JAMMING WITH JAVA™ TECHNOLOGY: MAKING MUSIC WITH JFUGUE AND JFRETS

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TS-5263

Java

Sun microsystems

Learn how to create music from within your own Java™ application

Recapture the joy of programming

GOAL

Agenda

- Introduction to JFugue
- Making Music with JFugue
- JFugue's Advanced Features
- JFugue Under the Hood
- Applications of JFugue
- JFugue and JFrets

Introduction to JFugue

- JFugue is an open-source API for programming music in Java code
- Prevents you from dealing with MIDI messages!
  - But generates MIDI behind the scenes
- Allows you to specify music naturally
  - `player.play("C D E F G A B");`
- Provides classes that make music exploration fun and easy
  - Microtonal music
  - Rhythms
  - Interacting with external devices
  - Many other easy-to-use features
- Enables interaction with other music tools and formats
  - Read or write musical data from MIDI, MusicXML, etc.
  - Extensible architecture

How hard is music programming?
Music without JFugue

```
// Play a Middle-C
Sequencer sequencer = MidiSystem.getSequencer();
Sequence sequence = sequencer.getSequence();
Track track = sequence.createTrack();
ShortMessage onMessage = new ShortMessage();
onMessage.setMessage(ShortMessage.NOTE_ON, 0, 60, 128);
MidiEvent noteOnEvent = new MidiEvent(onMessage, 0);
track.add(noteOnEvent);
ShortMessage offMessage = new ShortMessage();
offMessage.setMessage(ShortMessage.NOTE_OFF, 0, 60, 128);
MidiEvent noteOffEvent = new MidiEvent(offMessage, 200);
track.add(noteOffEvent);
sequencer.start();
try {
    Thread.sleep(track.ticks());
} catch (InterruptedException e) {
    Thread.currentThread().interrupt();
}
```

How hard is music programming?
Music without JFugue – another way

```
// Play a Middle-C
try {
    Synthesizer synthesizer = MidiSystem.getSynthesizer();
    synthesizer.open();
    MidiChannel[] channels = synthesizer.getChannels();
    channels[0].noteOn(60, 128);
    try {
        Thread.sleep(200);
    } catch (InterruptedException e)
    {
        // handle exception
    }
    channels[0].noteOff(60);
    synthesizer.close();
} catch (MidiUnavailableException e) {
    // handle exception
}
```

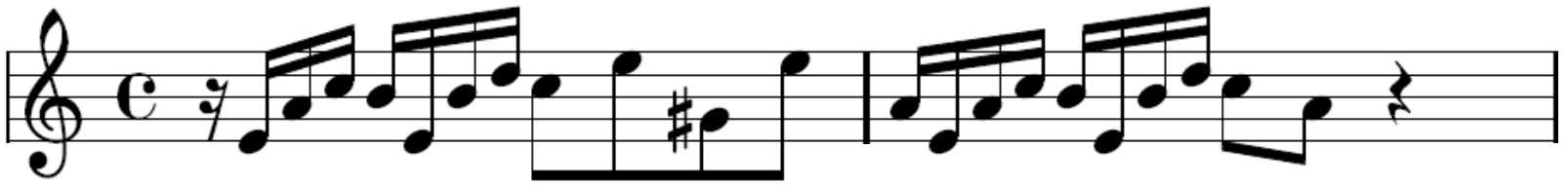
Make it easy!
Music with JFugue

```
// Play a Middle-C
Player player = new Player();
player.play("C");
```

Wow, only 2 lines of code?

- The Magic of JFugue: Music is specified using JFugue's "MusicString"
  - `player.play("C")` is a simple case
  - J. S. Bach's *Inventio 13*

```
player.play("E5s A5s C6s B5s E5s B5s D6s C6i E6i G#5i
E6i | A5s E5s A5s C6s B5s E5s B5s D6s C6i A5i Ri");
```



- JFugue creates all of the MIDI messages behind the scenes

But… it creates MIDI… that's so *1980*

- Problem: You heard the notes, but it doesn't sound like *Music*
- Bias: MIDI is dead. MP3 rules!
  - But MIDI specifies musical messages; MP3 is a compression format
- Cause: The MIDI synthesizer doesn't have a good soundbank
  - People tend to associate MIDI with bad-sounding music
  - But MIDI is just a specification for musical messages
  - What you're hearing is messages turned into sound using synthesizer
  - Soundbanks are replaceable, thanks to the Audio Synthesis Engine Project http://openjdk.java.net/projects/audio-engine/
- Solution: Use a synthesizer that can load better soundbanks!
  - There are a lot of soundbanks in the world that sound *fantastic*!
- Use Gervill, an audio synthesis engine, to load new soundbanks https://gervill.dev.java.net/

