property file is not needed.
`-f filename+`	Specify the name of one or more files that contains CmdRunner commands. If this argument is not supplied, then the interpreter starting in the command entry mode. After the `-f` is seen, all subsequent arguments are interpreted as filenames.
`-x xmla_filename+`	Specify the name of one or more files that contains XMAL request that has no SOAP wrapper. After the `-x` is seen, all subsequent arguments are interpreted as XMLA filenames.
`-xs soap_xmla_filename+`	Specify the name of one or more files that contains XMAL request with a SOAP wrapper. After the `-xs` is seen, all subsequent arguments are interpreted as SOAP XMLA filenames.
`-vt`	Validate the XMLA response using XSLT transform. This can only be used with the `-x` or `-xs` flags.
`-vx`	Validate the XMLA response using XPaths. This can only be used with the `-x` or `-xs` flags.
`mdx_command`	A string representing one or more CmdRunner commands.

CmdRunner Commands

The command interpreter has a fixed set of built in commands. When a line is read, if the first word of the line matches one of the commands, then the rest of the line is assumed to be arguments to that command. On the other hand, if the first word does not match a built in command, then all text until a ';' is seen or until a '=' is entered by itself on a command continuation line is seen will be passed to the Mondrian query engine.

help

```
> help <cr>
```

Prints help for all commands.

set

```
> set [ property[=value ] ] <cr>
```

With no args, prints all mondrian properties and values.

With "property" prints property's value.

With "property=value" set property to that value.

log

```
> log [ classname[=level ] ] <cr>
```

With no args, prints the current log level of all classes.

With "classname" prints the current log level of the class.

With "classname=level" set log level to new value.

file

```
> file [ filename | '=' ] <cr>
```

With no args, prints the last filename executed.

With "filename", read and execute filename.

With "=" character, re-read and re-execute previous filename.

list

```
> list [ cmd | result ] <cr>
```

With no arguments, list previous cmd and result

With "cmd" argument, list the last mdx query cmd.

With "result" argument, list the last mdx query result.

func

```
> func [ name ] <cr>
```

With no arguments, list all defined function names.

With "name" argument, display the functions: name, description, and syntax.

param

```
> param [ name[=value ] ] <cr>
```

With no arguments, all param name/value pairs are printed.

With "name" argument, the value of the param is printed.

With "name=value" sets the parameter with name to value. If name is null, then unsets all parameters. If value is null, then unsets the parameter associated with value.

cube

```
> cube [ cubename [ name [=value | command] ] ] <cr>
```

With no arguments, all cubes are listed by name.

With "cubename" argument, cube attribute name/values for: fact table (readonly) aggregate caching (readwrite) are printed.

With "cubename name=value", sets the readwrite attribute with name to value.

With "cubename command", executes the commands: clearCache.

error

```
> error [ msg | stack ] <cr>
```

With no arguments, both message and stack are printed.

With "msg" argument, the Error message is printed.

With "stack" argument, the Error stack trace is printed.

echo

```
> echo text <cr>
```

Prints text to standard out.

expr

```
> expr cubename expression <cr>
```

Evaluates an expression against a cube

=

```
> = <cr>
```

Re-executes previous MDX query.

~

```
> ~ <cr>
```

Clears any text entered so far for the current command.

exit

```
> exit <cr>
```

Exits the MDX command interpreter.

run an MDX query

```
> <mdx query> ( [ ';' ] <cr> | <cr> ( '=' | '~' ) <cr> )
```

Executes or cancels an MDX query.

An MDX query may span one or more lines. The continuation prompt is a '?'.

After the last line of the query has been entered, on the next line a single execute character, '=', may be entered followed by a carriage return. The lone '=' informs the interpreter that the query has has been entered and is ready to execute.

At anytime during the entry of a query the cancel character, '~', may be entered alone on a line. This removes all of the query text from the the command interpreter.

Queries can also be ended by using a semicolon ';' at the end of a line.

During general operation, Mondrian Property triggers are disabled. If you enable Mondrian Property triggers for a CmdRunner session, either in the property file read on starup or by explicitly using the `set` property command

```
> set mondrian.olap.triggers.enable=true <cr>
```

then one can force a re-scanning of the database for aggregate tables by disabling and then re-enabling the use of aggregates:

```
> set mondrian.olap.aggregates.Read=false <cr>
> set mondrian.olap.aggregates.Read=true <cr>
```

In fact, as long as one does not use the `-rc` command line argument so that a new connection is gotten every time a query is executed, one can edit the Mondrian schema file between MDX

query execute. This allows one to not only change what aggregates tables are in seen by Mondrian but also the definitions of the cubes within a given CmdRunner session.

Similarly, one can change between aggregate table partial ordering algorithm by changing the value of the associated property, `mondrian.olap.aggregates.ChooseByVolume` thus triggering internal code to reorder the aggregate table lookup order.

Within the command interpreter there is no ability to edit a previously entered MDX query. If you wish to iteratively edit and run a MDX query, put the query in a file, tell the CmdRunner to execute the file using the `file` command, re-execute the file using the = command, and in separate window edit/save MDX in the file.

There is also no support for a command history (other than the '=' command).

AggGen: Aggregate SQL Generator

Mondrian release 1.2 introduced Aggregate Tables as a means of improving performance, but aggregate tables are difficult to use without tools to support them.

`CmdRunner` includes a utility called `AggGen`, the Aggregate Table Generator. With it, you can issue an MDX query, and generate a script to create and populate the appropriate aggregate tables to support that MDX query. (The query does not actually return a result.)

In the property file provided to the `CmdRunner` at startup add the line:

```
mondrian.rolap.aggregates.generateSql=true
```

or from the `CmdRunner` command line enter:

```
> set mondrian.rolap.aggregates.generateSql=true <cr>
```

This instructs Mondrian whenever an MDX query is executed (and the cube associated with the query is not virtual) to output to standard out the Sql associated with the creation and population of both the "lost" dimension aggregate table and the "collapsed" dimension aggregate table which would be best suited to optimize the given MDX query. This Sql has to be edited to change the "l_XXX" in the "lost" dimension statements or "c_XXX" in the "collapsed" dimension statements to more appropriate table names (remembering to make sure that the new names can still be recognized by Mondrian as aggregates of the particular fact table).

As an example, if the following MDX is run against a MySql system:

```
WITH MEMBER
    [Store].[Nat'l Avg] AS
   'AVG(  { [Store].[Store Country].Members}, [Measures].[Units
Shipped])'
SELECT
    { [Store].[Store Country].Members, [Store].[Nat'l Avg] } ON
COLUMNS,
    { [Product].[Product Family].[Non-Consumable].Children } ON ROWS
FROM
   [Warehouse]
```

```
WHERE
    [Measures].[Units Shipped];
```

Then the following is written to standard output:

```
WARN  [main] AggGen For RolapStar: "inventory_fact_1997" measure with
name, "warehouse_sales"-"inventory_fact_1997"."warehouse_cost", is not
a column
name. The measure's column name may be an expression and currently
AggGen does
not handle expressions. You will have to add this measure to the
aggregate table
definition by hand.

CREATE TABLE agg_l_XXX_inventory_fact_1997 (
    time_id INT,
    product_id INT NOT NULL,
    store_id INT,
    store_invoice DECIMAL(10,4),
    supply_time SMALLINT,
    warehouse_cost DECIMAL(10,4),
    warehouse_sales DECIMAL(10,4),
    units_shipped INT,
    units_ordered INT,
    fact_count INTEGER NOT NULL);

INSERT INTO agg_l_XXX_inventory_fact_1997 (
    time_id,
    product_id,
    store_id,
    store_invoice,
    supply_time,
    warehouse_cost,
    warehouse_sales,
    units_shipped,
    units_ordered,
    fact_count)
SELECT
    `inventory_fact_1997`.`time_id` AS `time_id`,
    `inventory_fact_1997`.`product_id` AS `product_id`,
    `inventory_fact_1997`.`store_id` AS `store_id`,
    SUM(`inventory_fact_1997`.`store_invoice`) AS `store_invoice`,
    SUM(`inventory_fact_1997`.`supply_time`) AS `supply_time`,
    SUM(`inventory_fact_1997`.`warehouse_cost`) AS `warehouse_cost`,
    SUM(`inventory_fact_1997`.`warehouse_sales`) AS `warehouse_sales`,
    SUM(`inventory_fact_1997`.`units_shipped`) AS `units_shipped`,
    SUM(`inventory_fact_1997`.`units_ordered`) AS `units_ordered`,
    COUNT(*) AS `fact_count`
FROM
    `inventory_fact_1997` AS `inventory_fact_1997`
GROUP BY
    `inventory_fact_1997`.`time_id`,
    `inventory_fact_1997`.`product_id`,
    `inventory_fact_1997`.`store_id`;

CREATE TABLE agg_c_XXX_inventory_fact_1997 (
```

```
    product_family VARCHAR(30),
    product_department VARCHAR(30),
    store_country VARCHAR(30),
    the_year SMALLINT,
    store_invoice DECIMAL(10,4),
    supply_time SMALLINT,
    warehouse_cost DECIMAL(10,4),
    warehouse_sales DECIMAL(10,4),
    units_shipped INT,
    units_ordered INT,
    fact_count INTEGER NOT NULL);

INSERT INTO agg_c_XXX_inventory_fact_1997 (
    product_family,
    product_department,
    store_country,
    the_year,
    store_invoice,
    supply_time,
    warehouse_cost,
    warehouse_sales,
    units_shipped,
    units_ordered,
    fact_count)
SELECT
    `product_class`.`product_family` AS `product_family`,
    `product_class`.`product_department` AS `product_department`,
    `store`.`store_country` AS `store_country`,
    `time_by_day`.`the_year` AS `the_year`,
    SUM(`inventory_fact_1997`.`store_invoice`) AS `store_invoice`,
    SUM(`inventory_fact_1997`.`supply_time`) AS `supply_time`,
    SUM(`inventory_fact_1997`.`warehouse_cost`) AS `warehouse_cost`,
    SUM(`inventory_fact_1997`.`warehouse_sales`) AS `warehouse_sales`,
    SUM(`inventory_fact_1997`.`units_shipped`) AS `units_shipped`,
    SUM(`inventory_fact_1997`.`units_ordered`) AS `units_ordered`,
    COUNT(*) AS `fact_count`
FROM
    `inventory_fact_1997` AS `inventory_fact_1997`,
    `product_class` AS `product_class`,
    `product` AS `product`,
    `store` AS `store`,
    `time_by_day` AS `time_by_day`
WHERE
    `product`.`product_class_id` = `product_class`.`product_class_id`
and
    `inventory_fact_1997`.`product_id` = `product`.`product_id` and
    `inventory_fact_1997`.`store_id` = `store`.`store_id` and
    `inventory_fact_1997`.`time_id` = `time_by_day`.`time_id`
GROUP BY
    `product_class`.`product_family`,
    `product_class`.`product_department`,
    `store`.`store_country`,
    `time_by_day`.`the_year`;
```

There are a couple of things to notice about the output.

First, is the WARN log message. This appears because the inventory_fact_1997 table has a measure with a column attribute "warehouse_sales"-"inventory_fact_1997"."warehouse_cost" that is not a column name, its an expression. The AggGen code does not currently know what to do with such an expression, so it issues a warning. A user would have to take the generated aggregate table Sql scripts and alter them to accommodate this measure.

There are two aggregate tables, agg_l_XXX_inventory_fact_1997 the "lost" dimension case and agg_c_XXX_inventory_fact_1997 the "collapsed" dimension case. The "lost" dimension table, keeps the foreign keys for those dimension used by the MDX query and discards the other foreign keys, while the "collapsed" dimension table also discards the foreign keys that are not needed but, in addition, rolls up or collapses the remaining dimensions to just those levels needed by the query.

There are no indexes creation Sql statements for the aggregate tables. This is because not all databases require indexes to achive good performance against star schemas - your mileage may vary so do some testing. (With MySql indexes are a good idea).

If one is creating a set of aggregate tables, there are cases where it is more efficient to create the set of aggregates that are just above the fact tables and then create each subsequent level of aggregates from one of the preceeding aggregate tables rather than always going back to the fact table.

There are many possible aggregate tables for a given set of fact tables. AggGen just provides example Sql scripts based upon the MDX query run. Judgement has to be used when creating aggregate tables. There are tradeoffs such as which are the MDX queries that are run the most often? How much space does each aggregate table take? How long does it take to create the aggregate tables? How often does the set of MDX queries change? etc.

During normal Mondrian operation, for instance, with JPivot, it is recommended that the above AggGen property not be set to true as it will slow down Mondrian and generate a lot of text in the log file.

Mondrian FAQs

How do I use Mondrian in my application?

There are several ways. If you have a fixed set of queries which you'd like to display as HTML tables, use the tab library. webapp/taglib.jsp is an example of this.

The JPivot project (http://jpivot.sourceforge.net) is a JSP-based pivot table, and will allow you to dynamically explore a dataset over the web. It replaces the prototype pivot table webapp/morph.jsp.

You could also build a pivot table in a client technology such as Swing.

Why doesn't Mondrian use a standard API?

Because there isn't one. MDX is a component of Microsoft's OLE DB for OLAP standard which, as the name implies, only runs on Windows. Mondrian's API is fairly similar in flavor to ADO MD (ActiveX Data Objects for Multidimensional), a API which Microsoft built in order to make OLE DB for OLAP easier to use.

XML for Analysis is pretty much OLE DB for OLAP expressed in Web Services rather than COM, and therefore seems to offer a platform-neutral standard for OLAP, but take-up seems to be limited to vendors who supported OLE DB for OLAP already.

The other query vendors failed to reach consensus several years ago with the OLAP Council API, and are now encamped on the JOLAP specification.

We plan to provide a JOLAP API to Mondrian as soon as JOLAP is available.

How does Mondrian's dialect of MDX differ from Microsoft Analysis Services?

See MDX language specification.

Not very much.

1. The `StrToSet()` and `StrToTuple()` functions take an extra parameter.
2. Parsing is case-sensitive.
3. Pseudo-functions `Param()` and `ParamRef()` allow you to create parameterized MDX statements.

How can Mondrian be extended?

See User-defined function, Cell reader, Member reader

Can Mondrian handle large datasets?

Yes, if your RDBMS can. We delegate the aggregation to the RDBMS, and if your RDBMS happens to have materialized group by views created, your query will fly. And the next time you run the same or a similar query, that will really fly, because the results will be in the aggregation cache.

How do I enable tracing?

To enable tracing, set `mondrian.trace.level` to 1 in `mondrian.properties`. You will see text and execution time of each SQL statement, like this:

```
SqlMemberSource.getLevelMemberCount: executing sql [select count(*) as
`c0` from (select distinct `store`.`store_country` as `c0` from `store`
as `store`) as `foo`], 110 ms
SqlMemberSource.getMembers: executing sql [select distinct
`store`.`store_sqft` as `c0` from `store` as `store` order by
`store`.`store_sqft`], 50 ms
```

Notes:

- If you are running mondrian from the command-line, or via Ant, `mondrian.properties` should be in the current directory.
- If you are running in Tomcat, `mondrian.properties` should be in *`TOMCAT_HOME`*`/bin`. Changes will only take effect when you re-start Tomcat. The output goes to the console from which you started Tomcat.

How do I enable logging?

Mondrian uses the Apache Log4j logger. To build, test, and run Mondrian requires a log4j.jar file. A log4j.jar file is provided as part of the Mondrian distribution.

Also provided is a log4j.properties file. Such a file is needed when running Mondrian in standalone mode (such as when running the Mondrian junit tests or the CmdRunner utility). Generally, Mondrian is embedded in an application, such as a webserver, which may have their own log4j.properties file or some other mechanism for setting log4j properties. In such cases, the user must use those for controlling Mondrian's logging.

Mondrian follows Apache's guidance on what type of information is logged at what level:

- `FATAL`: A very severe error event that will presumably lead the application to abort.
- `ERROR`: An error event that might still allow the application to continue running.
- `WARN`: A potentially harmful situation.
- `INFO`: An informational message that highlight the progress of the application at a coarse-grained level.
- `DEBUG`: A fine-grained informational event that is most useful to debug an application.

It is recommended for general use that the Mondrian log level be set to `WARN`; arguably, its good to know when things are going South.

What is the syntax of a Mondrian connect string?

The syntax of the connect string is described in the Javadoc for the method mondrian.olap.DriverManager.getConnection(String connectString, boolean fresh).

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Where is Mondrian going in the future?

1. Presentation layer (see JPivot for more details).

2. Complete implementation of MDX (not all of the functions implemented yet)

3. Tuning

Where can I find out more?

MDX Solutions with Microsoft SQL Server Analysis Services by George Spofford is the best book I have found on MDX. Despite the title, principles it describes can be applied to any RDBMS.

OLAP Solutions: Building Multidimensional Information Systems by Erik Thomsen is a great overview of multidimensional databases, but does not deal with MDX.

The reference work on data warehousing is *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling (Second Edition)*, by Ralph Kimball, Margy Ross. It covers the business process well, but the focus is more on star schemas and ROLAP than OLAP.

The Microsoft Analysis Services online documentation has excellent online documentation of MDX, including a list of MDX functions.

Mondrian is wonderful! How can I possibly thank you?

We'd love to hear what you liked and didn't like about it. If you can think of ways that Mondrian can be improved, roll up your sleeves and help make it better. If you use Mondrian in your application, consider sharing your work so that everyone can use it.

Modeling

Measures not stored in the fact table

I am trying to build a cube with measures from 2 different tables. I have tried a virtual cube, but it does not seem to work - it only relates measures and dimensions from the same table. Is there a way to specify that a measure is not coming from the fact table? Say using SQL select?

Virtual cubes sound like the right approach. The way to do it is to first create a dummy cube on your lookup table, with dimensions for as many columns as are applicable. (A classic example of this kind of cube is an 'ExchangeRate' cube, whose only dimensions are time and currency.)

Then create a virtual cube of the dummy cube and the real cube (onto your fact table).

Note that you will need to use shared dimensions for the cubes to join implicitly.

How can I define my fact table based on an arbitrary SQL statement?

Use the <View> element INSTEAD OF the <Table> element. You need to specify the 'alias' attribute, which Mondrian uses as a table alias.

The XML 'CDATA' construct is useful in case there are strange characters in your SQL, but isn't essential.

```
<View alias="DFACD_filtered"> <SQL dialect="generic"> <![CDATA[select *
from DFACD where CSOC = '09']]> </SQL> </View>
```

Why can't Mondrian find my tables?

Consider this scenario. I have created some tables in Oracle, like this:

```
CREATE TABLE sales ( prodid INTEGER, day INTEGER, amount NUMBER);
```

and referenced it in my schema.xml like this:

```
<Cube name="Sales"> <Table name="sales"/> ... <Measure name="Sales"
column="amount" aggregator="sum"/> <Measure name="Sales count"
column="prodid" aggregator="count"/> </Cube>
```

Now I start up Mondrian and get an error `ORA-00942: Table or view "sales" does not exist` while executing the SQL statement `SELECT "prodid", count(*) FROM "sales" GROUP BY "prodid"`. The query looks valid, and the table exists, so why is Oracle giving an error?

The problem is that table and column names are case-sensitive. You told Mondrian to look for a table called "sales", not "SALES" or "Sales".

Oracle's table and column names are case-sensitive too, provided that you enclose them in double-quotes, like this:

```
CREATE TABLE "sales" ( "prodid" INTEGER, "day" INTEGER, "amount"
NUMBER);
```

If you omit the double-quotes, Oracle automatically converts the identifiers to upper-case, so the first `CREATE TABLE` command actually created a table called "SALES". When the query gets run, Mondrian is looking for a table called "sales" (because that's what you called it in your schema.xml), yet Oracle only has a table called "SALES".

There are two possible solutions. The simplest is to change the objects to upper-case in your schema.xml file:

```
<Cube name="Sales"> <Table name="SALES"/> ... <Measure name="Sales"
column="AMOUNT" aggregator="sum"/> <Measure name="Sales count"
column="PRODID" aggregator="count"/> </Cube>
```

Alternatively, if you decide you would like your table and column names to be in lower or mixed case (or even, for that matter, to contain spaces), then you must double-quote object names when you issue `CREATE TABLE` statements to Oracle.

Build/install

I get compilation errors? Why is this?

For example:

"SchemaTreeModel.java": Error #: 302 : cannot access class MondrianDef.Schema; java.io.IOException: class not found: class MondrianDef.Schema at line 29, column 14

You can't just compile the source code using your IDE; you must build using ant, as described in the build instructions. This is because several Java classes, such as mondrian.olap.MondrianDef (as in this case), mondrian.olap.MondrianResource and mondrian.olap.Parser are generated from other files. I recommend that you do ant clean before trying to build again.

Another example:

"NamedObject.java": Error #: 704 : cannot access directory javax\jmi\reflect at line 4, column 1

You don't have the correct JAR files (in this case, lib/jmi.jar) on your classpath. Again, you should have followed the build instructions. This problem often happens when people try to build using an IDE. You must use ant for the first ever build, but you may be able to setup your IDE to do incremental builds.

Performance

When I change the data in the RDBMS, the result doesn't change even if i refresh the browser. Why is this?

Mondrian uses a cache to improve performance. The first time you run a query, Mondrian will execute various SQL statements to load the data (you can see these statements by turning on tracing). The next time, it will use the information in the cache.

Cache control is primitive right now. If the data in the RDBMS is modified, Mondrian has no way to know, and does not refresh its cache. If you are using the JPivot web ui and refresh the browser, that will simply regenerate the web page, not flush the cache. The only way to refresh the cache is to call the following piece of code, which flushes the entire contents:

```
mondrian.rolap.CachePool.instance().flush();
```

See caching design for more information.

Tuning the Aggregate function

I am using an MDX query with a calculated "aggregate" member. It aggregates the values between Node A and Node B. The dimension that it is aggregating on is a Time dimension. This Time dimension has a granularity of one minute. When executing this MDX query, the performance seems to be fairly bad.

Here is the query:

```
WITH MEMBER [Time].[AggregateValues] AS
  'Aggregate([Time].[2004].[October].[1].[12].[10] :
[Time].[2004].[October].[20].[12].[10])'
SELECT [Measures].[Volume] ON ROWS,
  NON EMPTY {[Service].[Name]}
WHERE ([Time].[AggregateValues])
```

Is this normal behavior? Is there any way I can speed this up?

Answer:

The performance is bad because you are pulling 19 days * 1440 minutes per day = 27360 cells from the database into memory per cell that you actually display. Mondrian is a lot less efficient at crunching numbers than the database is, and uses a lot of memory.

The best way to improve performance is to push as much of the processing to the database as possible. If you were asking for a whole month, it would be easy:

```
WITH MEMBER [Time].[AggregateValues]
AS 'Aggregate({[Time].[2004].[October]})'
SELECT [Measures].[Volume] ON ROWS,
NON EMPTY {[Service].[Name]}
WHERE ([Time].[AggregateValues])
```

But since you're working with time periods which are not aligned with the dimensional structure, you'll have to chop up the interval:

```
WITH MEMBER [Time].[AggregateValues]
  AS 'Aggregate({
    [Time].[2004].[October].[1].[12].[10]
     : [Time].[2004].[October].[1].[23].[59],
    [Time].[2004].[October].[2]
     : [Time].[2004].[October].[19],
    [Time].[2004].[October].[20].[0].[00]
```

```
     : [Time].[2004].[October].[20].[12].[10]})'
SELECT [Measures].[Volume] ON ROWS,
NON EMPTY {[Service].[Name]}
WHERE ([Time].[AggregateValues])
```

This will retrieve a much smaller number of cells from the database — 18 days + no more than 1440 minutes — and therefore do more of the heavy lifting using SQL's `GROUP BY` operator. If you want to improve it still further, introduce hourly aggregates.

Q. I saw the perforce files, but a I couldn't find where to register and get new user, or the instructions that you have mentioned above;

A. The project administrators (Julian) register you. I would suggest that you start with guest level access and let's see if you need update access later.

Q. Do you have some model for development environment (e.g. eclipse 3.0 + ant 1.6 + jboss x.x + ...)?

A. Using Eclipse for Mondrian development works fine. There is an Eclipse Perforce plug-in, too, but you can use the Perforce client outside of Eclipse. Some people use Intellij (which is free for open-source use).

As a test web-server, most people use Tomcat 5.0.

Q. Are all the updated documentation in the perforce server? How could I get more materials, howtos, etc. to reduce my learn curve?

A. As with any open source project, the documentation is the web site (which is source-controlled in Perforce too), the forums and mailing lists, the test suite and the code.

Q. How could I enroll myself into mondrian source forge project?

A. Sign up as a SourceForge user and subscribe to the Mondrian mailing lists and forums. Also, there are a lot of Mondrian related questions from the JPivot project - I suggest you subscribe to JPivot too.

Results Caching – The key to performance

The various subsystems of Mondrian have different memory requirements. Some of them require a fixed amount of memory to do their work, whereas others can exploit extra memory to increase their performance. This is an overview of how the various subsystems use memory.