Code for adding Gervill to JFugue

```
// There is no code!
//
// Just add gervill.jar to your classpath,
// and MidiSystem.getSynthesizer() will return
// an instance of a Gervill Synthesizer.
```

Code for loading a better soundbank

```
// Really, the hardest part is finding
// a soundbank you like.
Soundbank soundbank =
    MidiSystem.getSoundbank(new File("filename"));

// Load instruments from the soundbank
// into the synthesizer
Synthesizer synth = MidiSystem.getSynthesizer();
synth.loadAllInstruments(soundbank);

// Create a JFugue Player object that is attached
// to the synthesizer with the new instrument
Player player = new Player(synth);

// Now play your music with better results!
player.play(your music here);
```

Using a better soundbank

- Find new soundbanks… Some are free, some cost money
- My favorite: **SONiVOX's 250 Meg GM Wavetable**
  http://www.sonivoxrocks.com/

SONiVOX
sound that rocks.

- Sample of MIDI music rendered using SONiVOX soundbanks:
- Revisiting *"Inventio 13"*

Using standard soundbank

Using **SONiVOX 250 Meg GM Wavetable** soundbank

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Making Music with JFugue
Two building blocks

- Programming music in JFugue comes down to two key ideas:

- **MusicString** – a String that contains notation for specifying music
  - Example: `"C5q E5q Cmajq"`

- **Pattern** – a class that allows MusicStrings to be built, altered, recombined, etc.
  - Example:

```
Pattern pattern = new Pattern("C5q E5q Cmajq");
pattern.add("D5s");
```

  - Most features in JFugue API return instances of Pattern

Specifying Music in JFugue

The JFugue MusicString

- Three rules of thumb when using JFugue:
  - If it can be specified in MIDI, JFugue can create it
  - If it requires memorization, JFugue has predefined constants
  - If it takes work to make it right, JFugue simplifies it

Specifying Music in JFugue

Anatomy of a MusicString

```
player.play("T[Adagio] V0 I[Piano] C5q F#5q
CmajQ V1 I[Flute] C3q+E3q E3q+G3q Ri
C2majI");
```

Specifying Music in JFugue

Anatomy of a MusicString

```
player.play("T[Adagio] V0 I[Piano] C5q F#5q
CmajQ V1 I[Flute] C3q+E3q E3q+G3q Ri
C2majI");
```

- Tempo
  - Indicates speed of music
  - Letter T followed by Beats Per Minute (as of JFugue 4.0)
  - Pre-defined constants, like ‘Adagio’ or ‘Largo’, also provided

Specifying Music in JFugue

Anatomy of a MusicString

```
player.play("T[Adagio] V0 I[Piano] C5q F#5q
CmajQ V1 I[Flute] C3q+E3q E3q+G3q Ri
C2majI");
```

- Voice
  - Specifies MIDI channel for subsequent notes and other musical events
  - Letter V followed by one of the 16 MIDI channels (0-15)
  - The 10th voice (V9) is special – that's MIDI's percussion track

Specifying Music in JFugue

Anatomy of a MusicString

```
player.play("T[Adagio] V0 I[Piano] C5q F#5q
CmajQ V1 I[Flute] C3q+E3q E3q+G3q Ri
C2majI");
```

- Instrument
  - Selects which instrument to use for playing music
  - Letter I followed by a number from 0-127, representing the 128 MIDI instruments
  - Pre-defined constants, like “Piano” and “Flute”, are provided for each of the MIDI instruments