Caching is a scheme whereby a component uses extra memory when it is available in order to boost its performance, and when times are hard, it releases memory with loss of performance but with no loss of correctness. A cache is the use of extra memory when times are good, use varying amounts of memory.

Garbage collection is carried out by the Java VM to reclaim objects which are unreachable from 'live' objects. A special construct called a *soft reference* allows objects to be garbage-collected in hard times.

The garbage collector is not very discriminating in what it chooses to throw out, so mondrian has its own caching strategy. There are several caches in the system (described below), but they all of the objects in these caches are registered in the singleton instance of class mondrian.rolap.CachePool (currently there is just a single instance). The cache pool doesn't actually store the objects, but handles all of the events related to their life cycle in a cache. It weighs objects' cost (some function involving their size in bytes and their usefulness, which is based upon how recently they were used) and their benefit (the effort it would take to re-compute them).

The cache pool is not infallible — in particular, it can not adapt to conditions where memory is in short supply — so uses soft references, so that the garbage collector can overrule its wisdom.

Cached objects must obey the following contract:

1. They must implement interface mondrian.rolap.CachePool.Cacheable, which includes methods to measure objects' cost, benefit, record each time they are used, and tell them to remove themselves from their cache.
2. They must call CachePool.register(Cacheable) either in their constructor or, in any case, before they are made visible in their cache.
3. They they must call CachePool.unregister(Cacheable) when they are removed from their cache and in their `finalize()` method.
4. They must be despensable: if they disappear, their subsystem will continue to work correctly, albeit slower. A subsystem can declare an object to be temporarily indispensable by calling CachePool.pin(Cacheable, Collection) and then unpin it a short time later.
5. Their cache must reference them via soft references, so that they are available for garbage collection.
6. Thread safety. Their cache must be thread-safe.

If a cached object takes a significant time to initialize, it may not be possible to construct it, register it, and initialize it within the same synchronized section without unnacceptably reducing concurrency. If this is the case, you should use phased construction. First construct and register the object, but mark it 'under construction'. Then release the lock on the CachePool and the

object's cache, and continue initializing the object. Other threads will be able to see the object, and should be able to wait until the object is constructed. The method Segment.waitUntilLoaded() is an example of this.

The following objects are cached.

Segment

A Segment (class mondrian.rolap.agg.Segment) is a collection of cell values parameterized by a measure, and a set of (column, value) pairs. An example of a segment is

(Unit sales, Gender = 'F', State in {'CA','OR'}, Marital Status = *anything*)

All segments over the same set of columns belong to an Aggregation, in this case

('Sales' Star, Gender, State, Marital Status)

Note that different measures (in the same Star) occupy the same Aggregation. Aggregations belong to the AggregationManager, a singleton.

Segments are pinned during the evaluation of a single MDX query. The query evaluates the expressions twice. The first pass, it finds which cell values it needs, pins the segments containing the ones which are already present (one pin-count for each cell value used), and builds a cell request (class mondrian.rolap.agg.CellRequest) for those which are not present. It executes the cell request to bring the required cell values into the cache, again, pinned. Then it evalutes the query a second time, knowing that all cell values are available. Finally, it releases the pins.

Member set

A member set (class mondrian.rolap.SmartMemberReader.ChildrenList) is a set of children of a particular member. It belongs to a member reader (class mondrian.rolap.SmartMemberReader).

Schema

Schemas (class mondrian.rolap.RolapSchema) are cached in class mondrian.rolap.RolapSchema.Pool, which is a singleton (todo: use soft references). The cache key is the URL which the schema was loaded from.

Star schemas

Star schemas (class mondrian.rolap.RolapStar) are stored in the static member `RolapStar.stars` (todo: use soft references), and accessed via `RolapStar.getOrCreateStar(RolapSchema, MondrianDef.Relation)`.

Learning more about Mondrian

How Mondrian generates SQL

If you're feeling mystified where the various SQL statements come from, here's a good way to learn more. Give it a try, and if you have more questions I'll be glad to answer them.

In a debugger, put a break point in the `RolapUtil.executeQuery()` method, and run a simple query. The easiest way to run a query is to run a junit testcase such as BasicQueryTest.testSample0(). The debugger will stop every time a SQL statement is executed, and you should be able to loop up the call stack to which component is executing the query.

I expect that you will see the following phases in the execution:

- One or two SQL queries will be executed as the `schema.xml` file is read (validating calculated members and named sets, resolving default members of hierarchies, and such)
- A few SQL queries will be executed to resolve members as the query is parsed. (For example, if a query uses `[Store].[USA].[CA]`, it will look all members of the `[Store Nation]` level, then look up all children of the `[USA]` member.)
- When the query is executed, the axes (slicer, columns, rows) are executed first. Expect to see more queries on dimension tables when expressions like `[Product].children` are evaluated.
- Once the axes are populated, the cells are evaluated. Rather than executing a SQL query per cell, Mondrian makes a pass over all cells building a list of cells which are not in the cache. Then it builds and executes a SQL query to fetch all of those cells. If it didn't manage to fetch all cell values, it will repeat this step until it does.

Remember that the purpose of these queries is to populate cache. There are two caches. The dimension cache which maps a member to its children, e.g.

```
[Store].[All Stores] → { [Store].[USA], [Store].[Canada],
[Store].[Mexico]}
```

The aggregation cache maps a tuple a measure value, e.g.

```
([Store].[USA], [Gender].[F], [Measures].[Unit Sales]) → 123,456
```

Once the cache has been populated, the query won't be executed again. That's why I recommend that you restart the process each time you run this in the debugger.

Logging Levels and Information

Some of the Mondrian classes are instrumented with Apache Log4J Loggers. For some of these classes there are certain logging setting that provide information for not just the code developer but also for someone setting up a Mondrian installation. The following is a list of some of those log setting and the associated information.

Category	Level	Description
`mondrian.rolap.aggmatcher.AggTableManager`	`INFO`	A list of the RolapStar fact table names (aliases) and for each fact table, a list of all of its associated aggregate tables.
`mondrian.rolap.aggmatcher.AggTableManager`	`DEBUG`	A verbose output of all RolapStar fact tables, their measures columns, and dimension tables and columnns, along with all of each fact table's aggregate tables, columns and dimension tables.
`mondrian.rolap.aggmatcher.DefaultDef`	`DEBUG`	For each candidate aggregate table, the Matcher regular expressions for matching: table name and the fact count, foreign key, level and measure columns. Helpful in finding out why an aggregate table was not recognized.
`mondrian.rolap.agg.AggregationManager`	`DEBUG`	For each aggregate Sql query, if an aggregate table can be used to fulfill the query, which aggregate it was along with bitKeys and column names.
`mondrian.rolap.RolapUtil`	`DEBUG`	Prints out all Sql statements and their execution time. If one set the Mondrian property, `mondrian.rolap.generate.formatted.sql` to true, then the Sql is pretty printed (very nice).
`mondrian.rolap.RolapConnection`	`DEBUG`	Prints out each MDX query prior to its execution. (No pretty printing, sigh.)
`mondrian.rolap.RolapSchema`	`DEBUG`	Prints out each Rolap Schema as it is being loaded.

There are more classes with logging, but their logging is at a lower, more detailed level of more use to code developers.

Log levels can be set in either a log4j.properties file or log4j.xml file. You have to make sure you tell Mondrian which one to use. For the log4j.properties, entries might look like:

log4j.category.mondrian.rolap.RolapConnection=DEBUG
log4j.category.mondrian.rolap.RolapUtil=DEBUG

while for the log4.xml:

```
<category name="mondrian.rolap.RolapConnection">
  <priority value="DEBUG"/>
</category>
<category name="mondrian.rolap.RolapUtil">
  <priority value="DEBUG"/>
</category>
```

Default aggregate table recognition rules

The default Mondrian rules for recognizing aggregate tables are specified by creating an instance of the rule schema found in the file: `MONDRIAN_HOME/src/main/rolap/aggmatcher/DefaultRulesSchema.xml.` The instance of this schema that is built into the `mondrian.jar` after a build is in the same directory, `MONDRIAN_HOME/src/main/rolap/aggmatcher/DefaultRules.xml.`

There are six different default rules that are used to match and map a candidate aggregate table: table name, ignore column, fact count column, foreign key column, level column and measure column. All of these rules are defined by creating an instance of the DefaultRulesSchema.xml grammar. The DefaultRulesSchema.xml instance, the DefaultRules.xml file mentioned above, that by default is built as part of the mondrian.jar does not contain an ignore column rule. This grammar has base/supporting classes that are common to the above rules. In `XOM` terms, these are classes and super classes of the rule elements.

The first `XOM` class dealing with matching is the `CaseMatcher` class. This has an attribute "charcase" that takes the legal values of

"ignore" (default)
"exact"
"upper"
"lower"

When the value of the attribute is "ignore", then the regular expression formed by an element extending the `CaseMatcher` class will be case independent for both any parameters used to instantiate the regular expression template as well as for the text in the post-instantiated regular expression. On the other hand, when the "charcase" attribute take any of the other three values, it is only the parameter values themselves that are "exact", unchanged, "lower", converted to lower case, or "upper", converted to upper case.

The class `NameMatcher` extends the `CaseMatcher` class. This class has pre-template and post-template attributes whose default values is the empty string. These attributes are prepended/appended to a parameter to generate a regular expression. As an example, the `TableMatcher` element extends `NameMatcher` class. The parameter in this case is the fact table name and the regular expression would be:

pre-template-attribute${fact_table_name}post-template-attribute

For Mondrian, the builtin rule has the pre template value "agg_.+_" and the post template attribute value is the default so the regular expression becomes:

agg_.+_${fact_table_name}

Also, the NameMatcher has an attribute called basename which is optional. If set, then its value must be a regular expression with a single capture group. A capture group is an regular expression component surrounded by "(" and ")". As an example, "(.*)" is a capture group and if this was the total regular expression, then it would match anything and the single capture would match the same. On the other hand if the total regular expression was "RF_(.*)_TBL", then a name such as "RF_SHIPPMENTS_TBL" would match the regular expression while the capture group would be "SHIPPMENTS". Now, if the basename attribute is defined, then it is applied to each fact table name allowing one to strip away information and get to the "base" name. This might be needed because a DBA might prepend or append a tag to all of your fact table names and the DBA might wish to have a different tag prepend or append to all of your aggregate table names (RF_SHIPPMENTS_TBL as the fact table and RA_SHIPPMENTS_AGG_14 as an example aggregate name (the DBA prepended the "RA_" and you appended the "_AGG_14")).

Both the FactCountMatch and ForeignKeyMatch elements also extend the NameMatcher class. In these cases, the builtin Mondrian rule has no pre or post template attribute values, no regular expression, The FactCountMatch takes no other parameter from the fact table (the fact table does not have a fact count column) rather it takes a fact count attribute with default value "fact_count", and this is used to create the regular expression. For the ForeignKeyMatch matcher, its the fact table's foreign key that is used as the regular expression.

The ignore, asdf level and measure column matching elements have one or more Regex child elements. These allow for specifying multiple possible matches (if any match, then its a match). The IgnoreMap, LevelMap and MeasureMap elements extend the RegexMapper which holds an array of Regex elements. The Regex element extends CaseMatcher It has two attributes, space with default value '_' which says how space characters should be mapped, and dot with default value '_' which says how '.' characters should be mapped. If a name were the string "Unit Sales.Case" then (with the default values for the space and dot attributes and with CaseMatcher mapping to lower case) this would become "unit_sales_case".

The IgnoreMap element has NO template parameter names. Each Regex value is simply a regular expression. As an example (Mondrian by default does not include an IgnoreMap by default), a regular expression that matches all aggregate table columns then end with '_DO_NOT_USE' would be:

```
.*_DO_NOT_USE
```

One might want to use an IgnoreMap element to filter out aggregate columns if, for example, the aggregate table is a materialized view, since with each "normal" column of such a materialized view there is an associated support column used by the database which has no significance to Mondrian. In the process of recognizing aggregate tables, Mondrian logs a warning message for each column whose use can not be determined. Materialized views have so many of these support columns that if, in fact, there was a column whose use was desired but was not recognized (for instance, the column name is misspelt) all of the materialized view column warning message mask the one warning message that one really needs to see.

The IgnoreMap regular expressions are applied before any of the other column matching actions. If one sets the IgnoreMap regular expression to, for example,

```
.*
```

then all columns are marked as "ignore" and there are no other columns left to match anything else. One must be very careful when choosing `IgnoreMap` regular expressions not just for your current columns but for columns that might be created in the future. Its best to document this usage in your organization.

The following is what the element might look like in a DefaultRules.xml file:

```
<IgnoreMap id="ixx" >
  <Regex id="physical" charcase="ignore">
      .*_DO_NOT_USE
  </Regex>
</IgnoreMap>
```

The `LevelMap` element has the four template parameter names (hardcoded):

hierarchy_name
level_name
level_column_name
usage_prefix

These are names that can be used in creating template regular expressions. The builtin Mondrian default rules for level matching defines three `Regex` child elements for the `LevelMap` element. These define the template regular expressions:

${hierarchy_name}_${level_name}
${hierarchy_name}_${level_column_name}
${usage_prefix}${level_column_name}
${level_column_name}

Mondrian while attempting to match a candidate aggregate table against a particular fact table, iterates through the fact table's cube's hierarchy name, level name and level colum names looking for matches.

The `MeasureMap` element has the three template parameter names (hardcoded):

measure_name
measure_column_name
aggregate_name

which can appear in template regular expressions. The builtin Mondrian default rules for measure matching defines three `Regex` child elements for the `MeasureMap` element. These are

${measure_name}
${measure_column_name}
${measure_column_name}_${aggregate_name}

and Mondrian attempts to match a candidate aggregate table's column names against these as it iterators over a fact table's measures.

A grouping of `FactCountMatch` , `ForeignKeyMatch` , `TableMatcher` , `LevelMap` , and `MeasureMap` make up a `AggRule` element, a rule set. Each `AggRule` has a `tag` attribute

which is a unique identifier for the rule. There can be multiple `AggRule` elements in the outer `AggRules` element. Each `AggRule` having its own `tag` attribute. When Mondrian runs, it selects (via the `mondrian.rolap.aggregates.rule.tag` property) which rule set to use.

One last wrinkle, within a `AggRule` the `FactCountMatch`, `ForeignKeyMatch`, `TableMatcher`, `LevelMap`, and `MeasureMap` child elements can be either defined explicitly within the `AggRule` element or by reference `FactCountMatchRef`, `ForeignKeyMatchRef`, `TableMatcherRef`, `LevelMapRef`, and `MeasureMapRef` The references are defined as child elements of the top level `AggRules` element. With references the same rule element can be used by more than one `AggRule` (code reuse).

Below is an example of a default rule set with rather different matching rules.

```
<AggRules tag="your_mamas_dot_com">
  <AggRule tag="default" >
    <FactCountMatch id="fca" factCountName="FACT_TABLE_COUNT"
      charcase="exact" />
    <ForeignKeyMatch id="fka" pretemplate="agg_" />
    <TableMatch id="ta" pretemplate="agg_" posttemplate="_.+"/>
    <LevelMap id="lxx" >
      <Regex id="logical" charcase="ignore" space="_" dot="_">
          ${hierarchy_name}_${level_name}
      </Regex>
      <Regex id="mixed" charcase="ignore" >
          ${hierarchy_name}_${level_name}_${level_column_name}
      </Regex>
      <Regex id="mixed" charcase="ignore" >
          ${hierarchy_name}_${level_column_name}
      </Regex>
      <Regex id="usage" charcase="exact" >
          ${usage_prefix}${level_column_name}
      </Regex>
      <Regex id="physical" charcase="exact" >
          ${level_column_name}_.+
      </Regex>
    </LevelMap>
    <MeasureMap id="mxx" >
      <Regex id="one" charcase="lower" >

${measure_name}(_${measure_column_name}(_${aggregate_name})?)?
      </Regex>
      <Regex id="two" charcase="exact" >
        ${measure_column_name}(_${aggregate_name})?
      </Regex>
    </MeasureMap>
  </AggRule>
</AggRules>
```

First, all fact count columns must be called `FACT_TABLE_COUNT` exactly, no ignoring case. Next, foreign key columns match the regular expression

agg_${foreign_key_name}

that is, the fact table foreign key column name with "agg_" prepened such as `agg_time_id` . The aggregate table names match the regular expression

agg_${fact_table_name}_.+

For the FoodMart `sales_fact_1997` fact table, an aggregate could be named,

agg_sales_fact_1997_01
agg_sales_fact_1997_lost_time_id
agg_sales_fact_1997_top

If the hierarchy, level and level column names were:

hierarchy_name="Sales Location"
level_name="State"
level_column_name="state_location"
usage_prefix=null

then the following aggregate table column names would be recognizing as level column names:

SALES_LOCATION_STATE
Sales_Location_State_state_location
state_location_level.

If in the schema file the DimensionUsage for the hierarchy had a usagePrefix attribute,

usage_prefix="foo_"

then with the above level and level column names and usage_prefix the following aggregate table column names would be recognizing as level column names:

SALES_LOCATION_STATE
Sales_Location_State_state_location
state_location_level.
foo_state_location.

In the case of matching measure columns, if the measure template parameters have the following values:

measure_name="Unit Sales"
measure_column_name="m1"
aggregate_name="Avg"

then possible aggregate columns that could match are:

unit_sales_m1
unit_sales_m1_avg
m1
m1_avg

The intent of the above example default rule set is not that they are necessarily realistic or usable, rather, it just shows what is possible.

Snowflakes and the DimensionUsage level attribute

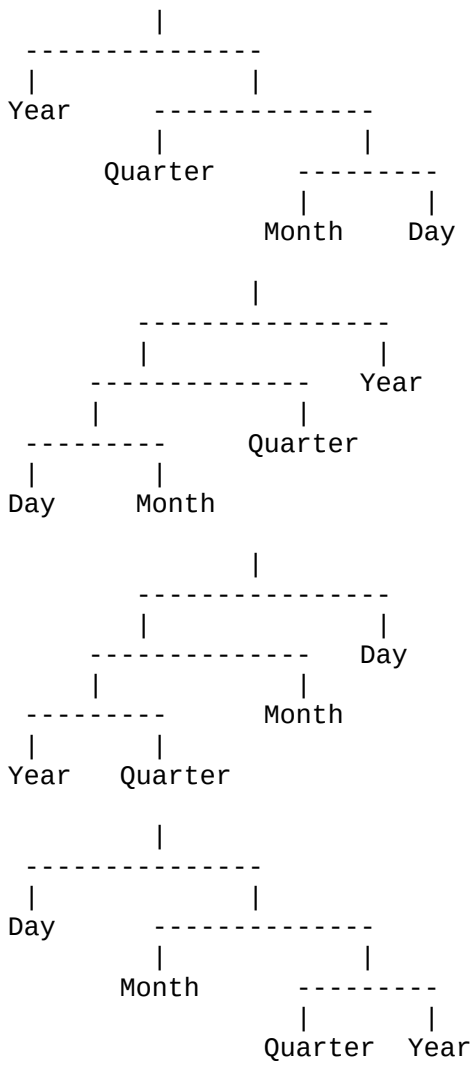
Mondrian supports dimensions with all of their levels lumped into a single table (with all the duplication of data that that entails), but also snowflakes. A snowflake dimension is one where the fact table joins to one table (generally the lowest) and that table then joins to a table representing the next highest level, and so on until the top level's table is reached. For each level there is a separate table.

As an example snowflake, below is a set of Time levels and four possible join element blocks, relationships between the tables making up the Time dimension. (In a schema file, the levels must appear after the joins.)

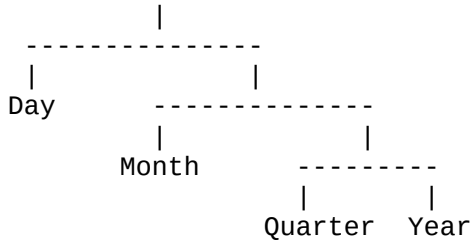
```
<Level name="Calendar Year" table="TimeYear" column="YEAR_SID"
  nameColumn="YEAR_NAME" levelType="TimeYears" uniqueMembers="true"/>
<Level name="Quarter" table="TimeQtr" column="QTR_SID"
  nameColumn="QTR_NAME" levelType="TimeQuarters" uniqueMembers="true"/>
<Level name="Month" table="TimeMonth" column="MONTH_SID"
  nameColumn="MONTH_ONLY_NAME" levelType="TimeMonths"
uniqueMembers="false"/>
<Level name="Day" table="TimeDay" column="DAY_SID"
nameColumn="DAY_NAME"
  levelType="TimeDays" uniqueMembers="true"/>


  <Join leftAlias="TimeYear" leftKey="YEAR_SID"
        rightAlias="TimeQtr" rightKey="YEAR_SID" >
    <Table name="RD_PERIOD_YEAR" alias="TimeYear" />
    <Join leftAlias="TimeQtr" leftKey="QTR_SID"
        rightAlias="TimeMonth" rightKey="QTR_SID" >
        <Table name="RD_PERIOD_QTR" alias="TimeQtr" />
        <Join leftAlias="TimeMonth" leftKey="MONTH_SID"
            rightAlias="TimeDay" rightKey="MONTH_SID" >
            <Table name="RD_PERIOD_MONTH" alias="TimeMonth" />
            <Table name="RD_PERIOD_DAY" alias="TimeDay" />
        </Join>
    </Join>
  </Join>

  <Join leftAlias="TimeQtr" leftKey="YEAR_SID"
        rightAlias="TimeYear" rightKey="YEAR_SID" >
    <Join leftAlias="TimeMonth" leftKey="QTR_SID"
        rightAlias="TimeQtr" rightKey="QTR_SID" >
        <Join leftAlias="TimeDay" leftKey="MONTH_SID"
            rightAlias="TimeMonth" rightKey="MONTH_SID" >
            <Table name="RD_PERIOD_DAY" alias="TimeDay" />
            <Table name="RD_PERIOD_MONTH" alias="TimeMonth" />
        </Join>
        <Table name="RD_PERIOD_QTR" alias="TimeQtr" />
    </Join>
    <Table name="RD_PERIOD_YEAR" alias="TimeYear" />
  </Join>
```

```
<Join leftAlias="TimeMonth" leftKey="MONTH_SID"
      rightAlias="TimeDay" rightKey="MONTH_SID" >
  <Join leftAlias="TimeQtr" leftKey="QTR_SID"
      rightAlias="TimeMonth" rightKey="QTR_SID" >
      <Join leftAlias="TimeYear" leftKey="YEAR_SID"
          rightAlias="TimeQtr" rightKey="YEAR_SID" >
          <Table name="RD_PERIOD_YEAR" alias="TimeYear" />
          <Table name="RD_PERIOD_QTR" alias="TimeQtr" />
      </Join>
      <Table name="RD_PERIOD_MONTH" alias="TimeMonth" />
  </Join>
  <Table name="RD_PERIOD_DAY" alias="TimeDay" />
</Join>

<Join leftAlias="TimeDay" leftKey="MONTH_SID"
      rightAlias="TimeMonth" rightKey="MONTH_SID" >
  <Table name="RD_PERIOD_DAY" alias="TimeDay" />
  <Join leftAlias="TimeMonth" leftKey="QTR_SID"
      rightAlias="TimeQtr" rightKey="QTR_SID" >
      <Table name="RD_PERIOD_MONTH" alias="TimeMonth" />
      <Join leftAlias="TimeQtr" leftKey="YEAR_SID"
          rightAlias="TimeYear" rightKey="YEAR_SID" >
          <Table name="RD_PERIOD_QTR" alias="TimeQtr" />
          <Table name="RD_PERIOD_YEAR" alias="TimeYear" />
      </Join>
  </Join>
</Join>
```

Viewed as trees these can be represented as follows:

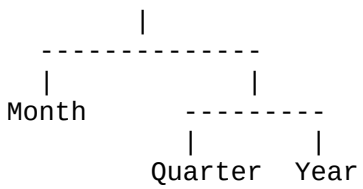


It turns out that these join block are equivalent; what table joins to what other table using what keys. In addition, they are all (now) treated the same by Mondrian. The last join block is the canonical representation; left side components are levels of greater depth than right side components, and components of greater depth are higher in the join tree than those of lower depth:



Mondrian reorders these join blocks into the canonical form and uses that to build subtables in the RolapStar.

In addition, if a cube had a `DimensionUsage` of this Time dimension with, for example, its `level` attribute set to Month, then the above tree is pruned



and the pruned tree is what is used to create the subtables in the RolapStar. Of course, the fact table must, in this case, have a MONTH_SID foreign key.

Note that the `Level` element's table attribute MUST use the table alias and NOT the table name.

Appendix A – MDX Function List

These are the functions implemented in the current Mondrian release.

Name	Description
$AggregateChildren	Equivalent to 'Aggregate(<Hierarchy>.CurrentMember.Children); for internal use. **Syntax** <Numeric Expression> $AggregateChildren(<Hierarchy>)
()	**Syntax**
*	Multiplies two numbers. **Syntax** <Numeric Expression> * <Numeric Expression>
*	Returns the cross product of two sets. **Syntax** <Set> * <Set> <Member> * <Set> <Set> * <Member> <Member> * <Member>
+	Adds two numbers. **Syntax** <Numeric Expression> + <Numeric Expression>
-	Subtracts two numbers. **Syntax** <Numeric Expression> - <Numeric Expression>
-	Returns the negative of a number. **Syntax** - <Numeric Expression>
/	Divides two numbers. **Syntax** <Numeric Expression> / <Numeric Expression>
:	Infix colon operator returns the set of members between a given pair of members.

	Syntax <Member> : <Member>
<	Returns whether an expression is less than another. **Syntax** <Numeric Expression> < <Numeric Expression>
<	Returns whether an expression is less than another. **Syntax** <String> < <String>
<=	Returns whether an expression is less than or equal to another. **Syntax** <Numeric Expression> <= <Numeric Expression>
<=	Returns whether an expression is less than or equal to another. **Syntax** <String> <= <String>
<>	Returns whether two expressions are not equal. **Syntax** <Numeric Expression> <> <Numeric Expression>
<>	Returns whether two expressions are not equal. **Syntax** <String> <> <String>
=	Returns whether two expressions are equal. **Syntax** <Numeric Expression> = <Numeric Expression>
=	Returns whether two expressions are equal. **Syntax** <String> = <String>
>	Returns whether an expression is greater than another. **Syntax** <Numeric Expression> > <Numeric Expression>

>	Returns whether an expression is greater than another. **Syntax** <String> > <String>
>=	Returns whether an expression is greater than or equal to another. **Syntax** <Numeric Expression> >= <Numeric Expression>
>=	Returns whether an expression is greater than or equal to another. **Syntax** <String> >= <String>
AND	Returns the conjunction of two conditions. **Syntax** <Logical Expression> AND <Logical Expression>
Abs	Returns a value of the same type that is passed to it specifying the absolute value of a number. **Syntax** <Numeric Expression> Abs(<Numeric Expression>)
Acos	Returns the arccosine, or inverse cosine, of a number. The arccosine is the angle whose cosine is Arg1. The returned angle is given in radians in the range 0 (zero) to pi. **Syntax** <Numeric Expression> Acos(<Numeric Expression>)
Acosh	Returns the inverse hyperbolic cosine of a number. Number must be greater than or equal to 1. The inverse hyperbolic cosine is the value whose hyperbolic cosine is Arg1, so Acosh(Cosh(number)) equals Arg1. **Syntax** <Numeric Expression> Acosh(<Numeric Expression>)
AddCalculatedMembers	Adds calculated members to a set. Syntax <Set> AddCalculatedMembers(<Set>)
Aggregate	Returns a calculated value using the appropriate aggregate function, based on the context of the query. Syntax <Numeric Expression> Aggregate(<Set>) <Numeric Expression> Aggregate(<Set>, <Numeric Expression>)
AllMembers	Returns a set that contains all members, including calculated members, of the specified dimension.

	Syntax <Dimension>.AllMembers
AllMembers	Returns a set that contains all members, including calculated members, of the specified hierarchy. **Syntax** <Hierarchy>.AllMembers
AllMembers	Returns a set that contains all members, including calculated members, of the specified level. **Syntax** <Level>.AllMembers
Ancestor	Returns the ancestor of a member at a specified level. **Syntax** <Member> Ancestor(<Member>, <Level>) <Member> Ancestor(<Member>, <Numeric Expression>)
Asc	Returns an Integer representing the character code corresponding to the first letter in a string. **Syntax** <Integer> Asc(<String>)
AscB	See Asc. **Syntax** <Integer> AscB(<String>)
AscW	See Asc. **Syntax** <Integer> AscW(<String>)
Ascendants	Returns the set of the ascendants of a specified member. **Syntax** <Set> Ascendants(<Member>)
Asin	Returns the arcsine, or inverse sine, of a number. The arcsine is the angle whose sine is Arg1. The returned angle is given in radians in the range -pi/2 to pi/2. **Syntax** <Numeric Expression> Asin(<Numeric Expression>)
Asinh	Returns the inverse hyperbolic sine of a number. The inverse hyperbolic sine is the value whose hyperbolic sine is Arg1, so

	Asinh(Sinh(number)) equals Arg1. **Syntax** <Numeric Expression> Asinh(<Numeric Expression>)
Atan2	Returns the arctangent, or inverse tangent, of the specified x- and y-coordinates. The arctangent is the angle from the x-axis to a line containing the origin (0, 0) and a point with coordinates (x_num, y_num). The angle is given in radians between -pi and pi, excluding -pi. **Syntax** <Numeric Expression> Atan2(<Numeric Expression>, <Numeric Expression>)
Atanh	Returns the inverse hyperbolic tangent of a number. Number must be between -1 and 1 (excluding -1 and 1). **Syntax** <Numeric Expression> Atanh(<Numeric Expression>)
Atn	Returns a Double specifying the arctangent of a number. **Syntax** <Numeric Expression> Atn(<Numeric Expression>)
Avg	Returns the average value of a numeric expression evaluated over a set. **Syntax** <Numeric Expression> Avg(<Set>) <Numeric Expression> Avg(<Set>, <Numeric Expression>)
BottomCount	Returns a specified number of items from the bottom of a set, optionally ordering the set first. **Syntax** <Set> BottomCount(<Set>, <Numeric Expression>, <Numeric Expression>) <Set> BottomCount(<Set>, <Numeric Expression>)
BottomPercent	Sorts a set and returns the bottom N elements whose cumulative total is at least a specified percentage. **Syntax** <Set> BottomPercent(<Set>, <Numeric Expression>, <Numeric Expression>)
BottomSum	Sorts a set and returns the bottom N elements whose cumulative total is at least a specified value.

	Syntax <Set> BottomSum(<Set>, <Numeric Expression>, <Numeric Expression>)
CBool	Returns an expression that has been converted to a Variant of subtype Boolean. **Syntax** <Logical Expression> CBool(<Value>)
CByte	Returns an expression that has been converted to a Variant of subtype Byte. **Syntax** <Integer> CByte(<Value>)
CDate	Returns an expression that has been converted to a Variant of subtype Date. **Syntax** <DateTime> CDate(<Value>)
CDbl	Returns an expression that has been converted to a Variant of subtype Double. **Syntax** <Numeric Expression> CDbl(<Value>)
CInt	Returns an expression that has been converted to a Variant of subtype Integer. **Syntax** <Integer> CInt(<Value>)
Cache	Evaluates and returns its sole argument, applying statement-level caching **Syntax** Cache(<<Exp>>)
CalculatedChild	Returns an existing calculated child member with name <String> from the specified <Member>. **Syntax** <Member> <Member>.CalculatedChild(<String>)
Caption	Returns the caption of a dimension.

	Syntax <Dimension>.Caption
Caption	Returns the caption of a hierarchy. **Syntax** <Hierarchy>.Caption
Caption	Returns the caption of a level. **Syntax** <Level>.Caption
Caption	Returns the caption of a member. **Syntax** <Member>.Caption
Cast	Converts values to another type **Syntax** Cast(<Expression> AS <Type>)
Children	Returns the children of a member. **Syntax** <Member>.Children
Chr	Returns a String containing the character associated with the specified character code. Syntax <String> Chr(<Integer>)
ChrB	See Chr. Syntax <String> ChrB(<Integer>)
ChrW	See Chr. Syntax <String> ChrW(<Integer>)
ClosingPeriod	Returns the last descendant of a member at a level. **Syntax** <Member> ClosingPeriod() <Member> ClosingPeriod(<Level>) <Member> ClosingPeriod(<Level>, <Member>) <Member> ClosingPeriod(<Member>)
CoalesceEmpty	Coalesces an empty cell value to a different value. All of the expressions must be of the same type (number or string).

	Syntax CoalesceEmpty(<Value Expression>[, <Value Expression>...])
Correlation	Returns the correlation of two series evaluated over a set. **Syntax** <Numeric Expression> Correlation(<Set>, <Numeric Expression>) <Numeric Expression> Correlation(<Set>, <Numeric Expression>, <Numeric Expression>)
Cos	Returns a Double specifying the cosine of an angle. Syntax <Numeric Expression> Cos(<Numeric Expression>)
Cosh	Returns the hyperbolic cosine of a number. Syntax <Numeric Expression> Cosh(<Numeric Expression>)
Count	Returns the number of tuples in a set, empty cells included unless the optional EXCLUDEEMPTY flag is used. **Syntax** <Numeric Expression> Count(<Set>) <Numeric Expression> Count(<Set>, <Symbol>)
Count	Returns the number of tuples in a set including empty cells. **Syntax** <Set>.Count
Cousin	Returns the member with the same relative position under <ancestor member> as the member specified. **Syntax** <Member> Cousin(<Member>, <Ancestor Member>)
Covariance	Returns the covariance of two series evaluated over a set (biased). **Syntax** <Numeric Expression> Covariance(<Set>, <Numeric Expression>) <Numeric Expression> Covariance(<Set>, <Numeric Expression>, <Numeric Expression>)
CovarianceN	Returns the covariance of two series evaluated over a set (unbiased). **Syntax** <Numeric Expression> CovarianceN(<Set>, <Numeric Expression>) <Numeric Expression> CovarianceN(<Set>, <Numeric Expression>, <Numeric Expression>)
Crossjoin	Returns the cross product of two sets.

	Syntax <Set> Crossjoin(<Set>, <Set>)
CurrentDateMember	Returns the exact member within the specified dimension corresponding to the current date, in the format specified by the format parameter. If there is no such date, returns the NULL member. Format strings are the same as used by the MDX Format function, namely the Visual Basic format strings. See http://www.apostate.com/programming/vb-format.html **Syntax** <Member> CurrentDateMember(<Hierarchy>, <String>)
CurrentDateMember	Returns the closest or exact member within the specified dimension corresponding to the current date, in the format specified by the format parameter. Format strings are the same as used by the MDX Format function, namely the Visual Basic format strings. See http://www.apostate.com/programming/vb-format.html **Syntax** <Member> CurrentDateMember(<Hierarchy>, <String>, <Symbol>)
CurrentDateString	Returns the current date formatted as specified by the format parameter. **Syntax** <String> CurrentDateString(<String>)
CurrentMember	Returns the current member along a dimension during an iteration. **Syntax** <Dimension>.CurrentMember
CurrentMember	Returns the current member along a hierarchy during an iteration. **Syntax** <Hierarchy>.CurrentMember
DDB	Returns a Double specifying the depreciation of an asset for a specific time period using the double-declining balance method or some other method you specify. **Syntax** <Numeric Expression> DDB(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
DDB	Returns a Double specifying the depreciation of an asset for a specific time period using the double-declining balance method or some other

	method you specify. **Syntax** <Numeric Expression> DDB(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
DataMember	Returns the system-generated data member that is associated with a nonleaf member of a dimension. **Syntax** <Member>.DataMember
Date	Returns a Variant (Date) containing the current system date. **Syntax** <DateTime> Date()
DateAdd	Returns a Variant (Date) containing a date to which a specified time interval has been added. **Syntax** <DateTime> DateAdd(<String>, <Numeric Expression>, <DateTime>)
DateDiff	Returns a Variant (Long) specifying the number of time intervals between two specified dates. **Syntax** <Numeric Expression> DateDiff(<String>, <DateTime>, <DateTime>, <Integer>, <Integer>)
DateDiff	Returns a Variant (Long) specifying the number of time intervals between two specified dates. **Syntax** <Numeric Expression> DateDiff(<String>, <DateTime>, <DateTime>, <Integer>)
DateDiff	Returns a Variant (Long) specifying the number of time intervals between two specified dates. **Syntax** <Numeric Expression> DateDiff(<String>, <DateTime>, <DateTime>)
DatePart	Returns a Variant (Integer) containing the specified part of a given date. **Syntax** <Integer> DatePart(<String>, <DateTime>, <Integer>, <Integer>)

DatePart	Returns a Variant (Integer) containing the specified part of a given date. **Syntax** <Integer> DatePart(<String>, <DateTime>, <Integer>)
DatePart	Returns a Variant (Integer) containing the specified part of a given date. **Syntax** <Integer> DatePart(<String>, <DateTime>)
DateSerial	Returns a Variant (Date) for a specified year, month, and day. **Syntax** <DateTime> DateSerial(<Integer>, <Integer>, <Integer>)
DateValue	Returns a Variant (Date). **Syntax** <DateTime> DateValue(<DateTime>)
Day	Returns a Variant (Integer) specifying a whole number between 1 and 31, inclusive, representing the day of the month. **Syntax** <Integer> Day(<DateTime>)
DefaultMember	Returns the default member of a dimension. **Syntax** <Dimension>.DefaultMember
DefaultMember	Returns the default member of a hierarchy. **Syntax** <Hierarchy>.DefaultMember
Degrees	Converts radians to degrees. Syntax <Numeric Expression> Degrees(<Numeric Expression>)
Descendants	Returns the set of descendants of a member at a specified level, optionally including or excluding descendants in other levels. **Syntax** <Set> Descendants(<Member>) <Set> Descendants(<Member>, <Level>) <Set> Descendants(<Member>, <Level>, <Symbol>) <Set> Descendants(<Member>, <Numeric Expression>, <Symbol>)

	<Set> Descendants(<Member>, <Empty>, <Symbol>)
Dimension	Returns the dimension that contains a specified hierarchy. **Syntax** <Dimension>.Dimension
Dimension	Returns the dimension that contains a specified hierarchy. **Syntax** <Hierarchy>.Dimension
Dimension	Returns the dimension that contains a specified level. **Syntax** <Level>.Dimension
Dimension	Returns the dimension that contains a specified member. **Syntax** <Member>.Dimension
Dimensions	Returns the dimension whose zero-based position within the cube is specified by a numeric expression. **Syntax** <Dimension> Dimensions(<Numeric Expression>)
Dimensions	Returns the dimension whose name is specified by a string. **Syntax** <Dimension> Dimensions(<String>)
Distinct	Eliminates duplicate tuples from a set. **Syntax** <Set> Distinct(<Set>)
DrilldownLevel	Drills down the members of a set, at a specified level, to one level below. Alternatively, drills down on a specified dimension in the set. Syntax <Set> DrilldownLevel(<Set>) <Set> DrilldownLevel(<Set>, <Level>) <Set> DrilldownLevel(<Set>, <Empty>, <Numeric Expression>)
DrilldownLevelBottom	Drills down the bottommost members of a set, at a specified level, to one level below. **Syntax** <Set> DrilldownLevelBottom(<Set>, <Numeric Expression>) <Set> DrilldownLevelBottom(<Set>, <Numeric Expression>, <Level>)

	<Set> DrilldownLevelBottom(<Set>, <Numeric Expression>, <Level>, <Numeric Expression>) <Set> DrilldownLevelBottom(<Set>, <Numeric Expression>, <Empty>, <Numeric Expression>)
DrilldownLevelTop	Drills down the topmost members of a set, at a specified level, to one level below. **Syntax** <Set> DrilldownLevelTop(<Set>, <Numeric Expression>) <Set> DrilldownLevelTop(<Set>, <Numeric Expression>, <Level>) <Set> DrilldownLevelTop(<Set>, <Numeric Expression>, <Level>, <Numeric Expression>) <Set> DrilldownLevelTop(<Set>, <Numeric Expression>, <Empty>, <Numeric Expression>)
DrilldownMember	Drills down the members in a set that are present in a second specified set. **Syntax** <Set> DrilldownMember(<Set>, <Set>) <Set> DrilldownMember(<Set>, <Set>, <Symbol>)
Except	Finds the difference between two sets, optionally retaining duplicates. **Syntax** <Set> Except(<Set>, <Set>) <Set> Except(<Set>, <Set>, <Symbol>)
Exists	Returns the the set of tuples of the first set that exist with one or more tuples of the second set. **Syntax** <Set> Exists(<Set>, <Set>)
Exp	Returns a Double specifying e (the base of natural logarithms) raised to a power. **Syntax** <Numeric Expression> Exp(<Numeric Expression>)
Extract	Returns a set of tuples from extracted dimension elements. The opposite of Crossjoin. **Syntax** Extract(<Set>, <Dimension>[, <Dimension>...])
FV	Returns a Double specifying the future value of an annuity based on periodic, fixed payments and a fixed interest rate.

	Syntax <Numeric Expression> FV(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Logical Expression>)
FV	Returns a Double specifying the future value of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> FV(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
FV	Returns a Double specifying the future value of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> FV(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
Filter	Returns the set resulting from filtering a set based on a search condition. **Syntax** <Set> Filter(<Set>, <Logical Expression>)
FirstChild	Returns the first child of a member. **Syntax** <Member>.FirstChild
FirstQ	Returns the 1st quartile value of a numeric expression evaluated over a set. **Syntax** <Numeric Expression> FirstQ(<Set>) <Numeric Expression> FirstQ(<Set>, <Numeric Expression>)
FirstSibling	Returns the first child of the parent of a member. **Syntax** <Member>.FirstSibling
Format	Formats a number or date to a string. **Syntax** <String> Format(<Member>, <String>) <String> Format(<Numeric Expression>, <String>) <String> Format(<DateTime>, <String>)

FormatCurrency	Returns an expression formatted as a currency value using the currency symbol defined in the system control panel. **Syntax** <String> FormatCurrency(<Value>, <Integer>, <Integer>, <Integer>, <Integer>)
FormatCurrency	Returns an expression formatted as a currency value using the currency symbol defined in the system control panel. **Syntax** <String> FormatCurrency(<Value>, <Integer>, <Integer>, <Integer>)
FormatCurrency	Returns an expression formatted as a currency value using the currency symbol defined in the system control panel. **Syntax** <String> FormatCurrency(<Value>, <Integer>, <Integer>)
FormatCurrency	Returns an expression formatted as a currency value using the currency symbol defined in the system control panel. **Syntax** <String> FormatCurrency(<Value>, <Integer>)
FormatCurrency	Returns an expression formatted as a currency value using the currency symbol defined in the system control panel. **Syntax** <String> FormatCurrency(<Value>)
FormatDateTime	Returns an expression formatted as a date or time. **Syntax** <String> FormatDateTime(<DateTime>, <Integer>)
FormatDateTime	Returns an expression formatted as a date or time. **Syntax** <String> FormatDateTime(<DateTime>)
FormatNumber	Returns an expression formatted as a number. **Syntax** <String> FormatNumber(<Value>, <Integer>, <Integer>, <Integer>, <Integer>)
FormatNumber	Returns an expression formatted as a number.

	Syntax <String> FormatNumber(<Value>, <Integer>, <Integer>, <Integer>)
FormatNumber	Returns an expression formatted as a number. **Syntax** <String> FormatNumber(<Value>, <Integer>, <Integer>)
FormatNumber	Returns an expression formatted as a number. **Syntax** <String> FormatNumber(<Value>, <Integer>)
FormatNumber	Returns an expression formatted as a number. Syntax <String> FormatNumber(<Value>)
FormatPercent	Returns an expression formatted as a percentage (multipled by 100) with a trailing % character. **Syntax** <String> FormatPercent(<Value>, <Integer>, <Integer>, <Integer>, <Integer>)
FormatPercent	Returns an expression formatted as a percentage (multipled by 100) with a trailing % character. **Syntax** <String> FormatPercent(<Value>, <Integer>, <Integer>, <Integer>)
FormatPercent	Returns an expression formatted as a percentage (multipled by 100) with a trailing % character. **Syntax** <String> FormatPercent(<Value>, <Integer>, <Integer>)
FormatPercent	Returns an expression formatted as a percentage (multipled by 100) with a trailing % character. **Syntax** <String> FormatPercent(<Value>, <Integer>)
FormatPercent	Returns an expression formatted as a percentage (multipled by 100) with a trailing % character. **Syntax** <String> FormatPercent(<Value>)
Generate	Applies a set to each member of another set and joins the resulting

	sets by union. **Syntax** <Set> Generate(<Set>, <Set>) <Set> Generate(<Set>, <Set>, <Symbol>)
Generate	Applies a set to a string expression and joins resulting sets by string concatenation. **Syntax** <String> Generate(<Set>, <String>) <String> Generate(<Set>, <String>, <String>)
Head	Returns the first specified number of elements in a set. **Syntax** <Set> Head(<Set>) <Set> Head(<Set>, <Numeric Expression>)
Hex	Returns a String representing the hexadecimal value of a number. **Syntax** <String> Hex(<Value>)
Hierarchize	Orders the members of a set in a hierarchy. **Syntax** <Set> Hierarchize(<Set>) <Set> Hierarchize(<Set>, <Symbol>)
Hierarchy	Returns a level's hierarchy. **Syntax** <Level>.Hierarchy
Hierarchy	Returns a member's hierarchy. **Syntax** <Member>.Hierarchy
Hour	Returns a Variant (Integer) specifying a whole number between 0 and 23, inclusive, representing the hour of the day. **Syntax** <Integer> Hour(<DateTime>)
IIf	Returns one of two tuples determined by a logical test. **Syntax**

	<Tuple> IIf(<Logical Expression>, <Tuple>, <Tuple>)
IIf	Returns one of two dimension values determined by a logical test. **Syntax** <Dimension> IIf(<Logical Expression>, <Dimension>, <Dimension>)
IIf	Returns one of two hierarchy values determined by a logical test. **Syntax** <Hierarchy> IIf(<Logical Expression>, <Hierarchy>, <Hierarchy>)
IIf	Returns one of two level values determined by a logical test. **Syntax** <Level> IIf(<Logical Expression>, <Level>, <Level>)
IIf	Returns boolean determined by a logical test. **Syntax** <Logical Expression> IIf(<Logical Expression>, <Logical Expression>, <Logical Expression>)
IIf	Returns one of two member values determined by a logical test. **Syntax** <Member> IIf(<Logical Expression>, <Member>, <Member>)
IIf	Returns one of two numeric values determined by a logical test. **Syntax** <Numeric Expression> IIf(<Logical Expression>, <Numeric Expression>, <Numeric Expression>)
IIf	Returns one of two set values determined by a logical test. **Syntax** <Set> IIf(<Logical Expression>, <Set>, <Set>)
IIf	Returns one of two string values determined by a logical test. **Syntax** <String> IIf(<Logical Expression>, <String>, <String>)
IPmt	Returns a Double specifying the interest payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> IPmt(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>,

	<Numeric Expression>, <Logical Expression>)
IPmt	Returns a Double specifying the interest payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> IPmt(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
IPmt	Returns a Double specifying the interest payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> IPmt(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
IRR	Returns a Double specifying the internal rate of return for a series of periodic cash flows (payments and receipts). **Syntax** <Numeric Expression> IRR(<Array>, <Numeric Expression>)
IRR	Returns a Double specifying the internal rate of return for a series of periodic cash flows (payments and receipts). **Syntax** <Numeric Expression> IRR(<Array>)
IS	Returns whether two objects are the same **Syntax** <Member> IS <Member> <Level> IS <Level> <Hierarchy> IS <Hierarchy> <Dimension> IS <Dimension> <Tuple> IS <Tuple>
IS EMPTY	Determines if an expression evaluates to the empty cell value. **Syntax** <Member> IS EMPTY <Tuple> IS EMPTY
IS NULL	Returns whether an object is null **Syntax** <Member> IS NULL <Level> IS NULL <Hierarchy> IS NULL

	<Dimension> IS NULL
InStr	Returns the position of the first occurrence of one string within another. Implements very basic form of InStr **Syntax** <Numeric Expression> InStr(<String>, <String>)
InStrRev	Returns the position of an occurrence of one string within another, from the end of string. **Syntax** <Integer> InStrRev(<String>, <String>, <Integer>, <Integer>)
InStrRev	Returns the position of an occurrence of one string within another, from the end of string. **Syntax** <Integer> InStrRev(<String>, <String>, <Integer>)
InStrRev	Returns the position of an occurrence of one string within another, from the end of string. **Syntax** <Integer> InStrRev(<String>, <String>)
Int	Returns the integer portion of a number. If negative, returns the negative number less than or equal to the number. **Syntax** <Integer> Int(<Value>)
Intersect	Returns the intersection of two input sets, optionally retaining duplicates. **Syntax** <Set> Intersect(<Set>, <Set>, <Symbol>) <Set> Intersect(<Set>, <Set>)
IsDate	Returns a Boolean value indicating whether an expression can be converted to a date.. **Syntax** <Logical Expression> IsDate(<Value>)
IsEmpty	Determines if an expression evaluates to the empty cell value. **Syntax** <Logical Expression> IsEmpty(<String>) <Logical Expression> IsEmpty(<Numeric Expression>)

Item	Returns a member from the tuple specified in <Tuple>. The member to be returned is specified by the zero-based position of the member in the set in <Index>. **Syntax** <Member> <Tuple>.Item(<Numeric Expression>)
Item	Returns a tuple from the set specified in <Set>. The tuple to be returned is specified by the zero-based position of the tuple in the set in <Index>. **Syntax** <Member> <Set>.Item(<Numeric Expression>)
Item	Returns a tuple from the set specified in <Set>. The tuple to be returned is specified by the member name (or names) in <String>. **Syntax** <Set>.Item(<String> [, ...])
LCase	Returns a String that has been converted to lowercase. **Syntax** <String> LCase(<String>)
LTrim	Returns a Variant (String) containing a copy of a specified string without leading spaces. **Syntax** <String> LTrim(<String>)
Lag	Returns a member further along the specified member's dimension. **Syntax** <Member> <Member>.Lag(<Numeric Expression>)
LastChild	Returns the last child of a member. **Syntax** <Member>.LastChild
LastPeriods	Returns a set of members prior to and including a specified member. **Syntax** <Set> LastPeriods(<Numeric Expression>) <Set> LastPeriods(<Numeric Expression>, <Member>)
LastSibling	Returns the last child of the parent of a member.