Specifying Music in JFugue

Anatomy of a MusicString

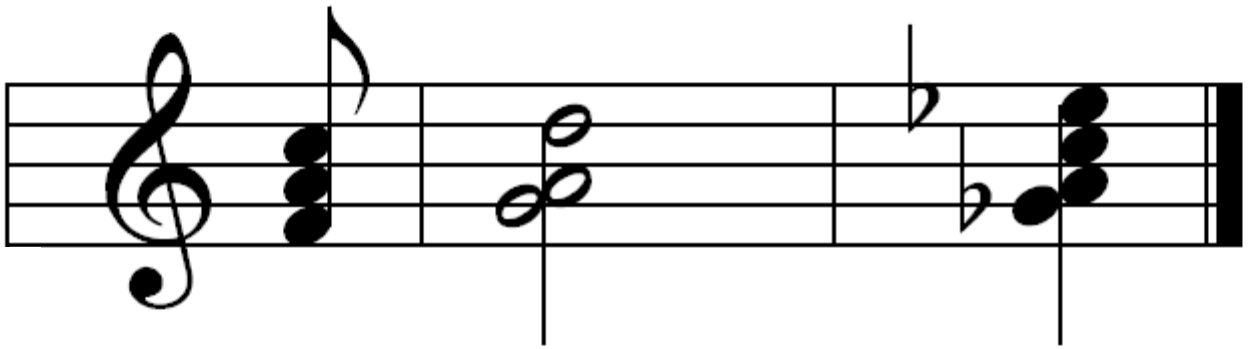
```
player.play("T[Adagio] V0 I[Piano] C5q F#5q
CmajQ V1 I[Flute] C3q+E3q E3q+G3q Ri
C2majI");
```

- Notes, Rests, and Chords
  - Note letter (C, D, E, F, G, A, or B), accidental (#, b, natural), and octave
    - Rest is specified with an R
  - Duration: w, h, q, i, s, t, x, o (whole, half, etc. down to 128th)
    - Dotted notes, tuplets, ties, and combined durations are all supported
  - Note and duration can each be specified numerically: [60], C5/0.5
  - Notes in harmony indicated with +: C3q+E3q
- Chords
  - Root note plus chord identifier (maj, min, aug, etc), then duration
  - Chord inversions can be specified with ^

Specifying Music in JFugue

Anatomy of a MusicString

- JFugue supports 30 types of chord (maj, min, aug, etc)
- Chord inversions are specified with ^



FmajQ Gsus2H Cdim7^^Q

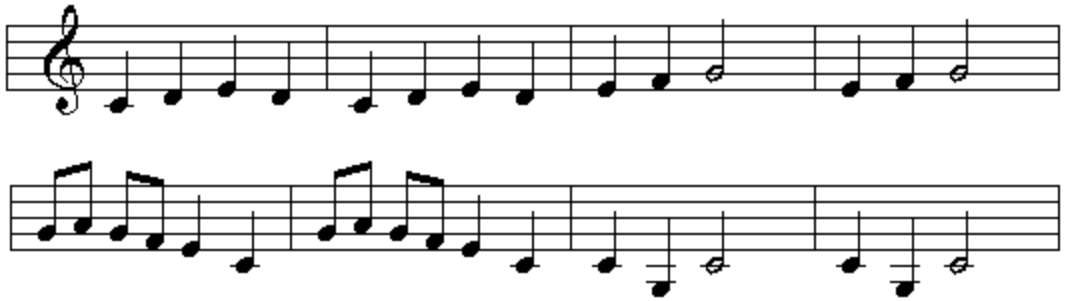
Specifying Music in JFugue

Additional MusicString commands

- Key Signature
  - Letter K followed by a key. Examples: KAbmin, KFmaj
  - All notes in the composition will be automatically played in the key
    - Example: a B note in an F-major key will be converted to B-flat.
- Timing Information
  - @ followed by a time in milliseconds to play next token
  - Seen especially when parsing MIDI files
- Grab bag of MIDI events
  - Pitch Wheel – useful for getting microtones out of MIDI!
  - Channel Pressure
  - Polyphonic Pressure
  - Controller Events – JFugue combines low- and high-bytes into one token

JFugue's Patterns
Music is Poetic

- Music frequently has repeated phrases
- "Frere Jacques"



- Patterns allow common bits of music to be re-used:

```
Pattern pattern1 = new Pattern("C5q D5q E5q C5q");
Pattern song = new Pattern();
song.add(pattern1, 2); // Adds 'pattern1' to 'song' twice
```