	Syntax <Member>.LastSibling
Lead	Returns a member further along the specified member's dimension. **Syntax** <Member> <Member>.Lead(<Numeric Expression>)
Left	Returns a specified number of characters from the left side of a string. **Syntax** <String> Left(<String>, <Integer>)
Len	Returns the number of characters in a string **Syntax** <Numeric Expression> Len(<String>)
Level	Returns a member's level. **Syntax** <Member>.Level
Levels	Returns the level whose position in a hierarchy is specified by a numeric expression. **Syntax** <Level> <Hierarchy>.Levels(<Numeric Expression>)
Levels	Returns the level whose name is specified by a string expression. **Syntax** <Level> <Hierarchy>.Levels(<String>)
Levels	Returns the level whose name is specified by a string expression. **Syntax** <Level> Levels(<String>)
LinRegIntercept	Calculates the linear regression of a set and returns the value of b in the regression line y = ax + b. **Syntax** <Numeric Expression> LinRegIntercept(<Set>, <Numeric Expression>) <Numeric Expression> LinRegIntercept(<Set>, <Numeric Expression>, <Numeric Expression>)
LinRegPoint	Calculates the linear regression of a set and returns the value of y in

	the regression line y = ax + b. **Syntax** <Numeric Expression> LinRegPoint(<Numeric Expression>, <Set>, <Numeric Expression>) <Numeric Expression> LinRegPoint(<Numeric Expression>, <Set>, <Numeric Expression>, <Numeric Expression>)
LinRegR2	Calculates the linear regression of a set and returns R2 (the coefficient of determination). **Syntax** <Numeric Expression> LinRegR2(<Set>, <Numeric Expression>) <Numeric Expression> LinRegR2(<Set>, <Numeric Expression>, <Numeric Expression>)
LinRegSlope	Calculates the linear regression of a set and returns the value of a in the regression line y = ax + b. **Syntax** <Numeric Expression> LinRegSlope(<Set>, <Numeric Expression>) <Numeric Expression> LinRegSlope(<Set>, <Numeric Expression>, <Numeric Expression>)
LinRegVariance	Calculates the linear regression of a set and returns the variance associated with the regression line y = ax + b. **Syntax** <Numeric Expression> LinRegVariance(<Set>, <Numeric Expression>) <Numeric Expression> LinRegVariance(<Set>, <Numeric Expression>, <Numeric Expression>)
Log	Returns a Double specifying the natural logarithm of a number. **Syntax** <Numeric Expression> Log(<Numeric Expression>)
Log10	Returns the base-10 logarithm of a number. **Syntax** <Numeric Expression> Log10(<Numeric Expression>)
MIRR	Returns a Double specifying the modified internal rate of return for a series of periodic cash flows (payments and receipts). **Syntax** <Numeric Expression> MIRR(<Array>, <Numeric Expression>, <Numeric Expression>)

Max	Returns the maximum value of a numeric expression evaluated over a set. **Syntax** <Numeric Expression> Max(<Set>) <Numeric Expression> Max(<Set>, <Numeric Expression>)
Median	Returns the median value of a numeric expression evaluated over a set. **Syntax** <Numeric Expression> Median(<Set>) <Numeric Expression> Median(<Set>, <Numeric Expression>)
Members	Returns the set of members in a dimension. **Syntax** <Dimension>.Members
Members	Returns the set of members in a hierarchy. **Syntax** <Hierarchy>.Members
Members	Returns the set of members in a level. **Syntax** <Level>.Members
Members	Returns the member whose name is specified by a string expression. **Syntax** <Member> Members(<String>)
Mid	Returns a specified number of characters from a string. **Syntax** <String> Mid(<String>, <Integer>, <Integer>)
Mid	Returns a specified number of characters from a string. **Syntax** <String> Mid(<String>, <Integer>)
Min	Returns the minimum value of a numeric expression evaluated over a set. **Syntax** <Numeric Expression> Min(<Set>)

	<Numeric Expression> Min(<Set>, <Numeric Expression>)
Minute	Returns a Variant (Integer) specifying a whole number between 0 and 59, inclusive, representing the minute of the hour. **Syntax** <Integer> Minute(<DateTime>)
Month	Returns a Variant (Integer) specifying a whole number between 1 and 12, inclusive, representing the month of the year. **Syntax** <Integer> Month(<DateTime>)
MonthName	Returns a string indicating the specified month. **Syntax** <String> MonthName(<Integer>, <Logical Expression>)
Mtd	A shortcut function for the PeriodsToDate function that specifies the level to be Month. **Syntax** <Set> Mtd() <Set> Mtd(<Member>)
NOT	Returns the negation of a condition. **Syntax** NOT <Logical Expression>
NPV	Returns a Double specifying the net present value of an investment based on a series of periodic cash flows (payments and receipts) and a discount rate. **Syntax** <Numeric Expression> NPV(<Numeric Expression>, <Array>)
NPer	Returns a Double specifying the number of periods for an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> NPer(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Logical Expression>)
Name	Returns the name of a dimension. **Syntax** <Dimension>.Name

Name	Returns the name of a hierarchy. **Syntax** <Hierarchy>.Name
Name	Returns the name of a level. **Syntax** <Level>.Name
Name	Returns the name of a member. **Syntax** <Member>.Name
NextMember	Returns the next member in the level that contains a specified member. **Syntax** <Member>.NextMember
NonEmptyCrossJoin	Returns the cross product of two sets, excluding empty tuples and tuples without associated fact table data. **Syntax** <Set> NonEmptyCrossJoin(<Set>, <Set>)
Now	Returns a Variant (Date) specifying the current date and time according your computer's system date and time. **Syntax** <DateTime> Now()
OR	Returns the disjunction of two conditions. **Syntax** <Logical Expression> OR <Logical Expression>
Oct	Returns a Variant (String) representing the octal value of a number. **Syntax** <String> Oct(<Value>)
OpeningPeriod	Returns the first descendant of a member at a level. **Syntax** <Member> OpeningPeriod() <Member> OpeningPeriod(<Level>) <Member> OpeningPeriod(<Level>, <Member>)

Order	Arranges members of a set, optionally preserving or breaking the hierarchy. **Syntax** <Set> Order(<Set>, <Value>, <Symbol>) <Set> Order(<Set>, <Value>)
Ordinal	Returns the zero-based ordinal value associated with a level. **Syntax** <Level>.Ordinal
PPmt	Returns a Double specifying the principal payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> PPmt(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Logical Expression>)
PPmt	Returns a Double specifying the principal payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> PPmt(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
PPmt	Returns a Double specifying the principal payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> PPmt(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
PV	Returns a Double specifying the present value of an annuity based on periodic, fixed payments to be paid in the future and a fixed interest rate. **Syntax** <Numeric Expression> PV(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Logical Expression>)
ParallelPeriod	Returns a member from a prior period in the same relative position as a specified member.

	Syntax <Member> ParallelPeriod() <Member> ParallelPeriod(<Level>) <Member> ParallelPeriod(<Level>, <Numeric Expression>) <Member> ParallelPeriod(<Level>, <Numeric Expression>, <Member>)
ParamRef	Returns the current value of this parameter. If it is null, returns the default value. **Syntax** <Value> ParamRef(<String>)
Parameter	Returns default value of parameter. **Syntax** <String> Parameter(<String>, <Symbol>, <String>, <String>) <String> Parameter(<String>, <Symbol>, <String>) <Numeric Expression> Parameter(<String>, <Symbol>, <Numeric Expression>, <String>) <Numeric Expression> Parameter(<String>, <Symbol>, <Numeric Expression>) <Member> Parameter(<String>, <Hierarchy>, <Member>, <String>) <Member> Parameter(<String>, <Hierarchy>, <Member>)
Parent	Returns the parent of a member. **Syntax** <Member>.Parent
Percentile	Returns the value of the tuple that is at a given percentile of a set. **Syntax** <Numeric Expression> Percentile(<Set>, <Numeric Expression>, <Numeric Expression>)
PeriodsToDate	Returns a set of periods (members) from a specified level starting with the first period and ending with a specified member. **Syntax** <Set> PeriodsToDate() <Set> PeriodsToDate(<Level>) <Set> PeriodsToDate(<Level>, <Member>)
Pi	Returns the number 3.14159265358979, the mathematical constant pi, accurate to 15 digits. **Syntax**

	<Numeric Expression> Pi()
Pmt	Returns a Double specifying the payment for an annuity based on periodic, fixed payments and a fixed interest rate. **Syntax** <Numeric Expression> Pmt(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Logical Expression>)
Power	Returns the result of a number raised to a power. **Syntax** <Numeric Expression> Power(<Numeric Expression>, <Numeric Expression>)
PrevMember	Returns the previous member in the level that contains a specified member. **Syntax** <Member>.PrevMember
Properties	Returns the value of a member property. **Syntax** <Member>.Properties(<String Expression>)
Qtd	A shortcut function for the PeriodsToDate function that specifies the level to be Quarter. **Syntax** <Set> Qtd() <Set> Qtd(<Member>)
RTrim	Returns a Variant (String) containing a copy of a specified string without trailing spaces. **Syntax** <String> RTrim(<String>)
Radians	Converts degrees to radians. **Syntax** <Numeric Expression> Radians(<Numeric Expression>)
Rank	Returns the one-based rank of a tuple in a set. **Syntax** <Integer> Rank(<Tuple>, <Set>) <Integer> Rank(<Tuple>, <Set>, <Numeric Expression>)

	<Integer> Rank(<Member>, <Set>) <Integer> Rank(<Member>, <Set>, <Numeric Expression>)
Rate	Returns a Double specifying the interest rate per period for an annuity. **Syntax** <Numeric Expression> Rate(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Logical Expression>, <Numeric Expression>)
Rate	Returns a Double specifying the interest rate per period for an annuity. **Syntax** <Numeric Expression> Rate(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Logical Expression>)
Rate	Returns a Double specifying the interest rate per period for an annuity. **Syntax** <Numeric Expression> Rate(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
Rate	Returns a Double specifying the interest rate per period for an annuity. **Syntax** <Numeric Expression> Rate(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
Replace	Returns a string in which a specified substring has been replaced with another substring a specified number of times. **Syntax** <String> Replace(<String>, <String>, <String>, <Integer>, <Integer>, <Integer>)
Replace	Returns a string in which a specified substring has been replaced with another substring a specified number of times. **Syntax** <String> Replace(<String>, <String>, <String>, <Integer>, <Integer>)
Replace	Returns a string in which a specified substring has been replaced with another substring a specified number of times. **Syntax** <String> Replace(<String>, <String>, <String>, <Integer>)
Replace	Returns a string in which a specified substring has been replaced with another substring once.

	Syntax <String> Replace(<String>, <String>, <String>)
Right	Returns a Variant (String) containing a specified number of characters from the right side of a string. **Syntax** <String> Right(<String>, <Integer>)
Round	Returns a number rounded to a specified number of decimal places. **Syntax** <Numeric Expression> Round(<Numeric Expression>, <Integer>)
Round	Returns a number rounded to a specified number of decimal places. **Syntax** <Numeric Expression> Round(<Numeric Expression>)
SLN	Returns a Double specifying the straight-line depreciation of an asset for a single period. **Syntax** <Numeric Expression> SLN(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
SYD	Returns a Double specifying the sum-of-years' digits depreciation of an asset for a specified period. **Syntax** <Numeric Expression> SYD(<Numeric Expression>, <Numeric Expression>, <Numeric Expression>, <Numeric Expression>)
Second	Returns a Variant (Integer) specifying a whole number between 0 and 59, inclusive, representing the second of the minute. **Syntax** <Integer> Second(<DateTime>)
SetToStr	Constructs a string from a set. **Syntax** <String> SetToStr(<Set>)
Sgn	Returns a Variant (Integer) indicating the sign of a number. **Syntax** <Integer> Sgn(<Numeric Expression>)

Siblings	Returns the siblings of a specified member, including the member itself. **Syntax** <Member>.Siblings
Sin	Returns a Double specifying the sine of an angle. **Syntax** <Numeric Expression> Sin(<Numeric Expression>)
Sinh	Returns the hyperbolic sine of a number. Syntax <Numeric Expression> Sinh(<Numeric Expression>)
Space	Returns a Variant (String) consisting of the specified number of spaces. **Syntax** <String> Space(<Integer>)
Sqr	Returns a Double specifying the square root of a number. **Syntax** <Numeric Expression> Sqr(<Numeric Expression>)
SqrtPi	Returns the square root of (number * pi). **Syntax** <Numeric Expression> SqrtPi(<Numeric Expression>)
Stddev	Alias for Stdev. **Syntax** <Numeric Expression> Stddev(<Set>) <Numeric Expression> Stddev(<Set>, <Numeric Expression>)
StddevP	Alias for StdevP. **Syntax** <Numeric Expression> StddevP(<Set>) <Numeric Expression> StddevP(<Set>, <Numeric Expression>)
Stdev	Returns the standard deviation of a numeric expression evaluated over a set (unbiased). **Syntax** <Numeric Expression> Stdev(<Set>) <Numeric Expression> Stdev(<Set>, <Numeric Expression>)
StdevP	Returns the standard deviation of a numeric expression evaluated over

	a set (biased). **Syntax** <Numeric Expression> StdevP(<Set>) <Numeric Expression> StdevP(<Set>, <Numeric Expression>)
Str	Returns a Variant (String) representation of a number. **Syntax** <String> Str(<Value>)
StrComp	Returns a Variant (Integer) indicating the result of a string comparison. **Syntax** <Integer> StrComp(<String>, <String>, <Integer>)
StrComp	Returns a Variant (Integer) indicating the result of a string comparison. **Syntax** <Integer> StrComp(<String>, <String>)
StrReverse	Returns a string in which the character order of a specified string is reversed. **Syntax** <String> StrReverse(<String>)
StrToMember	Returns a member from a unique name String in MDX format. **Syntax** <Member> StrToMember(<String>)
StrToSet	Constructs a set from a string expression. **Syntax** <Set> StrToSet(<String>[, <Dimension>...])
StrToTuple	Constructs a tuple from a string. **Syntax** <Tuple> StrToTuple(<String>)
String	Constructs a string containing <number> of the same <character>. **Syntax** <String> String(<Integer> number, <Integer> character)
StripCalculatedMembers	Removes calculated members from a set.

	Syntax <Set> StripCalculatedMembers(<Set>)
Subset	Returns a subset of elements from a set. **Syntax** <Set> Subset(<Set>, <Numeric Expression>) <Set> Subset(<Set>, <Numeric Expression>, <Numeric Expression>)
Sum	Returns the sum of a numeric expression evaluated over a set. **Syntax** <Numeric Expression> Sum(<Set>) <Numeric Expression> Sum(<Set>, <Numeric Expression>)
Tail	Returns a subset from the end of a set. **Syntax** <Set> Tail(<Set>) <Set> Tail(<Set>, <Numeric Expression>)
Tan	Returns a Double specifying the tangent of an angle. **Syntax** <Numeric Expression> Tan(<Numeric Expression>)
Tanh	Returns the hyperbolic tangent of a number. **Syntax** <Numeric Expression> Tanh(<Numeric Expression>)
ThirdQ	Returns the 3rd quartile value of a numeric expression evaluated over a set. **Syntax** <Numeric Expression> ThirdQ(<Set>) <Numeric Expression> ThirdQ(<Set>, <Numeric Expression>)
Time	Returns a Variant (Date) indicating the current system time. **Syntax** <DateTime> Time()
TimeSerial	Returns a Variant (Date) containing the time for a specific hour, minute, and second. **Syntax** <DateTime> TimeSerial(<Integer>, <Integer>, <Integer>)

TimeValue	Returns a Variant (Date) containing the time. **Syntax** <DateTime> TimeValue(<DateTime>)
Timer	Returns a Single representing the number of seconds elapsed since midnight. **Syntax** <Numeric Expression> Timer()
ToggleDrillState	Toggles the drill state of members. This function is a combination of DrillupMember and DrilldownMember. **Syntax** <Set> ToggleDrillState(<Set>, <Set>) <Set> ToggleDrillState(<Set>, <Set>, <Symbol>)
TopCount	Returns a specified number of items from the top of a set, optionally ordering the set first. **Syntax** <Set> TopCount(<Set>, <Numeric Expression>, <Numeric Expression>) <Set> TopCount(<Set>, <Numeric Expression>)
TopPercent	Sorts a set and returns the top N elements whose cumulative total is at least a specified percentage. **Syntax** <Set> TopPercent(<Set>, <Numeric Expression>, <Numeric Expression>)
TopSum	Sorts a set and returns the top N elements whose cumulative total is at least a specified value. **Syntax** <Set> TopSum(<Set>, <Numeric Expression>, <Numeric Expression>)
Trim	Returns a Variant (String) containing a copy of a specified string without leading and trailing spaces. **Syntax** <String> Trim(<String>)
TupleToStr	Constructs a string from a tuple. **Syntax**

	<String> TupleToStr(<Tuple>)
TypeName	Returns a String that provides information about a variable. **Syntax** <String> TypeName(<Value>)
UCase	Returns a string that has been converted to uppercase **Syntax** <String> UCase(<String>)
Union	Returns the union of two sets, optionally retaining duplicates. **Syntax** <Set> Union(<Set>, <Set>) <Set> Union(<Set>, <Set>, <Symbol>)
UniqueName	Returns the unique name of a dimension. **Syntax** <Dimension>.UniqueName
UniqueName	Returns the unique name of a hierarchy. **Syntax** <Hierarchy>.UniqueName
UniqueName	Returns the unique name of a level. **Syntax** <Level>.UniqueName
UniqueName	Returns the unique name of a member. **Syntax** <Member>.UniqueName
Unorder	Removes any enforced ordering from a specified set. **Syntax** <Set> Unorder(<Set>)
Val	Returns the numbers contained in a string as a numeric value of appropriate type. **Syntax** <Numeric Expression> Val(<String>)
ValidMeasure	Returns a valid measure in a virtual cube by forcing inapplicable dimensions to their top level.

	Syntax <Numeric Expression> ValidMeasure(<Tuple>)
Value	Returns the value of a measure. **Syntax** <Member>.Value
Var	Returns the variance of a numeric expression evaluated over a set (unbiased). **Syntax** <Numeric Expression> Var(<Set>) <Numeric Expression> Var(<Set>, <Numeric Expression>)
VarP	Returns the variance of a numeric expression evaluated over a set (biased). **Syntax** <Numeric Expression> VarP(<Set>) <Numeric Expression> VarP(<Set>, <Numeric Expression>)
Variance	Alias for Var. **Syntax** <Numeric Expression> Variance(<Set>) <Numeric Expression> Variance(<Set>, <Numeric Expression>)
VarianceP	Alias for VarP. **Syntax** <Numeric Expression> VarianceP(<Set>) <Numeric Expression> VarianceP(<Set>, <Numeric Expression>)
VisualTotals	Dynamically totals child members specified in a set using a pattern for the total label in the result set. **Syntax** <Set> VisualTotals(<Set>) <Set> VisualTotals(<Set>, <String>)
Weekday	Returns a Variant (Integer) containing a whole number representing the day of the week. **Syntax** <Integer> Weekday(<DateTime>, <Integer>)
Weekday	Returns a Variant (Integer) containing a whole number representing the day of the week.

	Syntax <Integer> Weekday(<DateTime>)
WeekdayName	Returns a string indicating the specified day of the week. **Syntax** <String> WeekdayName(<Integer>, <Logical Expression>, <Integer>)
Wtd	A shortcut function for the PeriodsToDate function that specifies the level to be Week. **Syntax** <Set> Wtd() <Set> Wtd(<Member>)
XOR	Returns whether two conditions are mutually exclusive. **Syntax** <Logical Expression> XOR <Logical Expression>
Year	Returns a Variant (Integer) containing a whole number representing the year. **Syntax** <Integer> Year(<DateTime>)
Ytd	A shortcut function for the PeriodsToDate function that specifies the level to be Year. **Syntax** <Set> Ytd() <Set> Ytd(<Member>)
_CaseMatch	Evaluates various expressions, and returns the corresponding expression for the first which matches a particular value. **Syntax** Case <Expression> When <Expression> Then <Expression> [...] [Else <Expression>] End
_CaseTest	Evaluates various conditions, and returns the corresponding expression for the first which evaluates to true. **Syntax** Case When <Logical Expression> Then <Expression> [...] [Else <Expression>] End
{}	Brace operator constructs a set.

	Syntax {<Member> [, <Member>...]}
||	Concatenates two strings. **Syntax** <String> || <String>

Visual Basic for Applications (VBA) Function List

following table describes the functions in the Visual Basic for Applications (VBA) specification, which are implicitly part of the MDX language specification.

Some of the functions are not implemented in mondrian, but are included for completeness. The 'Mondrian version/priority' column indicates which functions are implemented in mondrian, and if not, priority of the development team for adding them. Some functions, such as Beep, will never be implemented in Mondrian MDX.

The MDX language implemented by mondrian, including a list of set of functions implemented, is described in the MDX specification.

Name	Description	Mondrian version / priority
Abs	Returns a value of the same type that is passed to it specifying the absolute value of a number. Syntax Abs(number) The required number argument can be any valid numeric expression. If number contains Null, Null is returned; if it is an uninitialized variable, zero is returned. Remarks The absolute value of a number is its unsigned magnitude. For example, ABS(-1) and ABS(1) both return 1.	1
Add		-
AppActivate		-
Array	Returns a Variant containing an array. Syntax Array(arglist) The required arglist argument is a comma-delimited list of values that are assigned to the elements of the array contained within the Variant. If no arguments are specified, an array of zero length is created. Remarks	Not applicable - mondrian has no array data type

	The notation used to refer to an element of an array consists of the variable name followed by parentheses containing an index number indicating the desired element. In the following example, the first statement creates a variable named A as a Variant. The second statement assigns an array to variable A . The last statement assigns the value contained in the second array element to another variable. Dim A As Variant A = Array(10,20,30) B = A(2) The lower bound of an array created using the Array function is determined by the lower bound specified with the Option Base statement, unless Array is qualified with the name of the type library (for example VBA.Array). If qualified with the type-library name, Array is unaffected by Option Base. Note A Variant that is not declared as an array can still contain an array. A Variant variable can contain an array of any type, except fixed-length strings and user-defined types. Although a Variant containing an array is conceptually different from an array whose elements are of type Variant, the array elements are accessed in the same way.	
Asc	Returns an Integer representing the character code corresponding to the first letter in a string. Syntax Asc(string) The required string argument is any valid string expression. If the string contains no characters, a run-time error occurs. Remarks The range for returns is 0 255 on non-DBCS systems, but 32768 32767 on DBCS systems. Note The AscB function is used with byte data contained in a string. Instead of returning the character code for the first character, AscB returns the first byte. The AscW function returns the Unicode character code except on platforms where Unicode is not supported, in which case, the behavior is identical to the Asc function.	1
AscB	See Asc	N/A
AscW	See Asc	1
Atn	Returns a Double specifying the arctangent of a number. Syntax	1

	Atn(number) The required number argument is a Double or any valid numeric expression. Remarks The Atn function takes the ratio of two sides of a right triangle (number) and returns the corresponding angle in radians. The ratio is the length of the side opposite the angle divided by the length of the side adjacent to the angle. The range of the result is -pi/2 to pi/2 radians. To convert degrees to radians, multiply degrees by pi/180. To convert radians to degrees, multiply radians by 180/pi. Note Atn is the inverse trigonometric function of Tan, which takes an angle as its argument and returns the ratio of two sides of a right triangle. Do not confuse Atn with the cotangent, which is the simple inverse of a tangent (1/tangent).	
Beep		Not applicable in server
Calendar		-
CallByName	Executes a method of an object, or sets or returns a property of an object. Syntax CallByName(object, procname, calltype,[args()]) The CallByName function syntax has these named arguments: Part Description object Required; Variant (Object). The name of the object on which the function will be executed. procname Required; Variant (String). A string expression containing the name of a property or method of the object. calltype Required; Constant. A constant of type vbCallType representing the type of procedure being called. args() Optional: Variant (Array). Remarks The CallByName function is used to get or set a property, or invoke a method at run time using a string name. In the following example, the first line uses CallByName to set the MousePointer property of a text box, the second line gets the value of the MousePointer property, and the third line	-

	invokes the Move method to move the text box: CallByName Text1, "MousePointer", vbLet, vbCrosshair Result = CallByName (Text1, "MousePointer", vbGet) CallByName Text1, "Move", vbMethod, 100, 100	
CBool	Returns an expression that has been converted to a Variant of subtype Boolean. CBool(expression) The expression argument is any valid expression. If expression is zero, False is returned; otherwise, True is returned. If expression can't be interpreted as a numeric value, a run-time error occurs. The following example uses the CBool function to convert an expression to a Boolean. If the expression evaluates to a nonzero value, CBool returns True; otherwise, it returns False.	2
CByte	Returns an expression that has been converted to a Variant of subtype Byte. CByte(expression) The expression argument is any valid expression. In general, you can document your code using the subtype conversion functions to show that the result of some operation should be expressed as a particular data type rather than the default data type. For example, use CByte to force byte arithmetic in cases where currency, single-precision, double-precision, or integer arithmetic normally would occur. Use the CByte function to provide internationally aware conversions from any other data type to a Byte subtype. For example, different decimal separators are properly recognized depending on the locale setting of your system, as are different thousand separators. If expression lies outside the acceptable range for the byte subtype, an error occurs.	N/A; mondrian has no byte datatype
CCur	Returns an expression that has been converted to a Variant of subtype Currency. CCur(expression) The expression argument is any valid expression. In general, you can document your code using the subtype conversion functions to show that the result of some	-

	operation should be expressed as a particular data type rather than the default data type. For example, use CCur to force currency arithmetic in cases where integer arithmetic normally would occur. You should use the CCur function to provide internationally aware conversions from any other data type to a Currency subtype. For example, different decimal separators and thousands separators are properly recognized depending on the locale setting of your system.	
CDate	Returns an expression that has been converted to a Variant of subtype Date. CDate(date) The date argument is any valid date expression. Use the IsDate function to determine if date can be converted to a date or time. CDate recognizes date literals and time literals as well as some numbers that fall within the range of acceptable dates. When converting a number to a date, the whole number portion is converted to a date. Any fractional part of the number is converted to a time of day, starting at midnight. CDate recognizes date formats according to the locale setting of your system. The correct order of day, month, and year may not be determined if it is provided in a format other than one of the recognized date settings. In addition, a long date format is not recognized if it also contains the day-of-the-week string.	1
CDbl	Returns an expression that has been converted to a Variant of subtype Double. CDbl(expression) The expression argument is any valid expression. In general, you can document your code using the subtype conversion functions to show that the result of some operation should be expressed as a particular data type rather than the default data type. For example, use CDbl or CSng to force double-precision or single-precision arithmetic in cases where currency or integer arithmetic normally would occur. Use the CDbl function to provide internationally aware conversions from any other data type to a Double subtype. For example, different decimal separators and thousands separators are properly recognized depending on the locale setting of your system.	2
CDec		

ChDir		
ChDrive		
Choose		
Chr	Returns a String containing the character associated with the specified character code. Syntax Chr(charcode) The required charcode argument is a Long that identifies a character. Remarks Numbers from 0 31 are the same as standard, nonprintable ASCII codes. For example, Chr(10) returns a linefeed character. The normal range for charcode is 0 255. However, on DBCS systems, the actual range for charcode is -32768 to 65535. Note The ChrB function is used with byte data contained in a String. Instead of returning a character, which may be one or two bytes, ChrB always returns a single byte. The ChrW function returns a String containing the Unicode character except on platforms where Unicode is not supported, in which case, the behavior is identical to the Chr function.	1
ChrB	See Chr.	-
ChrW	See Chr.	1
CInt	Returns an expression that has been converted to a Variant of subtype Integer. CInt(expression) The expression argument is any valid expression. In general, you can document your code using the subtype conversion functions to show that the result of some operation should be expressed as a particular data type rather than the default data type. For example, use CInt or CLng to force integer arithmetic in cases where currency, single-precision, or double-precision arithmetic normally would occur. Use the CInt function to provide internationally aware conversions from any other data type to an Integer subtype. For example, different decimal separators are properly recognized depending on the locale setting of your system, as are different thousand separators. If expression lies outside the acceptable range for the Integer subtype, an error occurs.	2

	The following example uses the CInt function to convert a value to an Integer: Dim MyDouble, MyInt MyDouble = 2345.5678 ' MyDouble is a Double. MyInt = CInt(MyDouble) ' MyInt contains 2346. Note. CInt differs from the Fix and Int functions, which truncate, rather than round, the fractional part of a number. When the fractional part is exactly 0.5, the CInt function always rounds it to the nearest even number. For example, 0.5 rounds to 0, and 1.5 rounds to 2.	
Clear		
CLng	Returns an expression that has been converted to a Variant of subtype Long. CLng(expression) The expression argument is any valid expression. In general, you can document your code using the subtype conversion functions to show that the result of some operation should be expressed as a particular data type rather than the default data type. For example, use CInt or CLng to force integer arithmetic in cases where currency, single-precision, or double-precision arithmetic normally would occur. Use the CLng function to provide internationally aware conversions from any other data type to a Long subtype. For example, different decimal separators are properly recognized depending on the locale setting of your system, as are different thousand separators. If expression lies outside the acceptable range for the Long subtype, an error occurs. The following example uses the CLng function to convert a value to a Long: Dim MyVal1, MyVal2, MyLong1, MyLong2 MyVal1 = 25427.45: MyVal2 = 25427.55 ' MyVal1, MyVal2 are Doubles. MyLong1 = CLng(MyVal1) ' MyLong1 contains 25427. MyLong2 = CLng(MyVal2) ' MyLong2 contains 25428. Note. CLng differs from the Fix and Int functions, which truncate, rather than round, the fractional part of a number. When the fractional part is exactly 0.5, the CLng function always rounds it to the nearest even number. For example, 0.5 rounds to 0, and 1.5 rounds to 2.	2

Command	Returns the argument portion of the command line used to launch Microsoft Visual Basic or an executable program developed with Visual Basic. Syntax Command Remarks When Visual Basic is launched from the command line, any portion of the command line that follows /cmd is passed to the program as the command-line argument. In the following example, cmdlineargs represents the argument information returned by the Command function. VB /cmd cmdlineargs For applications developed with Visual Basic and compiled to an .exe file, Command returns any arguments that appear after the name of the application on the command line. For example: MyApp cmdlineargs To find how command line arguments can be changed in the user interface of the application you're using, search Help for "command line arguments."	-
Cos	Returns a Double specifying the cosine of an angle. Syntax Cos(number) The required number argument is a Double or any valid numeric expression that expresses an angle in radians. Remarks The Cos function takes an angle and returns the ratio of two sides of a right triangle. The ratio is the length of the side adjacent to the angle divided by the length of the hypotenuse. The result lies in the range -1 to 1. To convert degrees to radians, multiply degrees by pi/180. To convert radians to degrees, multiply radians by 180/pi.	1
Count		?
CreateObject	Creates and returns a reference to an ActiveX object.	-

	Syntax CreateObject(class,[servername]) The CreateObject function syntax has these parts: Part Description class Required; Variant (String). The application name and class of the object to create. servername Optional; Variant (String). The name of the network server where the object will be created. If servername is an empty string (""), the local machine is used. The class argument uses the syntax appname.objecttype and has these parts: Part Description appname Required; Variant (String). The name of the application providing the object. objecttype Required; Variant (String). The type or class of object to create. Remarks Every application that supports Automation provides at least one type of object. For example, a word processing application may provide an Application object, a Document object, and a Toolbar object.	
CSng		?
CStr		?
CurDir	Returns a Variant (String) representing the current path. Syntax CurDir[(drive)] The optional drive argument is a string expression that specifies an existing drive. If no drive is specified or if drive is a zero-length string (""), CurDir returns the path for the current drive.	
Cvar		
CVDate		
CVErr	Returns a Variant of subtype Error containing an error number specified by the user. Syntax CVErr(errornumber) The required errornumber argument is any valid error number.	-

	Remarks Use the CVErr function to create user-defined errors in user-created procedures. For example, if you create a function that accepts several arguments and normally returns a string, you can have your function evaluate the input arguments to ensure they are within acceptable range. If they are not, it is likely your function will not return what you expect. In this event, CVErr allows you to return an error number that tells you what action to take. Note that implicit conversion of an Error is not allowed. For example, you can't directly assign the return value of CVErr to a variable that is not a Variant. However, you can perform an explicit conversion (using CInt, CDbl, and so on) of the value returned by CVErr and assign that to a variable of the appropriate data type.	
Date	Returns a Variant (Date) containing the current system date. Syntax Date Remarks To set the system date, use the Date statement. Date, and if the calendar is Gregorian, Date$ behavior is unchanged by the Calendar property setting. If the calendar is Hijri, Date$ returns a 10-character string of the form mm-dd-yyyy, where mm (01-12), dd (01-30) and yyyy (1400-1523) are the Hijri month, day and year. The equivalent Gregorian range is Jan 1, 1980 through Dec 31, 2099.	1
DateAdd	Returns a Variant (Date) containing a date to which a specified time interval has been added. Syntax DateAdd(interval, number, date) The DateAdd function syntax has these named arguments: Part Description interval Required. String expression that is the interval of time you want to add. number Required. Numeric expression that is the number of intervals you want to add. It can be positive (to get dates in the future) or negative (to get dates in the past). date Required. Variant (Date) or literal representing date to which the interval is added. Settings	1

	The interval argument has these settings: Setting Description yyyy Year q Quarter m Month y Day of year d Day w Weekday ww Week h Hour n Minute s Second Remarks You can use the DateAdd function to add or subtract a specified time interval from a date. For example, you can use DateAdd to calculate a date 30 days from today or a time 45 minutes from now. To add days to date, you can use Day of Year ("y"), Day ("d"), or Weekday ("w"). The DateAdd function won't return an invalid date. The following example adds one month to January 31: DateAdd("m", 1, "31-Jan-95") In this case, DateAdd returns 28-Feb-95, not 31-Feb-95. If date is 31-Jan-96, it returns 29-Feb-96 because 1996 is a leap year. If the calculated date would precede the year 100 (that is, you subtract more years than are in date), an error occurs. If number isn't a Long value, it is rounded to the nearest whole number before being evaluated. Note The format of the return value for DateAdd is determined by Control Panel settings, not by the format that is passed in date argument. Note For date, if the Calendar property setting is Gregorian, the supplied date must be Gregorian. If the calendar is Hijri, the supplied date must be Hijri. If month values are names, the name must be consistent with the current Calendar property setting. To minimize the possibility of month names conflicting with the current Calendar property setting, enter numeric month values (Short Date format).	
DateDiff	Returns a Variant (Long) specifying the number of time intervals between two specified dates. Syntax	1

DateDiff(interval, date1, date2[, firstdayofweek[, firstweekofyear]])

The DateDiff function syntax has these named arguments:

Part Description
interval Required. String expression that is the interval of time you use to calculate the difference between date1 and date2.
date1, date2 Required; Variant (Date). Two dates you want to use in the calculation.
firstdayofweek Optional. A constant that specifies the first day of the week. If not specified, Sunday is assumed.
firstweekofyear Optional. A constant that specifies the first week of the year. If not specified, the first week is assumed to be the week in which January 1 occurs.

Settings

The interval argument has these settings:

Setting Description
yyyy Year
q Quarter
m Month
y Day of year
d Day
w Weekday
ww Week
h Hour
n Minute
s Second

The firstdayofweek argument has these settings:

Constant Value Description
vbUseSystem 0 Use the NLS API setting.
vbSunday 1 Sunday (default)
vbMonday 2 Monday
vbTuesday 3 Tuesday
vbWednesday 4 Wednesday
vbThursday 5 Thursday
vbFriday 6 Friday
vbSaturday 7 Saturday

Constant Value Description
vbUseSystem 0 Use the NLS API setting.
vbFirstJan1 1 Start with week in which January 1 occurs (default).
vbFirstFourDays 2 Start with the first week that has at least four days in the new year.
vbFirstFullWeek 3 Start with first full week of the year.

	Remarks You can use the DateDiff function to determine how many specified time intervals exist between two dates. For example, you might use DateDiff to calculate the number of days between two dates, or the number of weeks between today and the end of the year. To calculate the number of days between date1 and date2, you can use either Day of year ("y") or Day ("d"). When interval is Weekday ("w"), DateDiff returns the number of weeks between the two dates. If date1 falls on a Monday, DateDiff counts the number of Mondays until date2. It counts date2 but not date1. If interval is Week ("ww"), however, the DateDiff function returns the number of calendar weeks between the two dates. It counts the number of Sundays between date1 and date2. DateDiff counts date2 if it falls on a Sunday; but it doesn't count date1, even if it does fall on a Sunday. If date1 refers to a later point in time than date2, the DateDiff function returns a negative number. The firstdayofweek argument affects calculations that use the "w" and "ww" interval symbols. If date1 or date2 is a date literal, the specified year becomes a permanent part of that date. However, if date1 or date2 is enclosed in double quotation marks (" "), and you omit the year, the current year is inserted in your code each time the date1 or date2 expression is evaluated. This makes it possible to write code that can be used in different years. When comparing December 31 to January 1 of the immediately succeeding year, DateDiff for Year ("yyyy") returns 1 even though only a day has elapsed. Note For date1 and date2, if the Calendar property setting is Gregorian, the supplied date must be Gregorian. If the calendar is Hijri, the supplied date must be Hijri.	
DatePart	Returns a Variant (Integer) containing the specified part of a given date. Syntax DatePart(interval, date[,firstdayofweek[, firstweekofyear]]) The DatePart function syntax has these named arguments: Part Description interval Required. String expression that is the interval of time	1

	you want to return. date Required. Variant (Date) value that you want to evaluate. firstdayofweek Optional. A constant that specifies the first day of the week. If not specified, Sunday is assumed. firstweekofyear Optional. A constant that specifies the first week of the year. If not specified, the first week is assumed to be the week in which January 1 occurs. Settings The interval argument has these settings: Setting Description yyyy Year q Quarter m Month y Day of year d Day w Weekday ww Week h Hour n Minute s Second The firstdayofweek argument has these settings: Constant Value Description vbUseSystem 0 Use the NLS API setting. vbSunday 1 Sunday (default) vbMonday 2 Monday vbTuesday 3 Tuesday vbWednesday 4 Wednesday vbThursday 5 Thursday vbFriday 6 Friday vbSaturday 7 Saturday The firstweekofyear argument has these settings: Constant Value Description vbUseSystem 0 Use the NLS API setting. vbFirstJan1 1 Start with week in which January 1 occurs (default). vbFirstFourDays 2 Start with the first week that has at least four days in the new year. vbFirstFullWeek 3 Start with first full week of the year. Remarks You can use the DatePart function to evaluate a date and return a specific interval of time. For example, you might use DatePart to calculate the day of the week or the current hour.	

	The firstdayofweek argument affects calculations that use the "w" and "ww" interval symbols. If date is a date literal, the specified year becomes a permanent part of that date. However, if date is enclosed in double quotation marks (" "), and you omit the year, the current year is inserted in your code each time the date expression is evaluated. This makes it possible to write code that can be used in different years. Note For date, if the Calendar property setting is Gregorian, the supplied date must be Gregorian. If the calendar is Hijri, the supplied date must be Hijri. The returned date part is in the time period units of the current Arabic calendar. For example, if the current calendar is Hijri and the date part to be returned is the year, the year value is a Hijri year.	
DateSerial	Returns a Variant (Date) for a specified year, month, and day. Syntax DateSerial(year, month, day) The DateSerial function syntax has these named arguments: Part Description year Required; Integer. Number between 100 and 9999, inclusive, or a numeric expression. month Required; Integer. Any numeric expression. day Required; Integer. Any numeric expression. Remarks To specify a date, such as December 31, 1991, the range of numbers for each DateSerial argument should be in the accepted range for the unit; that is, 131 for days and 112 for months. However, you can also specify relative dates for each argument using any numeric expression that represents some number of days, months, or years before or after a certain date. The following example uses numeric expressions instead of absolute date numbers. Here the DateSerial function returns a date that is the day before the first day (1 - 1), two months before August (8 - 2), 10 years before 1990 (1990 - 10); in other words, May 31, 1980.	1

	DateSerial(1990 - 10, 8 - 2, 1 - 1) Under Windows 98 or Windows 2000, two digit years for the year argument are interpreted based on user-defined machine settings. The default settings are that values between 0 and 29, inclusive, are interpreted as the years 20002029. The default values between 30 and 99 are interpreted as the years 19301999. For all other year arguments, use a four-digit year (for example, 1800). Earlier versions of Windows interpret two-digit years based on the defaults described above. To be sure the function returns the proper value, use a four-digit year. When any argument exceeds the accepted range for that argument, it increments to the next larger unit as appropriate. For example, if you specify 35 days, it is evaluated as one month and some number of days, depending on where in the year it is applied. If any single argument is outside the range -32,768 to 32,767, an error occurs. If the date specified by the three arguments falls outside the acceptable range of dates, an error occurs. Note For year, month, and day, if the Calendar property setting is Gregorian, the supplied value is assumed to be Gregorian. If the Calendar property setting is Hijri, the supplied value is assumed to be Hijri. The returned date part is in the time period units of the current Visual Basic calendar. For example, if the current calendar is Hijri and the date part to be returned is the year, the year value is a Hijri year. For the argument year, values between 0 and 99, inclusive, are interpreted as the years 1400-1499. For all other year values, use the complete four-digit year (for example, 1520).	
DateValue	Returns a Variant (Date). Syntax DateValue(date) The required date argument is normally a string expression representing a date from January 1, 100 through December 31, 9999. However, date can also be any expression that can represent a date, a time, or both a date and time, in that range. Remarks If date is a string that includes only numbers separated by valid date separators, DateValue recognizes the order for month, day, and year according to the Short Date format you specified for your system. DateValue also recognizes unambiguous dates that contain month names, either in long	1

	or abbreviated form. For example, in addition to recognizing 12/30/1991 and 12/30/91, DateValue also recognizes December 30, 1991 and Dec 30, 1991. If the year part of date is omitted, DateValue uses the current year from your computer's system date. If the date argument includes time information, DateValue doesn't return it. However, if date includes invalid time information (such as "89:98"), an error occurs. Note For date, if the Calendar property setting is Gregorian, the supplied date must be Gregorian. If the calendar is Hijri, the supplied date must be Hijri. If the supplied date is Hijri, the argument date is a String representing a date from 1/1/100 (Gregorian Aug 2, 718) through 4/3/9666 (Gregorian Dec 31, 9999).	
Day	Returns a Variant (Integer) specifying a whole number between 1 and 31, inclusive, representing the day of the month. Syntax Day(date) The required date argument is any Variant, numeric expression, string expression, or any combination, that can represent a date. If date contains Null, Null is returned. Note If the Calendar property setting is Gregorian, the returned integer represents the Gregorian day of the month for the date argument. If the calendar is Hijri, the returned integer represents the Hijri day of the month for the date argument.	1
DDB	Returns a Double specifying the depreciation of an asset for a specific time period using the double-declining balance method or some other method you specify. Syntax DDB(cost, salvage, life, period[, factor]) The DDB function has these named arguments: Part Description cost Required. Double specifying initial cost of the asset. salvage Required. Double specifying value of the asset at the end of its useful life. life Required. Double specifying length of useful life of the asset. period Required. Double specifying period for which asset depreciation is calculated. factor Optional. Variant specifying rate at which the balance	2

	declines. If omitted, 2 (double-declining method) is assumed. Remarks The double-declining balance method computes depreciation at an accelerated rate. Depreciation is highest in the first period and decreases in successive periods. The life and period arguments must be expressed in the same units. For example, if life is given in months, period must also be given in months. All arguments must be positive numbers. The DDB function uses the following formula to calculate depreciation for a given period: Depreciation / period = ((cost salvage) * factor) / life	
Dir	Returns a String representing the name of a file, directory, or folder that matches a specified pattern or file attribute, or the volume label of a drive. Syntax Dir[(pathname[, attributes])] The Dir function syntax has these parts: Part Description pathname Optional. String expression that specifies a file name may include directory or folder, and drive. A zero-length string ("") is returned if pathname is not found. attributes Optional. Constant or numeric expression, whose sum specifies file attributes. If omitted, returns files that match pathname but have no attributes. Settings The attributes argument settings are: Constant Value Description vbNormal 0 (Default) Specifies files with no attributes. vbReadOnly 1 Specifies read-only files in addition to files with no attributes. vbHidden 2 Specifies hidden files in addition to files with no attributes. VbSystem 4 Specifies system files in addition to files with no attributes. vbVolume 8 Specifies volume label; if any other attributed is specified, vbVolume is ignored. vbDirectory 16 Specifies directories or folders in addition to files with no attributes. Note These constants are specified by Visual Basic for	-

	Applications and can be used anywhere in your code in place of the actual values.. Remarks Dir supports the use of multiple character (*) and single character (?) wildcards to specify multiple files.	
DoEvents	Yields execution so that the operating system can process other events. Syntax DoEvents( ) Remarks The DoEvents function returns an Integer representing the number of open forms in stand-alone versions of Visual Basic, such as Visual Basic, Professional Edition. DoEvents returns zero in all other applications. DoEvents passes control to the operating system. Control is returned after the operating system has finished processing the events in its queue and all keys in the SendKeys queue have been sent. DoEvents is most useful for simple things like allowing a user to cancel a process after it has started, for example a search for a file. For long-running processes, yielding the processor is better accomplished by using a Timer or delegating the task to an ActiveX EXE component.. In the latter case, the task can continue completely independent of your application, and the operating system takes case of multitasking and time slicing. Caution Any time you temporarily yield the processor within an event procedure, make sure the procedure is not executed again from a different part of your code before the first call returns; this could cause unpredictable results. In addition, do not use DoEvents if other applications could possibly interact with your procedure in unforeseen ways during the time you have yielded control.	-
DeleteSetting		
Description		
Environ	Returns the String associated with an operating system environment variable. Syntax Environ({envstring | number}) The Environ function syntax has these named arguments:	-

	Part Description envstring Optional. String expression containing the name of an environment variable. number Optional. Numeric expression corresponding to the numeric order of the environment string in the environment-string table. The number argument can be any numeric expression, but is rounded to a whole number before it is evaluated. Remarks If envstring can't be found in the environment-string table, a zero-length string ("") is returned. Otherwise, Environ returns the text assigned to the specified envstring; that is, the text following the equal sign (=) in the environment-string table for that environment variable. If you specify number, the string occupying that numeric position in the environment-string table is returned. In this case, Environ returns all of the text, including envstring. If there is no environment string in the specified position, Environ returns a zero-length string.	
EOF	Returns an Integer containing the Boolean value True when the end of a file opened for Random or sequential Input has been reached. Syntax EOF(filenumber) The required filenumber argument is an Integer containing any valid file number. Remarks Use EOF to avoid the error generated by attempting to get input past the end of a file. The EOF function returns False until the end of the file has been reached. With files opened for Random or Binary access, EOF returns False until the last executed Get statement is unable to read an entire record. With files opened for Binary access, an attempt to read through the file using the Input function until EOF returns True generates an error. Use the LOF and Loc functions instead of EOF when reading binary files with Input, or use Get when using the EOF function. With files opened for Output, EOF always returns True.	-
Err	Contains information about run-time errors.	