JFugue's Patterns
Music is Poetic

- Patterns are more than just MusicStrings…
- …Patterns can be altered in interesting ways
  - Reverse, invert, change durations, change pitches, swap instruments, etc.
- J. S. Bach's "Crab Canon" from "The Musical Offering"
  - Two players, playing simultaneously
  - The second player plays a mirror image of the first player's notes
  - See Douglas R. Hofstadter's "Gödel, Escher, Bach"
- CrabCanon in JFugue: (MusicString available at http://www.jfugue.org)

```
Pattern voice1 = new Pattern(notes for one voice);
Pattern voice2 = new
     RevesePatternTransformer.transform(voice1);
```

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Microtonal Music

"The notes between the cracks" – Charles Ives

- Occurrences of microtones:
  - Eastern music (Indian, Turkish)
  - Gamelan (Javanese, Balinese)
  - Modernist compositions (Charles Ives, Philip Glass)
  - Musical effects – portamento, slide trombone

- MIDI is capable of playing microtones, but it's hard to do
  - Requires combination of Note and Pitch Wheel events, and lots of math
- JFugue… wait for it… makes it easy!

- Three steps:
  - 1. Assign frequencies to microtonal notes
  - 2. Define your music
  - 3. Generate a Pattern and play it

Microtonal Music

```
public static void main(String[] args) {
 MicrotoneNotation microtone = new MicrotoneNotation();
 microtone.put("A440", 440.00); microtone.put("z3",   704.00);
 microtone.put("z1",   528.00); microtone.put("z4",   792.00);
 microtone.put("z2",   616.00); microtone.put("A880", 880.00);

 String micro1 = "<A440>s Rt <A440>s Rt <z1>s Rt <z1>s Rt";
 String micro2 = "<A440>q.";
 String micro3 = "<A880>t <z3>t <z4>t <z2>t <z3>t <z2>t”;

 Pattern pattern = new Pattern();
 pattern.add("V0 I[SKAKUHACHI]");
 pattern.add(microtone.getPattern(micro1), 3);
 pattern.add(microtone.getPattern(micro2));
 pattern.add("V1 I[VOICE_OOHS]");
 pattern.add(microtone.getPattern(micro3), 8);

 new Player().play(pattern);
}
```

Microtonal Music

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public static void main(String[] args) {
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 Pattern pattern = new Pattern();
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 pattern.add(microtone.getPattern(micro2));
 pattern.add("V1 I[VOICE_OOHS]");
 pattern.add(microtone.getPattern(micro3), 8);

 new Player().play(pattern);
}
```

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 pattern.add(microtone.getPattern(micro2));
 pattern.add("V1 I[VOICE_OOHS]");
 pattern.add(microtone.getPattern(micro3), 8);

 new Player().play(pattern);
}
```

Intervals

- Specify music as intervals instead of actual notes
  - Use the difference between the notes, instead of the notes themselves
  - This is different than Key Signature
  - Intervals can be followed by chords, durations, etc.
- Example:

```
public static void main(String[] args) {
    IntervalNotation riff =
        new IntervalNotation("<1>q <5>q <8>q <1>majH");

    Player player = new Player();
    player.play(riff.getPatternForRootNote("C5"));
    player.play(riff.getPatternForRootBote("Ab6"));
}
```

Rhythms

- Define beats in a natural, intuitive manner
  - Use your computer's keyboard like a drum machine
- Example:

O..oO...O..oOO..

- Three steps:
  - 1. Bang out your beat
  - 2. Assign MusicStrings to keys
  - 3. Generate a Pattern and play it

Rhythms

```
// This is a complete program for a 16-Beat Rock Rhythm
public static void main(String[] args) {
    Rhythm rhythm = new Rhythm();
    rhythm.setLayer(1, "O..oO...O..oOO..");
    rhythm.setLayer(2, "..*...*...*...*.");
    rhythm.setLayer(3, "^^^^^^^^^^^^^^^^");
    rhythm.setLayer(4, "................!");

    rhythm.addSubstitution('O', "[BASS_DRUM]i");
    rhythm.addSubstitution('o', "Rs [BASS_DRUM]s");
    rhythm.addSubstitution('*', "[ACOUSTIC_SNARE]i");
    rhythm.addSubstitution('^', "[PEDAL_HI_HAT]s Rs”);
    rhythm.addSubstitution('!', "[CRASH_CYMBAL_1]s Rs");
    rhythm.addSubstitution('.', "Ri");

    Pattern pattern = rhythm.getPattern();
    pattern.repeat(4);
    Player player = new Player();
    player.play(pattern);
}
```

Rhythms

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// This is a complete program for a 16-Beat Rock Rhythm
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    rhythm.setLayer(3, "^^^^^^^^^^^^^^^^");
    rhythm.setLayer(4, "...............!");

    rhythm.addSubstitution('O', "[BASS_DRUM]i");
    rhythm.addSubstitution('o', "Rs [BASS_DRUM]s");
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    rhythm.addSubstitution('.', "Ri");

    Pattern pattern = rhythm.getPattern();
    pattern.repeat(4);
    Player player = new Player();
    player.play(pattern);
}
```

Rhythms and Intervals

- You can use Intervals in your Rhythms to create beats with riffs

```
rhythm.setLayer(1, "o...o...o...o...o...o...o...o...");
rhythm.setLayer(2, "..*...*...*...*...*...*...*...*.");
rhythm.setLayer(3, "...%...%...%...%...%...%...%...%");
rhythm.setVoice(1, "jjnnjjmlnnllnnlkjjnnjjmlkkklnnnk");

rhythm.addSubstitution('j', "<1>s Rs");
rhythm.addSubstitution('k', "<6>s Rs");
rhythm.addSubstitution('l', "<8>s Rs");
// etc.
```

- Now get the music for given a specific root note


```
Pattern pattern = rhythm.getPatternWithInterval("Bb4");
Pattern pattern = rhythm.getPatternWithInterval("A5");
```

Sharing Music with MIDI Devices
Talk to Your Musical Keyboard

- Sending music to an external device is very easy:

```
DeviceThatWillReceiveMidi device =
    new DeviceThatWillReceiveMidi(MidiDevice.Info);
sequence = player.getSequence(pattern);
device.sendSequence(sequence);
// Also: sequence = MidiSystem.getSequence(File);
```

- Reading music from an external device is very easy:

```
DeviceThatWillTransmitMidi device =
    new DeviceThatWillTransmitMidi(MidiDevice.Info);
device.listenForMillis(5000);
Pattern pattern = device.getPatternFromListening();
```

- Each of these handles many of lines of MIDI code

Loading and Saving Patterns and MIDI

- Patterns can be loaded and saved:
  - `pattern.savePattern(File)`
  - `Pattern pattern = Pattern.loadPattern(File)`
- Music can be saved as MIDI
  - `player.saveMidi(Pattern, File)`
- Music can be loaded from MIDI and converted into a Pattern!
  - `Pattern pattern = Pattern.loadMidi(File)`
- JFugue can also be load and save MusicXML
  - Other formats on the horizon!

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JFugue Under the Hood
Parsers & ParserListeners

- JFugue parses musical notation, and generates musical events
- Originally, JFugue parsed MusicStrings and generated MIDI
- Then, JFugue could parse MIDI and generate MusicStrings
  - Get – and play with – JFugue notation for your favorite MIDI files!
- Most recently, JFugue can parse and render MusicXML files
  - Thanks to contributions from the community!
- All of these are interchangeable!

JFugue Under the Hood
Parsers & ParserListeners

- A Parser knows how to convert data into musical events
- A ParserListener knows how to handle/render musical events

- Code to connect Parsers and ParserListeners:

```
YourParser parser = new YourParser();
YourRenderer renderer = new YourRenderer();
parser.addParserListener(renderer);
parser.parse(whatever object the parser can parse);
```

JFugue Under the Hood
Fun with Parsers & ParserListeners

- Parsers and ParserListeners aren't limited to musical formats!
- Potential types of Parsers or ParserListeners:
  (none of these exist today)
  - SheetnoteRenderer – convert music to a graphical sheet of music
  - VisualizationRenderer – create fancy graphics based on the music
  - SpamParser – take junk email and convert it to music

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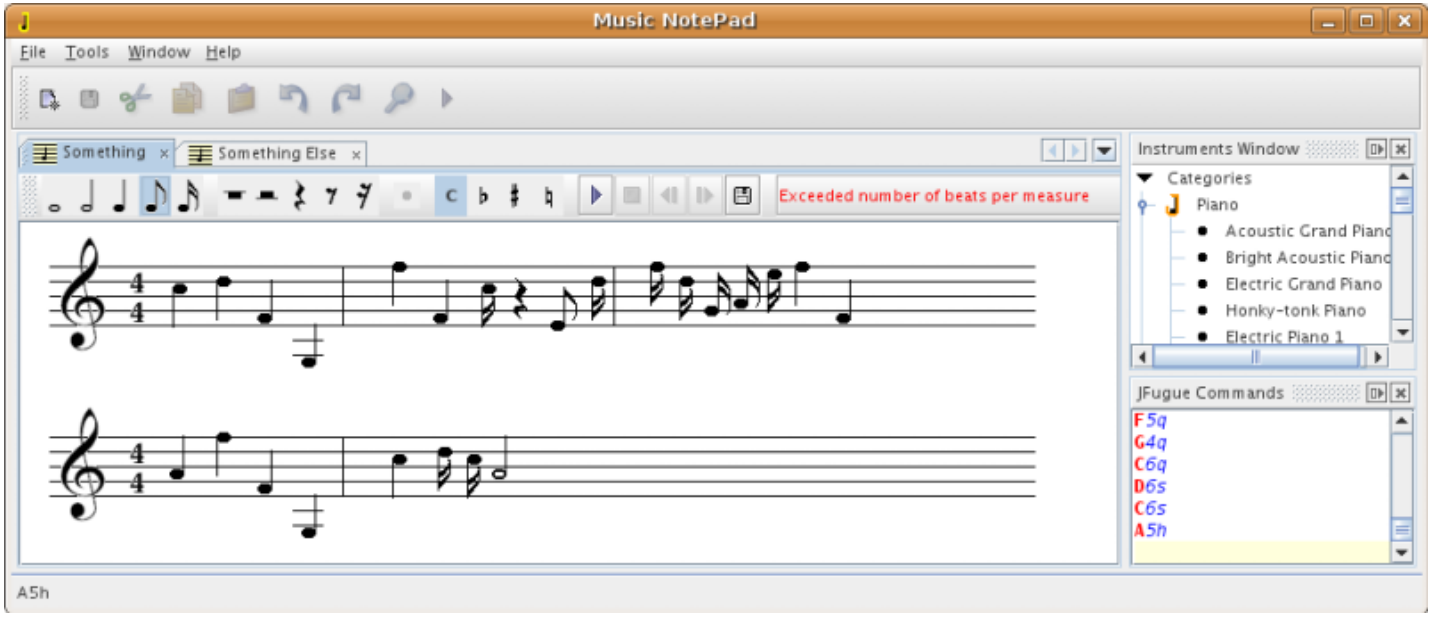
JFugue Music NotePad

- A simple, standalone application for creating music
  - Uses JFugue API; generates JFugue MusicStrings
- User interface is based on the NetBeans platform
- Entirely separate open-source project from JFugue
  - Started by Geertjan Weilenga – http://blogs.sun.com/geertjan/
  - Website: https://nbjfuguesupport.dev.java.net/



JFugue + Ant
Hear the status of your build

- From Geertjan Weilenga's blog
  http://blogs.sun.com/geertjan/entry/ode_to_build_scripts

- AntLogger class can listen to AntEvents
- Play a JFugue pattern when the build finishes
  - Happy tune for a successful build
  - Dark tune for a failed build

JFugue + Ant

```
import org.apache.tools.ant.module.spi.AntLogger;

public class BuildLogger extends AntLogger {

  public void buildFinished(AntEvent event) {
    Player player = new Player();
    Throwable t = event.getException();
    if (t != null) {
      // There has been an exception
      event.getSession().println(t.toString(), true, null);
      player.play("I[String_Ensemble_1] B3q Bb3q. G3i F3h");
    } else {
      // Build was successful
      player.play("I[French_Horn] As E6h As E6i Rt As E6h");
    }
  }

  public boolean interestedInSession(AntSession session) { return true; }
  public boolean interestedInAllScripts(AntSession session) { return true; }
}
```

When Programs Create Music

Use JFugue to Make Music Programmatically

- What might you create if you could programmatically define music?
  - *There's* something you can't do with a graphical music editor!

JFugue Drum Circle
We Got the Beat

- Start with JFugue's Rhythm class, with layers set to empty

t_0: `...............` `...............` `...............`

- Gradually and randomly add and remove 'strikes' from layers

t_1: `.a.............` `........b..b...` `..c.....cc......`
t_2: `.a...a....a.....` `..b.....b..b...` `...c....cc......`
t_3: `.a...aa...a...a.` `..bb.....b.....` `...c....c.......`
t_4: `.....a....a...a.` `..bb.....b....b.` `...cc...c....c..`

- Assign tones to strikes

```
rhythm.addSubstitution("a", "[HAND_CLAP]i");
rhythm.addSubstitution("b", "[BASS_DRUM]i");
rhythm.addSubstitution("c", "[LOW_BONGO]i");
```

- Play the rhythm!