	Remarks The properties of the Err object are set by the generator of an error Visual Basic, an object, or the programmer. The default property of the Err object is Number. Because the default property can be represented by the object name Err, earlier code written using the Err function or Err statement doesn't have to be modified. When a run-time error occurs, the properties of the Err object are filled with information that uniquely identifies the error and information that can be used to handle it. To generate a run-time error in your code, use the Raise method. The Err object's properties are reset to zero or zero-length strings ("") after an Exit Sub, Exit Function, Exit Property or Resume Next statement within an error-handling routine. Using any form of the Resume statement outside of an error-handling routine will not reset the Err object's properties. The Clear method can be used to explicitly reset Err. Use the Raise method, rather than the Error statement, to generate run-time errors for system errors and class modules. Using the Raise method in other code depends on the richness of the information you want to return. The Err object is an intrinsic object with global scope. There is no need to create an instance of it in your code.	
Error	Returns the error message that corresponds to a given error number. Syntax Error[(errornumber)] The optional errornumber argument can be any valid error number. If errornumber is a valid error number, but is not defined, Error returns the string "Application-defined or object-defined error." If errornumber is not valid, an error occurs. If errornumber is omitted, the message corresponding to the most recent run-time error is returned. If no run-time error has occurred, or errornumber is 0, Error returns a zero-length string (""). Remarks Examine the property settings of the Err object to identify the most recent run-time error. The return value of the Error function corresponds to the Description property of the Err object.	-
Exp	Returns a Double specifying e (the base of natural logarithms) raised to a power.	1

	Syntax Exp(number) The required number argument is a Double or any valid numeric expression. Remarks If the value of number exceeds 709.782712893, an error occurs. The constant e is approximately 2.718282. Note The Exp function complements the action of the Log function and is sometimes referred to as the antilogarithm.	
FileAttr	Returns a Long representing the file mode for files opened using the Open statement. Syntax FileAttr(filenumber, returntype) The FileAttr function syntax has these named arguments: Part Description filenumber Required; Integer. Any valid file number. returntype Required; Integer. Number indicating the type of information to return. Specify 1 to return a value indicating the file mode. On 16-bit systems only, specify 2 to retrieve an operating system file handle. Returntype 2 is not supported in 32-bit systems and causes an error. Return Values When the returntype argument is 1, the following return values indicate the file access mode: Mode Value Input 1 Output 2 Random 4 Append 8 Binary 32	-
FileCopy		-
FileDateTime	Returns a Variant (Date) that indicates the date and time when a file was created or last modified. Syntax FileDateTime(pathname) The required pathname argument is a string expression that	-

	specifies a file name. The pathname may include the directory or folder, and the drive.	
FileLen	Returns a Long specifying the length of a file in bytes. Syntax FileLen(pathname) The required pathname argument is a string expression that specifies a file. The pathname may include the directory or folder, and the drive. Remarks If the specified file is open when the FileLen function is called, the value returned represents the size of the file immediately before it was opened. Note To obtain the length of an open file, use the LOF function.	-
Filter	Returns a zero-based array containing subset of a string array based on a specified filter criteria. Syntax Filter(sourcesrray, match[, include[, compare]]) The Filter function syntax has these named argument: Part Description sourcearray Required. One-dimensional array of strings to be searched. match Required. String to search for. include Optional. Boolean value indicating whether to return substrings that include or exclude match. If include is True, Filter returns the subset of the array that contains match as a substring. If include is False, Filter returns the subset of the array that does not contain match as a substring. compare Optional. Numeric value indicating the kind of string comparison to use. See Settings section for values. Settings The compare argument can have the following values: Constant Value Description vbUseCompareOption 1 Performs a comparison using the setting of the Option Compare statement. vbBinaryCompare 0 Performs a binary comparison. vbTextCompare 1 Performs a textual comparison. vbDatabaseCompare 2 Microsoft Access only. Performs a comparison based on information in your database.	?

	Remarks If no matches of match are found within sourcearray, Filter returns an empty array. An error occurs if sourcearray is Null or is not a one-dimensional array. The array returned by the Filter function contains only enough elements to contain the number of matched items.	
Fix	See Int	1
Format	Returns a Variant (String) containing an expression formatted according to instructions contained in a format expression. Syntax Format(expression[, format[, firstdayofweek[, firstweekofyear]]]) The Format function syntax has these parts: Part Description expression Required. Any valid expression. format Optional. A valid named or user-defined format expression. firstdayofweek Optional. A constant that specifies the first day of the week. firstweekofyear Optional. A constant that specifies the first week of the year. Settings The firstdayofweek argument has these settings: Constant Value Description vbUseSystem 0 Use NLS API setting. VbSunday 1 Sunday (default) vbMonday 2 Monday vbTuesday 3 Tuesday vbWednesday 4 Wednesday vbThursday 5 Thursday vbFriday 6 Friday vbSaturday 7 Saturday The firstweekofyear argument has these settings: Constant Value Description vbUseSystem 0 Use NLS API setting. vbFirstJan1 1 Start with week in which January 1 occurs (default). vbFirstFourDays 2 Start with the first week that has at least	?

	four days in the year. vbFirstFullWeek 3 Start with the first full week of the year. Remarks To Format Do This Numbers Use predefined named numeric formats or create user-defined numeric formats. Dates and times Use predefined named date/time formats or create user-defined date/time formats. Date and time serial numbers Use date and time formats or numeric formats. Strings Create your own user-defined string formats. If you try to format a number without specifying format, Format provides functionality similar to the Str function, although it is internationally aware. However, positive numbers formatted as strings using Format dont include a leading space reserved for the sign of the value; those converted using Str retain the leading space. If you are formatting a non-localized numeric string, you should use a user-defined numeric format to ensure that you get the look you want. Note If the Calendar property setting is Gregorian and format specifies date formatting, the supplied expression must be Gregorian. If the Visual Basic Calendar property setting is Hijri, the supplied expression must be Hijri. If the calendar is Gregorian, the meaning of format expression symbols is unchanged. If the calendar is Hijri, all date format symbols (for example, dddd, mmmm, yyyy) have the same meaning but apply to the Hijri calendar. Format symbols remain in English; symbols that result in text display (for example, AM and PM) display the string (English or Arabic) associated with that symbol. The range of certain symbols changes when the calendar is Hijri. Symbol Range d 1-30 dd 1-30 ww 1-51 mmm Displays full month names (Hijri month names have no abbreviations). y 1-355 yyyy 100-9666	
FormatCurrency	Returns an expression formatted as a currency value using the currency symbol defined in the system control panel. Syntax	1

	FormatCurrency(Expression[,NumDigitsAfterDecimal [,IncludeLeadingDigit [,UseParensForNegativeNumbers [,GroupDigits]]]]) The FormatCurrency function syntax has these parts: Part Description Expression Required. Expression to be formatted. NumDigitsAfterDecimal Optional. Numeric value indicating how many places to the right of the decimal are displayed. Default value is 1, which indicates that the computer's regional settings are used. IncludeLeadingDigit Optional. Tristate constant that indicates whether or not a leading zero is displayed for fractional values. See Settings section for values. UseParensForNegativeNumbers Optional. Tristate constant that indicates whether or not to place negative values within parentheses. See Settings section for values. GroupDigits Optional. Tristate constant that indicates whether or not numbers are grouped using the group delimiter specified in the computer's regional settings. See Settings section for values. Settings The IncludeLeadingDigit, UseParensForNegativeNumbers, and GroupDigits arguments have the following settings: Constant Value Description vbTrue 1 True vbFalse 0 False vbUseDefault 2 Use the setting from the computer's regional settings. Remarks When one or more optional arguments are omitted, the values for omitted arguments are provided by the computer's regional settings. The position of the currency symbol relative to the currency value is determined by the system's regional settings. Note All settings information comes from the Regional Settings Currency tab, except leading zero which comes from the Number tab.	
FormatDateTime	Returns an expression formatted as a date or time. Syntax	1

	FormatDateTime(Date[,NamedFormat]) The FormatDateTime function syntax has these parts: Part Description Date Required. Date expression to be formatted. NamedFormat Optional. Numeric value that indicates the date/time format used. If omitted, vbGeneralDate is used. Settings The NamedFormat argument has the following settings: Constant Value Description vbGeneralDate 0 Display a date and/or time. If there is a date part, display it as a short date. If there is a time part, display it as a long time. If present, both parts are displayed. vbLongDate 1 Display a date using the long date format specified in your computer's regional settings. vbShortDate 2 Display a date using the short date format specified in your computer's regional settings. vbLongTime 3 Display a time using the time format specified in your computer's regional settings. vbShortTime 4 Display a time using the 24-hour format (hh:mm).	
FormatNumber	Returns an expression formatted as a number. Syntax FormatNumber(Expression[,NumDigitsAfterDecimal [,IncludeLeadingDigit [,UseParensForNegativeNumbers [,GroupDigits]]]]) The FormatNumber function syntax has these parts: Part Description Expression Required. Expression to be formatted. NumDigitsAfterDecimal Optional. Numeric value indicating how many places to the right of the decimal are displayed. Default value is 1, which indicates that the computer's regional settings are used. IncludeLeadingDigit Optional. Tristate constant that indicates whether or not a leading zero is displayed for fractional values. See Settings section for values. UseParensForNegativeNumbers Optional. Tristate constant that indicates whether or not to place negative values within parentheses. See Settings section for values. GroupDigits Optional. Tristate constant that indicates whether or not numbers are grouped using the group delimiter specified in the computer's regional settings. See Settings section for values.	1

	Settings The IncludeLeadingDigit, UseParensForNegativeNumbers, and GroupDigits arguments have the following settings: Constant Value Description vbTrue 1 True vbFalse 0 False vbUseDefault 2 Use the setting from the computer's regional settings. Remarks When one or more optional arguments are omitted, the values for omitted arguments are provided by the computer's regional settings. Note All settings information comes from the Regional Settings Number tab.	
FormatPercent	Returns an expression formatted as a percentage (multipled by 100) with a trailing % character. Syntax FormatPercent(Expression[,NumDigitsAfterDecimal [,IncludeLeadingDigit [,UseParensForNegativeNumbers [,GroupDigits]]]]) The FormatPercent function syntax has these parts: Part Description Expression Required. Expression to be formatted. NumDigitsAfterDecimal Optional. Numeric value indicating how many places to the right of the decimal are displayed. Default value is 1, which indicates that the computer's regional settings are used. IncludeLeadingDigit Optional. Tristate constant that indicates whether or not a leading zero is displayed for fractional values. See Settings section for values. UseParensForNegativeNumbers Optional. Tristate constant that indicates whether or not to place negative values within parentheses. See Settings section for values. GroupDigits Optional. Tristate constant that indicates whether or not numbers are grouped using the group delimiter specified in the computer's regional settings. See Settings section for values. Settings The IncludeLeadingDigit, UseParensForNegativeNumbers, and GroupDigits arguments have the following settings: Constant Value Description	1

	vbTrue 1 True vbFalse 0 False vbUseDefault 2 Use the setting from the computer's regional settings. Remarks When one or more optional arguments are omitted, the values for omitted arguments are provided by the computer's regional settings. Note All settings information comes from the Regional Settings Number tab.	
FreeFile	Returns an Integer representing the next file number available for use by the Open statement. Syntax FreeFile[(rangenumber)] The optional rangenumber argument is a Variant that specifies the range from which the next free file number is to be returned. Specify a 0 (default) to return a file number in the range 1 255, inclusive. Specify a 1 to return a file number in the range 256 511. Remarks Use FreeFile to supply a file number that is not already in use.	-
FV	Returns a Double specifying the future value of an annuity based on periodic, fixed payments and a fixed interest rate. Syntax FV(rate, nper, pmt[, pv[, type]]) The FV function has these named arguments: Part Description rate Required. Double specifying interest rate per period. For example, if you get a car loan at an annual percentage rate (APR) of 10 percent and make monthly payments, the rate per period is 0.1/12, or 0.0083. nper Required. Integer specifying total number of payment periods in the annuity. For example, if you make monthly payments on a four-year car loan, your loan has a total of 4 * 12 (or 48) payment periods. pmt Required. Double specifying payment to be made each period. Payments usually contain principal and interest that doesn't change over the life of the annuity. pv Optional. Variant specifying present value (or lump sum) of a series of future payments. For example, when you borrow money to buy a car, the loan amount is the present	2

	value to the lender of the monthly car payments you will make. If omitted, 0 is assumed. type Optional. Variant specifying when payments are due. Use 0 if payments are due at the end of the payment period, or use 1 if payments are due at the beginning of the period. If omitted, 0 is assumed. Remarks An annuity is a series of fixed cash payments made over a period of time. An annuity can be a loan (such as a home mortgage) or an investment (such as a monthly savings plan). The rate and nper arguments must be calculated using payment periods expressed in the same units. For example, if rate is calculated using months, nper must also be calculated using months. For all arguments, cash paid out (such as deposits to savings) is represented by negative numbers; cash received (such as dividend checks) is represented by positive numbers.	
GetAllSettings	Returns a list of key settings and their respective values (originally created with SaveSetting) from an application's entry in the Windows registry. Syntax GetAllSettings(appname, section) The GetAllSettings function syntax has these named arguments: Part Description appname Required. String expression containing the name of the application or project whose key settings are requested. section Required. String expression containing the name of the section whose key settings are requested. GetAllSettings returns a Variant whose contents is a two-dimensional array of strings containing all the key settings in the specified section and their corresponding values. Remarks GetAllSettings returns an uninitialized Variant if either appname or section does not exist.	-
GetAttr	Returns an Integer representing the attributes of a file, directory, or folder. Syntax	-

	GetAttr(pathname) The required pathname argument is a string expression that specifies a file name. The pathname may include the directory or folder, and the drive. Return Values The value returned by GetAttr is the sum of the following attribute values: Constant Value Description vbNormal 0 Normal. vbReadOnly 1 Read-only. vbHidden 2 Hidden. vbSystem 4 System file. vbDirectory 16 Directory or folder. vbArchive 32 File has changed since last backup. Note These constants are specified by Visual Basic for Applications. The names can be used anywhere in your code in place of the actual values. Remarks To determine which attributes are set, use the And operator to perform a bitwise comparison of the value returned by the GetAttr function and the value of the individual file attribute you want. If the result is not zero, that attribute is set for the named file. For example, the return value of the following And expression is zero if the Archive attribute is not set: Result = GetAttr(FName) And vbArchive A nonzero value is returned if the Archive attribute is set.	
GetObject	Returns a reference to an object provided by an ActiveX component. Syntax GetObject([pathname] [, class]) The GetObject function syntax has these named arguments: Part Description pathname Optional; Variant (String). The full path and name of the file containing the object to retrieve. If pathname is omitted, class is required. class Optional; Variant (String). A string representing the class of the object. The class argument uses the syntax appname.objecttype and	-

has these parts:

Part Description
appname Required; Variant (String). The name of the application providing the object.
objecttype Required; Variant (String). The type or class of object to create.

Remarks

Use the GetObject function to access an ActiveX object from a file and assign the object to an object variable. Use the Set statement to assign the object returned by GetObject to the object variable. For example:

```
Dim CADObject As Object
Set CADObject = GetObject("C:\CAD\SCHEMA.CAD")
```

When this code is executed, the application associated with the specified pathname is started and the object in the specified file is activated.

If pathname is a zero-length string (""), GetObject returns a new object instance of the specified type. If the pathname argument is omitted, GetObject returns a currently active object of the specified type. If no object of the specified type exists, an error occurs.

Some applications allow you to activate part of a file. Add an exclamation point (!) to the end of the file name and follow it with a string that identifies the part of the file you want to activate. For information on how to create this string, see the documentation for the application that created the object.

For example, in a drawing application you might have multiple layers to a drawing stored in a file. You could use the following code to activate a layer within a drawing called SCHEMA.CAD
:

```
Set LayerObject = GetObject("C:\CAD\SCHEMA.CAD!Layer3")
```

If you don't specify the object's class, Automation determines the application to start and the object to activate, based on the file name you provide. Some files, however, may support more than one class of object. For example, a drawing might support three different types of objects: an Application object, a Drawing object, and a Toolbar object, all of which are part of the same file. To specify which object in a file you want to activate, use the optional class argument. For example:

```
Dim MyObject As Object
Set MyObject = GetObject("C:\DRAWINGS\SAMPLE.DRW",
"FIGMENT.DRAWING")
```

	In the example, FIGMENT is the name of a drawing application and DRAWING is one of the object types it supports. Once an object is activated, you reference it in code using the object variable you defined. In the preceding example, you access properties and methods of the new object using the object variable MyObject . For example: MyObject.Line 9, 90 MyObject.InsertText 9, 100, "Hello, world." MyObject.SaveAs "C:\DRAWINGS\SAMPLE.DRW" Note Use the GetObject function when there is a current instance of the object or if you want to create the object with a file already loaded. If there is no current instance, and you don't want the object started with a file loaded, use the CreateObject function. If an object has registered itself as a single-instance object, only one instance of the object is created, no matter how many times CreateObject is executed. With a single-instance object, GetObject always returns the same instance when called with the zero-length string ("") syntax, and it causes an error if the pathname argument is omitted. You can't use GetObject to obtain a reference to a class created with Visual Basic.	
GetSetting	Returns a key setting value from an application's entry in the Windows registry. Syntax GetSetting(appname, section, key[, default]) The GetSetting function syntax has these named arguments: Part Description appname Required. String expression containing the name of the application or project whose key setting is requested. section Required. String expression containing the name of the section where the key setting is found. key Required. String expression containing the name of the key setting to return. default Optional. Expression containing the value to return if no value is set in the key setting. If omitted, default is assumed to be a zero-length string (""). Remarks If any of the items named in the GetSetting arguments do not	-

	exist, GetSetting returns the value of default.	
HelpContext		
HelpFile		
Hex	Returns a String representing the hexadecimal value of a number. Syntax Hex(number) The required number argument is any valid numeric expression or string expression. Remarks If number is not already a whole number, it is rounded to the nearest whole number before being evaluated. If number is Hex returns Null Null Empty Zero (0) Any other number Up to eight hexadecimal characters You can represent hexadecimal numbers directly by preceding numbers in the proper range with &H. For example, &H10 represents decimal 16 in hexadecimal notation.	1
Hour	Returns a Variant (Integer) specifying a whole number between 0 and 23, inclusive, representing the hour of the day. Syntax Hour(time) The required time argument is any Variant, numeric expression, string expression, or any combination, that can represent a time. If time contains Null, Null is returned.	1
IIf	Returns one of two parts, depending on the evaluation of an expression. Syntax IIf(expr, truepart, falsepart) The IIf function syntax has these named arguments: Part Description expr Required. Expression you want to evaluate.	?

	truepart Required. Value or expression returned if expr is True. falsepart Required. Value or expression returned if expr is False. Remarks IIf always evaluates both truepart and falsepart, even though it returns only one of them. Because of this, you should watch for undesirable side effects. For example, if evaluating falsepart results in a division by zero error, an error occurs even if expr is True.	
IMEStatus	Returns an Integer specifying the current Input Method Editor (IME) mode of Microsoft Windows; available in East Asian versions only. Syntax IMEStatus Return Values The return values for the Japanese locale are as follows: Constant Value Description vbIMEModeNoControl 0 Don't control IME (default) vbIMEModeOn 1 IME on vbIMEModeOff 2 IME off vbIMEModeDisable 3 IME disabled vbIMEModeHiragana 4 Full-width Hiragana mode vbIMEModeKatakana 5 Full-width Katakana mode vbIMEModeKatakanaHalf 6 Half-width Katakana mode vbIMEModeAlphaFull 7 Full-width Alphanumeric mode vbIMEModeAlpha 8 Half-width Alphanumeric mode The return values for the Korean locale are as follows: Constant Value Description vbIMEModeNoControl 0 Don't control IME(default) vbIMEModeAlphaFull 7 Full-width Alphanumeric mode vbIMEModeAlpha 8 Half-width Alphanumeric mode vbIMEModeHangulFull 9 Full-width Hangul mode vbIMEModeHangul 10 Half-width Hangul mode The return values for the Chinese locale are as follows: Constant Value Description vbIMEModeNoControl 0 Don't control IME (default) vbIMEModeOn 1 IME on vbIMEModeOff 2 IME off	-

Input	Returns String containing characters from a file opened in Input or Binary mode. Syntax Input(number, [#]filenumber) The Input function syntax has these parts: Part Description number Required. Any valid numeric expression specifying the number of characters to return. filenumber Required. Any valid file number. Remarks Data read with the Input function is usually written to a file with Print # or Put. Use this function only with files opened in Input or Binary mode. Unlike the Input # statement, the Input function returns all of the characters it reads, including commas, carriage returns, linefeeds, quotation marks, and leading spaces. With files opened for Binary access, an attempt to read through the file using the Input function until EOF returns True generates an error. Use the LOF and Loc functions instead of EOF when reading binary files with Input, or use Get when using the EOF function. Security Note When reading from files, do not make decisions about the contents of the file based on the file name extension. For example, a file named Form1.vb may not be a Visual Basic source file. Note Use the InputB function for byte data contained within text files. With InputB, number specifies the number of bytes to return rather than the number of characters to return.	-
InputB		-
InputBox	Displays a prompt in a dialog box, waits for the user to input text or click a button, and returns a String containing the contents of the text box. Syntax InputBox(prompt[, title] [, default] [, xpos] [, ypos] [, helpfile, context]) The InputBox function syntax has these named arguments: Part Description prompt Required. String expression displayed as the message in the dialog box. The maximum length of prompt is	-

	approximately 1024 characters, depending on the width of the characters used. If prompt consists of more than one line, you can separate the lines using a carriage return character (Chr(13)), a linefeed character (Chr(10)), or carriage returnlinefeed character combination (Chr(13) & Chr(10)) between each line. title Optional. String expression displayed in the title bar of the dialog box. If you omit title, the application name is placed in the title bar. default Optional. String expression displayed in the text box as the default response if no other input is provided. If you omit default, the text box is displayed empty. xpos Optional. Numeric expression that specifies, in twips, the horizontal distance of the left edge of the dialog box from the left edge of the screen. If xpos is omitted, the dialog box is horizontally centered. ypos Optional. Numeric expression that specifies, in twips, the vertical distance of the upper edge of the dialog box from the top of the screen. If ypos is omitted, the dialog box is vertically positioned approximately one-third of the way down the screen. helpfile Optional. String expression that identifies the Help file to use to provide context-sensitive Help for the dialog box. If helpfile is provided, context must also be provided. context Optional. Numeric expression that is the Help context number assigned to the appropriate Help topic by the Help author. If context is provided, helpfile must also be provided. Remarks When both helpfile and context are provided, the user can press F1 to view the Help topic corresponding to the context. Some host applications, for example, Microsoft Excel, also automatically add a Help button to the dialog box. If the user clicks OK or presses ENTER , the InputBox function returns whatever is in the text box. If the user clicks Cancel, the function returns a zero-length string (""). Note To specify more than the first named argument, you must use InputBox in an expression. To omit some positional arguments, you must include the corresponding comma delimiter.	
InStr	Returns a Variant (Long) specifying the position of the first occurrence of one string within another. Syntax InStr([start,]string1, string2[, compare]) The InStr function syntax has these arguments: Part Description	mondrian 2.4

	start Optional. Numeric expression that sets the starting position for each search. If omitted, search begins at the first character position. If start contains Null, an error occurs. The start argument is required if compare is specified. string1 Required. String expression being searched. string2 Required. String expression sought. compare Optional. Specifies the type of string comparison. If compare is Null, an error occurs. If compare is omitted, the Option Compare setting determines the type of comparison. Specify a valid LCID (LocaleID) to use locale-specific rules in the comparison. Settings The compare argument settings are: Constant Value Description vbUseCompareOption -1 Performs a comparison using the setting of the Option Compare statement. vbBinaryCompare 0 Performs a binary comparison. vbTextCompare 1 Performs a textual comparison. vbDatabaseCompare 2 Microsoft Access only. Performs a comparison based on information in your database. Return Values If InStr returns string1 is zero-length 0 string1 is Null Null string2 is zero-length start string2 is Null Null string2 is not found 0 string2 is found within string1 Position at which match is found start > string2 0 Remarks The InStrB function is used with byte data contained in a string. Instead of returning the character position of the first occurrence of one string within another, InStrB returns the byte position.	
InStrB	See InStr.	-
InStrRev	Returns the position of an occurrence of one string within another, from the end of string. Syntax InstrRev(stringcheck, stringmatch[, start[, compare]])	1

	The InstrRev function syntax has these named arguments: Part Description stringcheck Required. String expression being searched. stringmatch Required. String expression being searched for. start Optional. Numeric expression that sets the starting position for each search. If omitted, 1 is used, which means that the search begins at the last character position. If start contains Null, an error occurs. compare Optional. Numeric value indicating the kind of comparison to use when evaluating substrings. If omitted, a binary comparison is performed. See Settings section for values. Settings The compare argument can have the following values: Constant Value Description vbUseCompareOption 1 Performs a comparison using the setting of the Option Compare statement. vbBinaryCompare 0 Performs a binary comparison. vbTextCompare 1 Performs a textual comparison. vbDatabaseCompare 2 Microsoft Access only. Performs a comparison based on information in your database. Return Values InStrRev returns the following values: If InStrRev returns stringcheck is zero-length 0 stringcheck is Null Null stringmatch is zero-length start stringmatch is Null Null stringmatch is not found 0 stringmatch is found within stringcheck Position at which match is found start > Len(stringmatch) 0 Remarks Note that the syntax for the InstrRev function is not the same as the syntax for the Instr function.	
Int	Returns the integer portion of a number. Syntax Int(number) Fix(number)	1

	The required number argument is a Double or any valid numeric expression. If number contains Null, Null is returned. Remarks Both Int and Fix remove the fractional part of number and return the resulting integer value. The difference between Int and Fix is that if number is negative, Int returns the first negative integer less than or equal to number, whereas Fix returns the first negative integer greater than or equal to number. For example, Int converts -8.4 to -9, and Fix converts -8.4 to -8. Fix(number) is equivalent to: Sgn(number) * Int(Abs(number))	
IPmt	Returns a Double specifying the interest payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. Syntax IPmt(rate, per, nper, pv[, fv[, type]]) The IPmt function has these named arguments: Part Description rate Required. Double specifying interest rate per period. For example, if you get a car loan at an annual percentage rate (APR) of 10 percent and make monthly payments, the rate per period is 0.1/12, or 0.0083. per Required. Double specifying payment period in the range 1 through nper. nper Required. Double specifying total number of payment periods in the annuity. For example, if you make monthly payments on a four-year car loan, your loan has a total of 4 * 12 (or 48) payment periods. pv Required. Double specifying present value, or value today, of a series of future payments or receipts. For example, when you borrow money to buy a car, the loan amount is the present value to the lender of the monthly car payments you will make. fv Optional. Variant specifying future value or cash balance you want after you've made the final payment. For example, the future value of a loan is $0 because that's its value after the final payment. However, if you want to save $50,000 over 18 years for your child's education, then $50,000 is the future value. If omitted, 0 is assumed. type Optional. Variant specifying when payments are due. Use 0 if payments are due at the end of the payment period, or use 1 if payments are due at the beginning of the period. If omitted, 0 is assumed.	2

	Remarks An annuity is a series of fixed cash payments made over a period of time. An annuity can be a loan (such as a home mortgage) or an investment (such as a monthly savings plan). The rate and nper arguments must be calculated using payment periods expressed in the same units. For example, if rate is calculated using months, nper must also be calculated using months. For all arguments, cash paid out (such as deposits to savings) is represented by negative numbers; cash received (such as dividend checks) is represented by positive numbers.	
IRR	Returns a Double specifying the internal rate of return for a series of periodic cash flows (payments and receipts). Syntax IRR(values()[, guess]) The IRR function has these named arguments: Part Description values() Required. Array of Double specifying cash flow values. The array must contain at least one negative value (a payment) and one positive value (a receipt). guess Optional. Variant specifying value you estimate will be returned by IRR. If omitted, guess is 0.1 (10 percent). Remarks The internal rate of return is the interest rate received for an investment consisting of payments and receipts that occur at regular intervals. The IRR function uses the order of values within the array to interpret the order of payments and receipts. Be sure to enter your payment and receipt values in the correct sequence. The cash flow for each period doesn't have to be fixed, as it is for an annuity. IRR is calculated by iteration. Starting with the value of guess, IRR cycles through the calculation until the result is accurate to within 0.00001 percent. If IRR can't find a result after 20 tries, it fails.	2
IsArray	Returns a Boolean value indicating whether a variable is an array.	2

	Syntax IsArray(varname) The required varname argument is an identifier specifying a variable. Remarks IsArray returns True if the variable is an array; otherwise, it returns False. IsArray is especially useful with variants containing arrays.	
IsDate	Returns a Boolean value indicating whether an expression can be converted to a date. Syntax IsDate(expression) The required expression argument is a Variant containing a date expression or string expression recognizable as a date or time. Remarks IsDate returns True if the expression is a date or is recognizable as a valid date; otherwise, it returns False. In Microsoft Windows, the range of valid dates is January 1, 100 A.D. through December 31, 9999 A.D.; the ranges vary among operating systems.	1
IsEmpty	Returns a Boolean value indicating whether a variable has been initialized. Syntax IsEmpty(expression) The required expression argument is a Variant containing a numeric or string expression. However, because IsEmpty is used to determine if individual variables are initialized, the expression argument is most often a single variable name. Remarks IsEmpty returns True if the variable is uninitialized, or is explicitly set to Empty; otherwise, it returns False. False is always returned if expression contains more than one variable. IsEmpty only returns meaningful information for variants.	since mondrian 0.6
IsError	Returns a Boolean value indicating whether an expression is an error value.	?