```
player.play(rhythm.getPattern());
```

“The Sound of Shopping”
Turning Barcodes into Music

- Interactive exhibit turns barcodes, date and time of purchase into sequence of numbers
- A human composer specifies how numbers are made into music

Date start = 2008-02-08 14:42:10
Date end = 2008-02-08 14:42:47
ID = AA020
Barcodes = [54353]
K-Code =
770837452031941401436563400765351575415656506754345837825622920046164328 7
Ruleset = RuleSet4
Instrumentset = InstrumentSet4_3
JFugue = T113V15 [76]qia87 [73]sa91 Rs [69]qia79 [73]sa77 [78]qa75 [73]hqa79 [68]sa67 [71]sa80 Ri [73]sa80 [75]sa80 Rs [76]hqa83 [69]ha75 Rq [75]ha91 [78]ha75 [76]hqa95 [80]hqa75 [73]qia79 Rs . . .

- http://www.soundofshopping.com

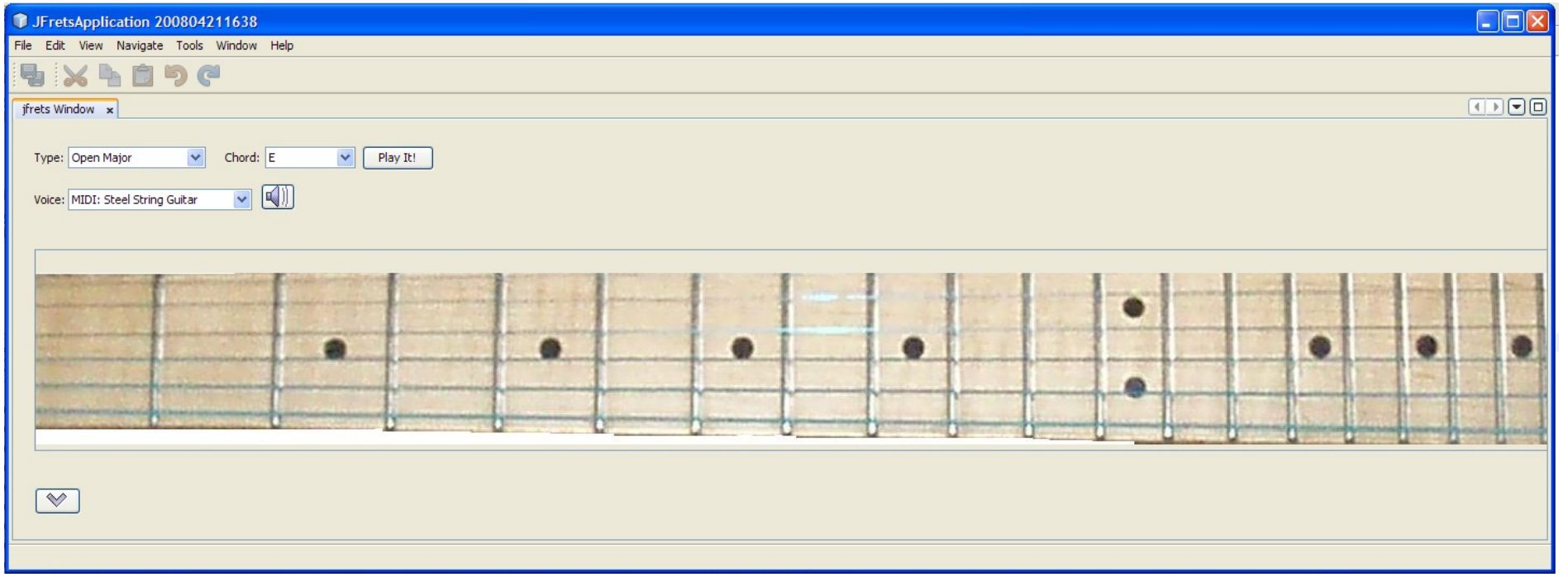
Agenda

- Introduction to JFugue
- Making Music with JFugue
- JFugue's Advanced Features
- Applications of JFugue
- JFugue Under the Hood
- JFugue and JFrets

What Is JFrets?

- Teaches guitar in an interactive desktop tool
- Displays notes, chords, and scales
- Plays sounds to aid in learning process
- Provides tutorials and exercises
- Ability to create and save guitar tablature
- Guitar tablature playback

What is JFrets?



How is JFugue used in JFrets?

- User selects MIDI voice
- User selects a note/chord
- User can set the Beats Per Minute
- The selection is parsed into a JFugue format and played

JFugue Code