	Syntax IsError(expression) The required expression argument can be any valid expression. Remarks Error values are created by converting real numbers to error values using the CVErr function. The IsError function is used to determine if a numeric expression represents an error. IsError returns True if the expression argument indicates an error; otherwise, it returns False.	

IsMissing	Returns a Boolean value indicating whether an optional Variant argument has been passed to a procedure.
	
	Syntax
	
	IsMissing(argname)
	
	The required argname argument contains the name of an optional Variant procedure argument.
	
	Remarks
	
	Use the IsMissing function to detect whether or not optional Variant arguments have been provided in calling a procedure. IsMissing returns True if no value has been passed for the specified argument; otherwise, it returns False. If IsMissing returns True for an argument, use of the missing argument in other code may cause a user-defined error. If IsMissing is used on a ParamArray argument, it always returns False. To detect an empty ParamArray, test to see if the arrays upper bound is less than its lower bound.
	
	Note IsMissing does not work on simple data types (such as Integer or Double) because, unlike Variants, they don't have a provision for a "missing" flag bit. Because of this, the syntax for typed optional arguments allows you to specify a default value. If the argument is omitted when the procedure is called, then the argument will have this default value, as in the example below:
	
	Sub MySub(Optional MyVar As String = "specialvalue")
	If MyVar = "specialvalue" Then
	' MyVar was omitted.
	Else
	...
	End Sub
	In many cases you can omit the
	If MyVar
	test entirely by making the default value equal to the value
		?

	you want MyVar to contain if the user omits it from the function call. This makes your code more concise and efficient.	
IsNull	Returns a Boolean value that indicates whether an expression contains no valid data (Null). Syntax IsNull(expression) The required expression argument is a Variant containing a numeric expression or string expression. Remarks IsNull returns True if expression is Null; otherwise, IsNull returns False. If expression consists of more than one variable, Null in any constituent variable causes True to be returned for the entire expression. The Null value indicates that the Variant contains no valid data. Null is not the same as Empty, which indicates that a variable has not yet been initialized. It is also not the same as a zero-length string (""), which is sometimes referred to as a null string. Important Use the IsNull function to determine whether an expression contains a Null value. Expressions that you might expect to evaluate to True under some circumstances, such as If Var = Null and If Var <> Null , are always False. This is because any expression containing a Null is itself Null and, therefore, False.	1
IsNumeric	Returns a Boolean value indicating whether an expression can be evaluated as a number. Syntax IsNumeric(expression) The required expression argument is a Variant containing a numeric expression or string expression. Remarks IsNumeric returns True if the entire expression is recognized as a number; otherwise, it returns False. IsNumeric returns False if expression is a date expression.	1

IsObject	Returns a Boolean value indicating whether an identifier represents an object variable. Syntax IsObject(identifier) The required identifier argument is a variable name. Remarks IsObject is useful only in determining whether a Variant is of VarType vbObject. This could occur if the Variant actually references (or once referenced) an object, or if it contains Nothing. IsObject returns True if identifier is a variable declared with Object type or any valid class type, or if identifier is a Variant of VarType vbObject, or a user-defined object; otherwise, it returns False. IsObject returns True even if the variable has been set to Nothing. Use error trapping to be sure that an object reference is valid.	2
Item		?
Join	Returns a string created by joining a number of substrings contained in an array. Syntax Join(sourcearray[, delimiter]) The Join function syntax has these named arguments: Part Description sourcearray Required. One-dimensional array containing substrings to be joined. delimiter Optional. String character used to separate the substrings in the returned string. If omitted, the space character (" ") is used. If delimiter is a zero-length string (""), all items in the list are concatenated with no delimiters.	-
Kill		
LastDllError		
LCase	Returns a String that has been converted to lowercase. Syntax LCase(string) The required string argument is any valid string expression. If string contains Null, Null is returned. Remarks	1

	Only uppercase letters are converted to lowercase; all lowercase letters and nonletter characters remain unchanged.	
Left	Returns a Variant (String) containing a specified number of characters from the left side of a string. Syntax Left(string, length) The Left function syntax has these named arguments: Part Description string Required. String expression from which the leftmost characters are returned. If string contains Null, Null is returned. length Required; Variant (Long). Numeric expression indicating how many characters to return. If 0, a zero-length string ("") is returned. If greater than or equal to the number of characters in string, the entire string is returned. Remarks To determine the number of characters in string, use the Len function. Note Use the LeftB function with byte data contained in a string. Instead of specifying the number of characters to return, length specifies the number of bytes.	mondrian 2.4
LeftB	See Left.	
Len	Returns a Long containing the number of characters in a string or the number of bytes required to store a variable. Syntax Len(string | varname) The Len function syntax has these parts: Part Description string Any valid string expression. If string contains Null, Null is returned. Varname Any valid variable name. If varname contains Null, Null is returned. If varname is a Variant, Len treats it the same as a String and always returns the number of characters it contains. Remarks One (and only one) of the two possible arguments must be	mondrian 2.4

	specified. With user-defined types, Len returns the size as it will be written to the file. Note Use the LenB function with byte data contained in a string, as in double-byte character set (DBCS) languages. Instead of returning the number of characters in a string, LenB returns the number of bytes used to represent that string. With user-defined types, LenB returns the in-memory size, including any padding between elements. For sample code that uses LenB, see the second example in the example topic. Note Len may not be able to determine the actual number of storage bytes required when used with variable-length strings in user-defined data types.	
LenB	See Len.	
Loc	Returns a Long specifying the current read/write position within an open file. Syntax Loc(filenumber) The required filenumber argument is any valid Integer file number. Remarks The following describes the return value for each file access mode: Mode Return Value Random Number of the last record read from or written to the file. Sequential Current byte position in the file divided by 128. However, information returned by Loc for sequential files is neither used nor required. Binary Position of the last byte read or written.	-
LOF	Returns a Long representing the size, in bytes, of a file opened using the Open statement. Syntax LOF(filenumber) The required filenumber argument is an Integer containing a valid file number. Note Use the FileLen function to obtain the length of a file that is not open.	-
Log	Returns a Double specifying the natural logarithm of a number.	1

	Syntax Log(number) The required number argument is a Double or any valid numeric expression greater than zero. Remarks The natural logarithm is the logarithm to the base e. The constant e is approximately 2.718282. You can calculate base-n logarithms for any number x by dividing the natural logarithm of x by the natural logarithm of n as follows: Logn(x) = Log(x) / Log(n) The following example illustrates a custom Function that calculates base-10 logarithms: Static Function Log10(X) Log10 = Log(X) / Log(10#) End Function	
LTrim	Returns a Variant (String) containing a copy of a specified string without leading spaces (LTrim), trailing spaces (RTrim), or both leading and trailing spaces (Trim). Syntax LTrim(string) RTrim(string) Trim(string) The required string argument is any valid string expression. If string contains Null, Null is returned.	1
Mid	Returns a Variant (String) containing a specified number of characters from a string. Syntax Mid(string, start[, length]) The Mid function syntax has these named arguments: Part Description string Required. String expression from which characters are returned. If string contains Null, Null is returned. start Required; Long. Character position in string at which the part to be taken begins. If start is greater than the number of characters in string, Mid returns a zero-length string (""). length Optional; Variant (Long). Number of characters to	mondrian 2.4

	return. If omitted or if there are fewer than length characters in the text (including the character at start), all characters from the start position to the end of the string are returned. Remarks To determine the number of characters in string, use the Len function. Note Use the MidB function with byte data contained in a string, as in double-byte character set languages. Instead of specifying the number of characters, the arguments specify numbers of bytes. For sample code that uses MidB, see the second example in the example topic.	
MidB	See Mid.	-
Minute	Returns a Variant (Integer) specifying a whole number between 0 and 59, inclusive, representing the minute of the hour. Syntax Minute(time) The required time argument is any Variant, numeric expression, string expression, or any combination, that can represent a time. If time contains Null, Null is returned.	1
MIRR	Returns a Double specifying the modified internal rate of return for a series of periodic cash flows (payments and receipts). Syntax MIRR(values(), finance_rate, reinvest_rate) The MIRR function has these named arguments: Part Description values() Required. Array of Double specifying cash flow values. The array must contain at least one negative value (a payment) and one positive value (a receipt). finance_rate Required. Double specifying interest rate paid as the cost of financing. reinvest_rate Required. Double specifying interest rate received on gains from cash reinvestment. Remarks The modified internal rate of return is the internal rate of return when payments and receipts are financed at different rates. The MIRR function takes into account both the cost of the investment (finance_rate) and the interest rate received	2

	on reinvestment of cash (reinvest_rate). The finance_rate and reinvest_rate arguments are percentages expressed as decimal values. For example, 12 percent is expressed as 0.12. The MIRR function uses the order of values within the array to interpret the order of payments and receipts. Be sure to enter your payment and receipt values in the correct sequence.	
MkDir		-
Month	Returns a Variant (Integer) specifying a whole number between 1 and 12, inclusive, representing the month of the year. Syntax Month(date) The required date argument is any Variant, numeric expression, string expression, or any combination, that can represent a date. If date contains Null, Null is returned. Note If the Calendar property setting is Gregorian, the returned integer represents the Gregorian day of the week for the date argument. If the calendar is Hijri, the returned integer represents the Hijri day of the week for the date argument. For Hijri dates, the argument number is any numeric expression that can represent a date and/or time from 1/1/100 (Gregorian Aug 2, 718) through 4/3/9666 (Gregorian Dec 31, 9999).	1
MonthName	Returns a string indicating the specified month. Syntax MonthName(month[, abbreviate]) The MonthName function syntax has these parts: Part Description month Required. The numeric designation of the month. For example, January is 1, February is 2, and so on. abbreviate Optional. Boolean value that indicates if the month name is to be abbreviated. If omitted, the default is False, which means that the month name is not abbreviated.	1
MsgBox	Displays a message in a dialog box, waits for the user to click a button, and returns an Integer indicating which button the user clicked. Syntax MsgBox(prompt[, buttons] [, title] [, helpfile, context])	-

The MsgBox function syntax has these named arguments:

Part Description
prompt Required. String expression displayed as the message in the dialog box. The maximum length of prompt is approximately 1024 characters, depending on the width of the characters used. If prompt consists of more than one line, you can separate the lines using a carriage return character (Chr(13)), a linefeed character (Chr(10)), or carriage return linefeed character combination (Chr(13) & Chr(10)) between each line.
buttons Optional. Numeric expression that is the sum of values specifying the number and type of buttons to display, the icon style to use, the identity of the default button, and the modality of the message box. If omitted, the default value for buttons is 0.
title Optional. String expression displayed in the title bar of the dialog box. If you omit title, the application name is placed in the title bar.
helpfile Optional. String expression that identifies the Help file to use to provide context-sensitive Help for the dialog box. If helpfile is provided, context must also be provided.
context Optional. Numeric expression that is the Help context number assigned to the appropriate Help topic by the Help author. If context is provided, helpfile must also be provided.

Settings

The buttons argument settings are:

Constant Value Description
vbOKOnly 0 Display OK button only.
vbOKCancel 1 Display OK and Cancel buttons.
vbAbortRetryIgnore 2 Display Abort, Retry, and Ignore buttons.
vbYesNoCancel 3 Display Yes, No, and Cancel buttons.
vbYesNo 4 Display Yes and No buttons.
vbRetryCancel 5 Display Retry and Cancel buttons.
vbCritical 16 Display Critical Message icon.
vbQuestion 32 Display Warning Query icon.
vbExclamation 48 Display Warning Message icon.
vbInformation 64 Display Information Message icon.
vbDefaultButton1 0 First button is default.
vbDefaultButton2 256 Second button is default.
vbDefaultButton3 512 Third button is default.
vbDefaultButton4 768 Fourth button is default.
vbApplicationModal 0 Application modal; the user must respond to the message box before continuing work in the current application.
vbSystemModal 4096 System modal; all applications are suspended until the user responds to the message box.

	vbMsgBoxHelpButton 16384 Adds Help button to the message box VbMsgBoxSetForeground 65536 Specifies the message box window as the foreground window vbMsgBoxRight 524288 Text is right aligned vbMsgBoxRtlReading 1048576 Specifies text should appear as right-to-left reading on Hebrew and Arabic systems The first group of values (05) describes the number and type of buttons displayed in the dialog box; the second group (16, 32, 48, 64) describes the icon style; the third group (0, 256, 512) determines which button is the default; and the fourth group (0, 4096) determines the modality of the message box. When adding numbers to create a final value for the buttons argument, use only one number from each group. Note These constants are specified by Visual Basic for Applications. As a result, the names can be used anywhere in your code in place of the actual values. Return Values Constant Value Description vbOK 1 OK vbCancel 2 Cancel vbAbort 3 Abort vbRetry 4 Retry vbIgnore 5 Ignore vbYes 6 Yes vbNo 7 No Remarks When both helpfile and context are provided, the user can press F1 to view the Help topic corresponding to the context. Some host applications, for example, Microsoft Excel, also automatically add a Help button to the dialog box. If the dialog box displays a Cancel button, pressing the ESC key has the same effect as clicking Cancel. If the dialog box contains a Help button, context-sensitive Help is provided for the dialog box. However, no value is returned until one of the other buttons is clicked. Note To specify more than the first named argument, you must use MsgBox in an expression. To omit some positional arguments, you must include the corresponding comma delimiter.	
Now	Returns a Variant (Date) specifying the current date and time according your computer's system date and time.	1

	Syntax Now	
NPer	Returns a Double specifying the number of periods for an annuity based on periodic, fixed payments and a fixed interest rate. Syntax NPer(rate, pmt, pv[, fv[, type]]) The NPer function has these named arguments: Part Description rate Required. Double specifying interest rate per period. For example, if you get a car loan at an annual percentage rate (APR) of 10 percent and make monthly payments, the rate per period is 0.1/12, or 0.0083. pmt Required. Double specifying payment to be made each period. Payments usually contain principal and interest that doesn't change over the life of the annuity. pv Required. Double specifying present value, or value today, of a series of future payments or receipts. For example, when you borrow money to buy a car, the loan amount is the present value to the lender of the monthly car payments you will make. fv Optional. Variant specifying future value or cash balance you want after you've made the final payment. For example, the future value of a loan is $0 because that's its value after the final payment. However, if you want to save $50,000 over 18 years for your child's education, then $50,000 is the future value. If omitted, 0 is assumed. type Optional. Variant specifying when payments are due. Use 0 if payments are due at the end of the payment period, or use 1 if payments are due at the beginning of the period. If omitted, 0 is assumed. Remarks An annuity is a series of fixed cash payments made over a period of time. An annuity can be a loan (such as a home mortgage) or an investment (such as a monthly savings plan). For all arguments, cash paid out (such as deposits to savings) is represented by negative numbers; cash received (such as dividend checks) is represented by positive numbers.	2
NPV	Returns a Double specifying the net present value of an investment based on a series of periodic cash flows (payments and receipts) and a discount rate. Syntax	2

	NPV(rate, values()) The NPV function has these named arguments: Part Description rate Required. Double specifying discount rate over the length of the period, expressed as a decimal. values() Required. Array of Double specifying cash flow values. The array must contain at least one negative value (a payment) and one positive value (a receipt). Remarks The net present value of an investment is the current value of a future series of payments and receipts. The NPV function uses the order of values within the array to interpret the order of payments and receipts. Be sure to enter your payment and receipt values in the correct sequence. The NPV investment begins one period before the date of the first cash flow value and ends with the last cash flow value in the array. The net present value calculation is based on future cash flows. If your first cash flow occurs at the beginning of the first period, the first value must be added to the value returned by NPV and must not be included in the cash flow values of values( ). The NPV function is similar to the PV function (present value) except that the PV function allows cash flows to begin either at the end or the beginning of a period. Unlike the variable NPV cash flow values, PV cash flows must be fixed throughout the investment.	
Number		?
Oct	Returns a Variant (String) representing the octal value of a number. Syntax Oct(number) The required number argument is any valid numeric expression or string expression. Remarks If number is not already a whole number, it is rounded to the nearest whole number before being evaluated.	1

	If number is Oct returns Null Null Empty Zero (0) Any other number Up to 11 octal characters You can represent octal numbers directly by preceding numbers in the proper range with &O . For example, &O10 is the octal notation for decimal 8.	
Partition	Returns a Variant (String) indicating where a number occurs within a calculated series of ranges. Syntax Partition(number, start, stop, interval) The Partition function syntax has these named arguments: Part Description number Required. Whole number that you want to evaluate against the ranges. start Required. Whole number that is the start of the overall range of numbers. The number can't be less than 0. stop Required. Whole number that is the end of the overall range of numbers. The number can't be equal to or less than start. Remarks The Partition function identifies the particular range in which number falls and returns a Variant (String) describing that range. The Partition function is most useful in queries. You can create a select query that shows how many orders fall within various ranges, for example, order values from 1 to 1000, 1001 to 2000, and so on. The following table shows how the ranges are determined using three sets of start, stop, and interval parts. The First Range and Last Range columns show what Partition returns. The ranges are represented by lowervalue:uppervalue, where the low end (lowervalue) of the range is separated from the high end (uppervalue) of the range with a colon (:). start stop interval Before First First Range Last Range After Last 0 99 5 " :-1" " 0: 4" " 95: 99" " 100: " 20 199 10 " : 19" " 20: 29" " 190: 199" " 200: " 100 1010 20 " : 99" " 100: 119" " 1000: 1010" " 1011: "	2

	In the table shown above, the third line shows the result when start and stop define a set of numbers that can't be evenly divided by interval. The last range extends to stop (11 numbers) even though interval is 20. If necessary, Partition returns a range with enough leading spaces so that there are the same number of characters to the left and right of the colon as there are characters in stop, plus one. This ensures that if you use Partition with other numbers, the resulting text will be handled properly during any subsequent sort operation. If interval is 1, the range is number:number, regardless of the start and stop arguments. For example, if interval is 1, number is 100 and stop is 1000, Partition returns " 100: 100". If any of the parts is Null, Partition returns a Null.	
Pmt	Returns a Double specifying the payment for an annuity based on periodic, fixed payments and a fixed interest rate. Syntax Pmt(rate, nper, pv[, fv[, type]]) The Pmt function has these named arguments: Part Description rate Required. Double specifying interest rate per period. For example, if you get a car loan at an annual percentage rate (APR) of 10 percent and make monthly payments, the rate per period is 0.1/12, or 0.0083. nper Required. Integer specifying total number of payment periods in the annuity. For example, if you make monthly payments on a four-year car loan, your loan has a total of 4 * 12 (or 48) payment periods. pv Required. Double specifying present value (or lump sum) that a series of payments to be paid in the future is worth now. For example, when you borrow money to buy a car, the loan amount is the present value to the lender of the monthly car payments you will make. fv Optional. Variant specifying future value or cash balance you want after you've made the final payment. For example, the future value of a loan is $0 because that's its value after the final payment. However, if you want to save $50,000 over 18 years for your child's education, then $50,000 is the future value. If omitted, 0 is assumed. type Optional. Variant specifying when payments are due. Use 0 if payments are due at the end of the payment period, or use 1 if payments are due at the beginning of the period. If omitted, 0 is assumed.	2

	Remarks An annuity is a series of fixed cash payments made over a period of time. An annuity can be a loan (such as a home mortgage) or an investment (such as a monthly savings plan). The rate and nper arguments must be calculated using payment periods expressed in the same units. For example, if rate is calculated using months, nper must also be calculated using months. For all arguments, cash paid out (such as deposits to savings) is represented by negative numbers; cash received (such as dividend checks) is represented by positive numbers.	
PPmt	Returns a Double specifying the principal payment for a given period of an annuity based on periodic, fixed payments and a fixed interest rate. Syntax PPmt(rate, per, nper, pv[, fv[, type]]) The PPmt function has these named arguments: Part Description rate Required. Double specifying interest rate per period. For example, if you get a car loan at an annual percentage rate (APR) of 10 percent and make monthly payments, the rate per period is 0.1/12, or 0.0083. per Required. Integer specifying payment period in the range 1 through nper. nper Required. Integer specifying total number of payment periods in the annuity. For example, if you make monthly payments on a four-year car loan, your loan has a total of 4 * 12 (or 48) payment periods. pv Required. Double specifying present value, or value today, of a series of future payments or receipts. For example, when you borrow money to buy a car, the loan amount is the present value to the lender of the monthly car payments you will make. fv Optional. Variant specifying future value or cash balance you want after you've made the final payment. For example, the future value of a loan is $0 because that's its value after the final payment. However, if you want to save $50,000 over 18 years for your child's education, then $50,000 is the future value. If omitted, 0 is assumed. type Optional. Variant specifying when payments are due. Use 0 if payments are due at the end of the payment period, or use 1 if payments are due at the beginning of the period. If omitted, 0 is assumed.	2