```
Player player = new Player();
String patternString =
  getMidiType((String)this.voiceBox.getSelectedItem()) +
  noteName;
patternString = "T" + bpm + " " + patternString;
Pattern pattern = new Pattern(patternString);
player.play(pattern);
```

Audio Streaming Code

```
try
{
    File audio = new File(getClass().getResource("/org/jfrets/sounds/" + file).toURI());
    float sample = 128000;
    AudioInputStream ais = AudioSystem.getAudioInputStream(audio);
    AudioFormat af = ais.getFormat();
    AudioFormat target = new AudioFormat(AudioFormat.Encoding.PCM_SIGNED, af.getSampleRate(), 16,
    af.getChannels(), af.getChannels() * 2, af.getSampleRate(), false);
    AudioInputStream decode = AudioSystem.getAudioInputStream(target, ais);
    DataLine.Info info = new DataLine.Info(SourceDataLine.class, target);
    SourceDataLine line = (SourceDataLine) AudioSystem.getLine(info);
    line.open(target);
    if (line != null)
    {
         byte[] data = new byte[4096];
         line.start();
         int bytesRead;
         while ((bytesRead = decode.read(data, 0, data.length)) != -1)
         {
            line.write(data, 0, bytesRead);
         }
         line.drain();
         line.stop();
         line.close();
         decode.close();
    }
} catch (IOException e) {
    /* handle this exception */
} catch (LineUnavailableException e) {
    /* handle this exception */
} catch (URISyntaxException e) {
    /* handle this exception */
} catch (UnsupportedAudioFileException e) {
    /* handle this exception */
}
```

Don't worry, you're not supposed to be able to read this.

And you certainly shouldn't have to program it.

JFrets Capabilities

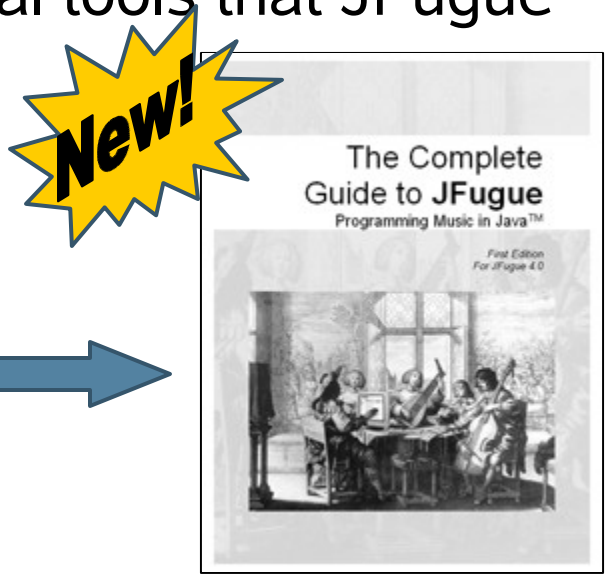
- Saves, displays, and plays guitar tablature
- Creates songs in tab or note format
- Provides a Metronome
- Provides a Scale Player
- Contains a guitar tuner with various tunings
- Prints tabs or songs

JFrets Demo

Summary

- JFugue makes music programming easy and fun
  - Create exciting new musical things!
  - Get your kids interested in programming!
  - Impress your co-workers!
  - Rekindle your joy of programming!
- JFrets exemplifies the kind of musical tools that JFugue can help make possible
- Java API Rocks!

- Project websites
  - JFugue – http://www.jfugue.org
  - JFrets - https://jfrets.dev.java.net



THANK YOU

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