	Remarks An annuity is a series of fixed cash payments made over a period of time. An annuity can be a loan (such as a home mortgage) or an investment (such as a monthly savings plan). The rate and nper arguments must be calculated using payment periods expressed in the same units. For example, if rate is calculated using months, nper must also be calculated using months. For all arguments, cash paid out (such as deposits to savings) is represented by negative numbers; cash received (such as dividend checks) is represented by positive numbers.	
PV	Returns a Double specifying the present value of an annuity based on periodic, fixed payments to be paid in the future and a fixed interest rate. Syntax PV(rate, nper, pmt[, fv[, type]]) The PV function has these named arguments: Part Description rate Required. Double specifying interest rate per period. For example, if you get a car loan at an annual percentage rate (APR) of 10 percent and make monthly payments, the rate per period is 0.1/12, or 0.0083. nper Required. Integer specifying total number of payment periods in the annuity. For example, if you make monthly payments on a four-year car loan, your loan has a total of 4 * 12 (or 48) payment periods. pmt Required. Double specifying payment to be made each period. Payments usually contain principal and interest that doesn't change over the life of the annuity. fv Optional. Variant specifying future value or cash balance you want after you've made the final payment. For example, the future value of a loan is $0 because that's its value after the final payment. However, if you want to save $50,000 over 18 years for your child's education, then $50,000 is the future value. If omitted, 0 is assumed. type Optional. Variant specifying when payments are due. Use 0 if payments are due at the end of the payment period, or use 1 if payments are due at the beginning of the period. If omitted, 0 is assumed. Remarks An annuity is a series of fixed cash payments made over a period of time. An annuity can be a loan (such as a home	2

	mortgage) or an investment (such as a monthly savings plan). The rate and nper arguments must be calculated using payment periods expressed in the same units. For example, if rate is calculated using months, nper must also be calculated using months. For all arguments, cash paid out (such as deposits to savings) is represented by negative numbers; cash received (such as dividend checks) is represented by positive numbers.	
QBColor	Returns a Long representing the RGB color code corresponding to the specified color number. Syntax QBColor(color) The required color argument is a whole number in the range 015. Settings The color argument has these settings: Number Color Number Color 0 Black 8 Gray 1 Blue 9 Light Blue 2 Green 10 Light Green 3 Cyan 11 Light Cyan 4 Red 12 Light Red 5 Magenta 13 Light Magenta 6 Yellow 14 Light Yellow 7 White 15 Bright White Remarks The color argument represents color values used by earlier versions of Basic (such as Microsoft Visual Basic for MS-DOS and the Basic Compiler). Starting with the least-significant byte, the returned value specifies the red, green, and blue values used to set the appropriate color in the RGB system used by Visual Basic for Applications.	2
Raise		
Randomize	See Rnd.	2
Rate	Returns a Double specifying the interest rate per period for an annuity. Syntax Rate(nper, pmt, pv[, fv[, type[, guess]]])	2

	The Rate function has these named arguments: Part Description nper Required. Double specifying total number of payment periods in the annuity. For example, if you make monthly payments on a four-year car loan, your loan has a total of 4 * 12 (or 48) payment periods. pmt Required. Double specifying payment to be made each period. Payments usually contain principal and interest that doesn't change over the life of the annuity. pv Required. Double specifying present value, or value today, of a series of future payments or receipts. For example, when you borrow money to buy a car, the loan amount is the present value to the lender of the monthly car payments you will make. fv Optional. Variant specifying future value or cash balance you want after you make the final payment. For example, the future value of a loan is $0 because that's its value after the final payment. However, if you want to save $50,000 over 18 years for your child's education, then $50,000 is the future value. If omitted, 0 is assumed. type Optional. Variant specifying a number indicating when payments are due. Use 0 if payments are due at the end of the payment period, or use 1 if payments are due at the beginning of the period. If omitted, 0 is assumed. guess Optional. Variant specifying value you estimate will be returned by Rate. If omitted, guess is 0.1 (10 percent). Remarks An annuity is a series of fixed cash payments made over a period of time. An annuity can be a loan (such as a home mortgage) or an investment (such as a monthly savings plan). For all arguments, cash paid out (such as deposits to savings) is represented by negative numbers; cash received (such as dividend checks) is represented by positive numbers. Rate is calculated by iteration. Starting with the value of guess, Rate cycles through the calculation until the result is accurate to within 0.00001 percent. If Rate can't find a result after 20 tries, it fails. If your guess is 10 percent and Rate fails, try a different value for guess.	
Remove		
Replace	Returns a string in which a specified substring has been replaced with another substring a specified number of times. Syntax Replace(expression, find, replace[, start[, count[, compare]]])	1

	The Replace function syntax has these named arguments: Part Description expression Required. String expression containing substring to replace. find Required. Substring being searched for. replace Required. Replacement substring. start Optional. Position within expression where substring search is to begin. If omitted, 1 is assumed. count Optional. Number of substring substitutions to perform. If omitted, the default value is 1, which means make all possible substitutions. compare Optional. Numeric value indicating the kind of comparison to use when evaluating substrings. See Settings section for values. Settings The compare argument can have the following values: Constant Value Description vbUseCompareOption 1 Performs a comparison using the setting of the Option Compare statement. vbBinaryCompare 0 Performs a binary comparison. vbTextCompare 1 Performs a textual comparison. vbDatabaseCompare 2 Microsoft Access only. Performs a comparison based on information in your database. Return Values Replace returns the following values: If Replace returns expression is zero-length Zero-length string ("") expression is Null An error. find is zero-length Copy of expression. replace is zero-length Copy of expression with all occurences of find removed. start > Len(expression) Zero-length string. count is 0 Copy of expression. Remarks The return value of the Replace function is a string, with substitutions made, that begins at the position specified by start and and concludes at the end of the expression string. It is not a copy of the original string from start to finish.	
Reset		
RGB	Returns a Long whole number representing an RGB color	2

	value. Syntax RGB(red, green, blue) The RGB function syntax has these named arguments: Part Description red Required; Variant (Integer). Number in the range 0255, inclusive, that represents the red component of the color. green Required; Variant (Integer). Number in the range 0255, inclusive, that represents the green component of the color. blue Required; Variant (Integer). Number in the range 0255, inclusive, that represents the blue component of the color. Remarks Application methods and properties that accept a color specification expect that specification to be a number representing an RGB color value. An RGB color value specifies the relative intensity of red, green, and blue to cause a specific color to be displayed. The value for any argument to RGB that exceeds 255 is assumed to be 255. The following table lists some standard colors and the red, green, and blue values they include: Color Red Value Green Value Blue Value Black 0 0 0 Blue 0 0 255 Green 0 255 0 Cyan 0 255 255 Red 255 0 0 Magenta 255 0 255 Yellow 255 255 0 White 255 255 255	
Right	Returns a Variant (String) containing a specified number of characters from the right side of a string. Syntax Right(string, length) The Right function syntax has these named arguments: Part Description string Required. String expression from which the rightmost characters are returned. If string contains Null, Null is returned.	1

	length Required; Variant (Long). Numeric expression indicating how many characters to return. If 0, a zero-length string ("") is returned. If greater than or equal to the number of characters in string, the entire string is returned. Remarks To determine the number of characters in string, use the Len function. Note Use the RightB function with byte data contained in a string. Instead of specifying the number of characters to return, length specifies the number of bytes.	
RightB	See Right.	-
RmDir		-
Rnd	Returns a Single containing a random number. Syntax Rnd[(number)] The optional number argument is a Single or any valid numeric expression. Return Values If number is Rnd generates Less than zero The same number every time, using number as the seed. Greater than zero The next random number in the sequence. Equal to zero The most recently generated number. Not supplied The next random number in the sequence. Remarks The Rnd function returns a value less than 1 but greater than or equal to zero. The value of number determines how Rnd generates a random number: For any given initial seed, the same number sequence is generated because each successive call to the Rnd function uses the previous number as a seed for the next number in the sequence. Before calling Rnd, use the Randomize statement without an argument to initialize the random-number generator with a seed based on the system timer.	2

	To produce random integers in a given range, use this formula: Int((upperbound - lowerbound + 1) * Rnd + lowerbound) Here, upperbound is the highest number in the range, and lowerbound is the lowest number in the range. Note To repeat sequences of random numbers, call Rnd with a negative argument immediately before using Randomize with a numeric argument. Using Randomize with the same value for number does not repeat the previous sequence. Security Note Because the Random statement and the Rnd function start with a seed value and generate numbers that fall within a finite range, the results may be predictable by someone who knows the algorithm used to generate them. Consequently, the Random statement and the Rnd function should not be used to generate random numbers for use in cryptography.	
Round	Returns a number rounded to a specified number of decimal places. Syntax Round(expression [,numdecimalplaces]) The Round function syntax has these parts: Part Description expression Required. Numeric expression being rounded. numdecimalplaces Optional. Number indicating how many places to the right of the decimal are included in the rounding. If omitted, integers are returned by the Round function.	1
RTrim	See LTrim.	1
SaveSetting		-
Second	Returns a Variant (Integer) specifying a whole number between 0 and 59, inclusive, representing the second of the minute. Syntax Second(time) The required time argument is any Variant, numeric expression, string expression, or any combination, that can represent a time. If time contains Null, Null is returned.	1
Seek	Returns a Long specifying the current read/write position within a file opened using the Open statement. Syntax	-

	Seek(filenumber) The required filenumber argument is an Integer containing a valid file number. Remarks Seek returns a value between 1 and 2,147,483,647 (equivalent to 2^31 1), inclusive. The following describes the return values for each file access mode. Mode Return Value Random Number of the next record read or written Binary, Output, Append, Input Byte position at which the next operation takes place. The first byte in a file is at position 1, the second byte is at position 2, and so on.	
SendKeys		
SetAttr		
Sgn	Returns a Variant (Integer) indicating the sign of a number. Syntax Sgn(number) The required number argument can be any valid numeric expression. Return Values If number is Sgn returns Greater than zero 1 Equal to zero 0 Less than zero -1 Remarks The sign of the number argument determines the return value of the Sgn function.	1
Shell	Runs an executable program and returns a Variant (Double) representing the program's task ID if successful, otherwise it returns zero. Syntax Shell(pathname[,windowstyle]) The Shell function syntax has these named arguments:	-

	Part Description pathname Required; Variant (String). Name of the program to execute and any required arguments or command-line switches; may include directory or folder and drive. windowstyle Optional. Variant (Integer) corresponding to the style of the window in which the program is to be run. If windowstyle is omitted, the program is started minimized with focus. The windowstyle named argument has these values: Constant Value Description vbHide 0 Window is hidden and focus is passed to the hidden window. vbNormalFocus 1 Window has focus and is restored to its original size and position. vbMinimizedFocus 2 Window is displayed as an icon with focus. vbMaximizedFocus 3 Window is maximized with focus. vbNormalNoFocus 4 Window is restored to its most recent size and position. The currently active window remains active. vbMinimizedNoFocus 6 Window is displayed as an icon. The currently active window remains active. Remarks If the Shell function successfully executes the named file, it returns the task ID of the started program. The task ID is a unique number that identifies the running program. If the Shell function can't start the named program, an error occurs. Note By default, the Shell function runs other programs asynchronously. This means that a program started with Shell might not finish executing before the statements following the Shell function are executed. Security Note If you do not enclose the path and file specification in quotes, there is a security risk if the file name or a path node contains spaces. If the path node specification is not inside quotes, for example \Program Files and a program named Program.exe had been installed in C:\, for example by illicit tampering, Windows would execute it instead of MyFile.exe	
Sin	Returns a Double specifying the sine of an angle. Syntax	1

	Sin(number) The required number argument is a Double or any valid numeric expression that expresses an angle in radians. Remarks The Sin function takes an angle and returns the ratio of two sides of a right triangle. The ratio is the length of the side opposite the angle divided by the length of the hypotenuse. The result lies in the range -1 to 1. To convert degrees to radians, multiply degrees by pi/180. To convert radians to degrees, multiply radians by 180/pi.	
SLN	Returns a Double specifying the straight-line depreciation of an asset for a single period. Syntax SLN(cost, salvage, life) The SLN function has these named arguments: Part Description cost Required. Double specifying initial cost of the asset. salvage Required. Double specifying value of the asset at the end of its useful life. life Required. Double specifying length of the useful life of the asset. Remarks The depreciation period must be expressed in the same unit as the life argument. All arguments must be positive numbers.	2
Source		
Space	Returns a Variant (String) consisting of the specified number of spaces. Syntax Space(number) The required number argument is the number of spaces you want in the string. Remarks The Space function is useful for formatting output and clearing data in fixed-length strings.	1

Split	Returns a zero-based, one-dimensional array containing a specified number of substrings. Syntax Split(expression[, delimiter[, limit[, compare]]]) The Split function syntax has these named arguments: Part Description expression Required. String expression containing substrings and delimiters. If expression is a zero-length string(""), Split returns an empty array, that is, an array with no elements and no data. delimiter Optional. String character used to identify substring limits. If omitted, the space character (" ") is assumed to be the delimiter. If delimiter is a zero-length string, a single-element array containing the entire expression string is returned. limit Optional. Number of substrings to be returned; 1 indicates that all substrings are returned. compare Optional. Numeric value indicating the kind of comparison to use when evaluating substrings. See Settings section for values. Settings The compare argument can have the following values: Constant Value Description vbUseCompareOption 1 Performs a comparison using the setting of the Option Compare statement. vbBinaryCompare 0 Performs a binary comparison. vbTextCompare 1 Performs a textual comparison. vbDatabaseCompare 2 Microsoft Access only. Performs a comparison based on information in your database.	-
Sqr	Returns a Double specifying the square root of a number. Syntax Sqr(number) The required number argument is a Double or any valid numeric expression greater than or equal to zero.	1
Str	Returns a Variant (String) representation of a number. Syntax Str(number) The required number argument is a Long containing any valid numeric expression.	1

	Remarks When numbers are converted to strings, a leading space is always reserved for the sign of number. If number is positive, the returned string contains a leading space and the plus sign is implied. Use the Format function to convert numeric values you want formatted as dates, times, or currency or in other user-defined formats. Unlike Str, the Format function doesn't include a leading space for the sign of number. Note The Str function recognizes only the period (.) as a valid decimal separator. When different decimal separators may be used (for example, in international applications), use CStr to convert a number to a string.	
StrComp	Returns a Variant (Integer) indicating the result of a string comparison. Syntax StrComp(string1, string2[, compare]) The StrComp function syntax has these named arguments: Part Description string1 Required. Any valid string expression. string2 Required. Any valid string expression. compare Optional. Specifies the type of string comparison. If the compare argument is Null, an error occurs. If compare is omitted, the Option Compare setting determines the type of comparison. Settings The compare argument settings are: Constant Value Description vbUseCompareOption -1 Performs a comparison using the setting of the Option Compare statement. vbBinaryCompare 0 Performs a binary comparison. vbTextCompare 1 Performs a textual comparison. vbDatabaseCompare 2 Microsoft Access only. Performs a comparison based on information in your database. Return Values The StrComp function has the following return values: If StrComp returns	1

	string1 is less than string2 -1 string1 is equal to string2 0 string1 is greater than string2 1 string1 or string2 is Null Null	
String	Returns a Variant (String) containing a repeating character string of the length specified. Syntax String(number, character) The String function syntax has these named arguments: Part Description number Required; Long. Length of the returned string. If number contains Null, Null is returned. character Required; Variant. Character code specifying the character or string expression whose first character is used to build the return string. If character contains Null, Null is returned. Remarks If you specify a number for character greater than 255, String converts the number to a valid character code using the formula: character Mod 256	1
StrReverse	Returns a string in which the character order of a specified string is reversed. Syntax StrReverse(expression) The expression argument is the string whose characters are to be reversed. If expression is a zero-length string (""), a zero-length string is returned. If expression is Null, an error occurs.	1
Switch	Evaluates a list of expressions and returns a Variant value or an expression associated with the first expression in the list that is True. Syntax Switch(expr-1, value-1[, expr-2, value-2 [, expr-n,value-n]]) The Switch function syntax has these parts: Part Description expr Required. Variant expression you want to evaluate.	?

	value Required. Value or expression to be returned if the corresponding expression is True. Remarks The Switch function argument list consists of pairs of expressions and values. The expressions are evaluated from left to right, and the value associated with the first expression to evaluate to True is returned. If the parts aren't properly paired, a run-time error occurs. For example, if expr-1 is True, Switch returns value-1. If expr-1 is False, but expr-2 is True, Switch returns value-2, and so on. Switch returns a Null value if: None of the expressions is True. The first True expression has a corresponding value that is Null. Switch evaluates all of the expressions, even though it returns only one of them. For this reason, you should watch for undesirable side effects. For example, if the evaluation of any expression results in a division by zero error, an error occurs.	
SYD	Returns a Double specifying the sum-of-years' digits depreciation of an asset for a specified period. Syntax SYD(cost, salvage, life, period) The SYD function has these named arguments: Part Description cost Required. Double specifying initial cost of the asset. salvage Required. Double specifying value of the asset at the end of its useful life. life Required. Double specifying length of the useful life of the asset. period Required. Double specifying period for which asset depreciation is calculated. Remarks The life and period arguments must be expressed in the same units. For example, if life is given in months, period must also be given in months. All arguments must be positive numbers.	2
Tan	Returns a Double specifying the tangent of an angle. Syntax	1

	Tan(number) The required number argument is a Double or any valid numeric expression that expresses an angle in radians. Remarks Tan takes an angle and returns the ratio of two sides of a right triangle. The ratio is the length of the side opposite the angle divided by the length of the side adjacent to the angle. To convert degrees to radians, multiply degrees by pi/180. To convert radians to degrees, multiply radians by 180/pi.	
Time	Returns a Variant (Date) indicating the current system time. Syntax Time Remarks To set the system time, use the Time statement.	1
Timer	Returns a Single representing the number of seconds elapsed since midnight. Syntax Timer Remarks In Microsoft Windows the Timer function returns fractional portions of a second.	1
TimeSerial	Returns a Variant (Date) containing the time for a specific hour, minute, and second. Syntax TimeSerial(hour, minute, second) The TimeSerial function syntax has these named arguments: Part Description hour Required; Variant (Integer). Number between 0 (12:00 A.M.) and 23 (11:00 P.M.), inclusive, or a numeric expression. minute Required; Variant (Integer). Any numeric expression. second Required; Variant (Integer). Any numeric expression. Remarks To specify a time, such as 11:59:59, the range of numbers for	1

	each TimeSerial argument should be in the normal range for the unit; that is, 023 for hours and 059 for minutes and seconds. However, you can also specify relative times for each argument using any numeric expression that represents some number of hours, minutes, or seconds before or after a certain time. The following example uses expressions instead of absolute time numbers. The TimeSerial function returns a time for 15 minutes before (-15) six hours before noon (12 - 6), or 5:45:00 A.M. TimeSerial(12 - 6, -15, 0) When any argument exceeds the normal range for that argument, it increments to the next larger unit as appropriate. For example, if you specify 75 minutes, it is evaluated as one hour and 15 minutes. If any single argument is outside the range -32,768 to 32,767, an error occurs. If the time specified by the three arguments causes the date to fall outside the acceptable range of dates, an error occurs.	
TimeValue	Returns a Variant (Date) containing the time. Syntax TimeValue(time) The required time argument is normally a string expression representing a time from 0:00:00 (12:00:00 A.M.) to 23:59:59 (11:59:59 P.M.), inclusive. However, time can also be any expression that represents a time in that range. If time contains Null, Null is returned. Remarks You can enter valid times using a 12-hour or 24-hour clock. For example, "2:24PM" and "14:24" are both valid time arguments. If the time argument contains date information, TimeValue doesn't return it. However, if time includes invalid date information, an error occurs.	1
Trim	See LTrim.	1
TypeName	Returns a String that provides information about a variable. Syntax TypeName(varname)	2

	The required varname argument is a Variant containing any variable except a variable of a user-defined type. Remarks The string returned by TypeName can be any one of the following: String returned Variable object type An object whose type is objecttype Byte Byte value Integer Integer Long Long integer Single Single-precision floating-point number Double Double-precision floating-point number Currency Currency value Decimal Decimal value Date Date value String String Boolean Boolean value Error An error value Empty Uninitialized Null No valid data Object An object Unknown An object whose type is unknown Nothing Object variable that doesn't refer to an object If varname is an array, the returned string can be any one of the possible returned strings (or Variant) with empty parentheses appended. For example, if varname is an array of integers, TypeName returns " Integer() ".	
UCase	Returns a Variant (String) containing the specified string, converted to uppercase. Syntax UCase(string) The required string argument is any valid string expression. If string contains Null, Null is returned. Remarks Only lowercase letters are converted to uppercase; all uppercase letters and nonletter characters remain unchanged.	mondrian 2.4
Val	Returns the numbers contained in a string as a numeric value of appropriate type. Syntax	1

	Val(string) The required string argument is any valid string expression. Remarks The Val function stops reading the string at the first character it can't recognize as part of a number. Symbols and characters that are often considered parts of numeric values, such as dollar signs and commas, are not recognized. However, the function recognizes the radix prefixes &O (for octal) and &H (for hexadecimal). Blanks, tabs, and linefeed characters are stripped from the argument. The following returns the value 1615198: Val(" 1615 198th Street N.E.") In the code below, Val returns the decimal value -1 for the hexadecimal value shown: Val("&HFFFF") Note The Val function recognizes only the period (.) as a valid decimal separator. When different decimal separators are used, as in international applications, use CDbl instead to convert a string to a number.	
VarType	Returns an Integer indicating the subtype of a variable. Syntax VarType(varname) The required varname argument is a Variant containing any variable except a variable of a user-defined type. Return Values Constant Value Description vbEmpty 0 Empty (uninitialized) vbNull 1 Null (no valid data) vbInteger 2 Integer vbLong 3 Long integer vbSingle 4 Single-precision floating-point number vbDouble 5 Double-precision floating-point number vbCurrency 6 Currency value vbDate 7 Date value vbString 8 String vbObject 9 Object vbError 10 Error value vbBoolean 11 Boolean value	2

	vbVariant 12 Variant (used only with arrays of variants) vbDataObject 13 A data access object vbDecimal 14 Decimal value vbByte 17 Byte value vbUserDefinedType 36 Variants that contain user-defined types vbArray 8192 Array Note These constants are specified by Visual Basic for Applications. The names can be used anywhere in your code in place of the actual values. Remarks The VarType function never returns the value for vbArray by itself. It is always added to some other value to indicate an array of a particular type. The constant vbVariant is only returned in conjunction with vbArray to indicate that the argument to the VarType function is an array of type Variant. For example, the value returned for an array of integers is calculated as vbInteger + vbArray, or 8194. If an object has a default property, VarType (object) returns the type of the object's default property.	
Weekday	Returns a Variant (Integer) containing a whole number representing the day of the week. Syntax Weekday(date, [firstdayofweek]) The Weekday function syntax has these named arguments: Part Description date Required. Variant, numeric expression, string expression, or any combination, that can represent a date. If date contains Null, Null is returned. firstdayofweek Optional. A constant that specifies the first day of the week. If not specified, vbSunday is assumed. Settings The firstdayofweek argument has these settings: Constant Value Description vbUseSystem 0 Use the NLS API setting. vbSunday 1 Sunday (default) vbMonday 2 Monday vbTuesday 3 Tuesday vbWednesday 4 Wednesday vbThursday 5 Thursday vbFriday 6 Friday	1

	vbSaturday 7 Saturday Return Values The Weekday function can return any of these values: Constant Value Description vbSunday 1 Sunday vbMonday 2 Monday vbTuesday 3 Tuesday vbWednesday 4 Wednesday vbThursday 5 Thursday vbFriday 6 Friday vbSaturday 7 Saturday Remarks If the Calendar property setting is Gregorian, the returned integer represents the Gregorian day of the week for the date argument. If the calendar is Hijri, the returned integer represents the Hijri day of the week for the date argument. For Hijri dates, the argument number is any numeric expression that can represent a date and/or time from 1/1/100 (Gregorian Aug 2, 718) through 4/3/9666 (Gregorian Dec 31, 9999).	
WeekdayName	Returns a string indicating the specified day of the week. Syntax WeekdayName(weekday, abbreviate, firstdayofweek) The WeekdayName function syntax has these parts: Part Description weekday Required. The numeric designation for the day of the week. Numeric value of each day depends on setting of the firstdayofweek setting. abbreviate Optional. Boolean value that indicates if the weekday name is to be abbreviated. If omitted, the default is False, which means that the weekday name is not abbreviated. firstdayofweek Optional. Numeric value indicating the first day of the week. See Settings section for values. Settings The firstdayofweek argument can have the following values: Constant Value Description vbUseSystem 0 Use National Language Support (NLS) API	1

	setting. vbSunday 1 Sunday (default) vbMonday 2 Monday vbTuesday 3 Tuesday vbWednesday 4 Wednesday vbThursday 5 Thursday vbFriday 6 Friday vbSaturday 7 Saturday	
Width		
Year	Returns a Variant (Integer) containing a whole number representing the year. Syntax Year(date) The required date argument is any Variant, numeric expression, string expression, or any combination, that can represent a date. If date contains Null, Null is returned. Note If the Calendar property setting is Gregorian, the returned integer represents the Gregorian year for the date argument. If the calendar is Hijri, the returned integer represents the Hijri year for the date argument. For Hijri dates, the argument number is any numeric expression that can represent a date and/or time from 1/1/100 (Gregorian Aug 2, 718) through 4/3/9666 (Gregorian Dec 31, 9999).	1