Using Type Annotations to Improve Your Code

Birds-of-a-Feather Session

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Schedule

Java 8 syntax for type annotations

Pluggable types: a use of type annotations

Questions and discussion

Since Java 5: declaration annotations

Only for **declaration** locations:

```
@Deprecated
class Foo {
    @Getter @Setter private String query;
    @SuppressWarnings(“unchecked”)
    void foo() { … }
}
```

class

field

method

✓

Java 8 adds type annotations

Annotations on all occurrences of types:

```
@Untainted String query;
List<@NonNull String> strings;
myGraph = (@Immutable Graph) tmp;
class UnmodifiableList<T>
  implements @Readonly List<T> {}
```

Stored in classfile

Handled by javac, javap, javadoc, …

✓

Array annotations

```
String [] [] a;
```

An array of arrays of strings

Array annotations

```
String          []          [] a;
```

An array of
arrays of
strings

✓

Array annotations

```
        String            []              [] a;
```

A read-only array of
    non-empty arrays of
        English strings

Array annotations

```
@English String @ReadOnly [] @NonEmpty [] a;
```

A read-only array of
    non-empty arrays of
        English strings

Rule: write the annotation before the type ✓

Explicit method receivers

```
class MyClass {
  public String toString() {}
  public boolean equals(Object other) {}


}
```

✓

Explicit method receivers

```
class MyClass {
  public String toString() {}
  public boolean equals(Object other) {}


}


myval.toString();
myval.equals(otherVal);
```

✓

Explicit method receivers

```
class MyClass {
  public String toString(MyClass this) {}
  public boolean equals(MyClass this,
                        Object other) {}
}
```

```
myval.toString();
myval.equals(otherVal);
```

No impact on method binding and overloading

✓

Explicit method receivers

```
class MyClass {
  public String toString(@ReadOnly MyClass this) {}
  public boolean equals(@ReadOnly MyClass this,
                        @ReadOnly Object other) {}
}

myval.toString();
myval.equals(otherVal);
```

Constructor return & receiver types

Every constructor has a return type

```
class MyClass {
  @TReturn MyClass(@TParam String p) {...}
```

Inner class constructors also have a receiver

```
class Outer {
  class Inner {
    @TReturn Inner(@TRecv Outer Outer.this,
                   @TParam String p) {...}
```

Why were type annotations added to Java?

Annotations are a specification

- More concise than English text or Javadoc
- Machine-readable
- Machine-checkable

- Improved documentation
- Improved correctness

Pluggable Type Systems

- Use Type Annotations to express properties
- Prevent errors at compile time

http://CheckerFramework.org/

Twitter: @CheckerFrmwrk

Facebook/Google+: CheckerFramework

Java's type system is too weak

Type checking prevents many errors

```
int i = “hello”;
```

Type checking doesn't prevent enough errors

```
System.console().readLine();

Collections.emptyList().add(“one”);
```

✓

Java's type system is too weak

Type checking prevents many errors

```
int i = “hello”;
```

Type checking doesn't prevent enough errors

NullPointerException

```
System.console().readLine();

Collections.emptyList().add(“one”);
```

Java's type system is too weak

Type checking prevents many errors

```
int i = “hello”;
```

Type checking doesn't prevent enough errors

```
System
Collections.emptyList().add(“one”);
```

UnsupportedOperationException

✓

Solution: Pluggable Type Checking

1. Design a type system to solve a specific problem
2. Write type qualifiers in code (or, use type inference)

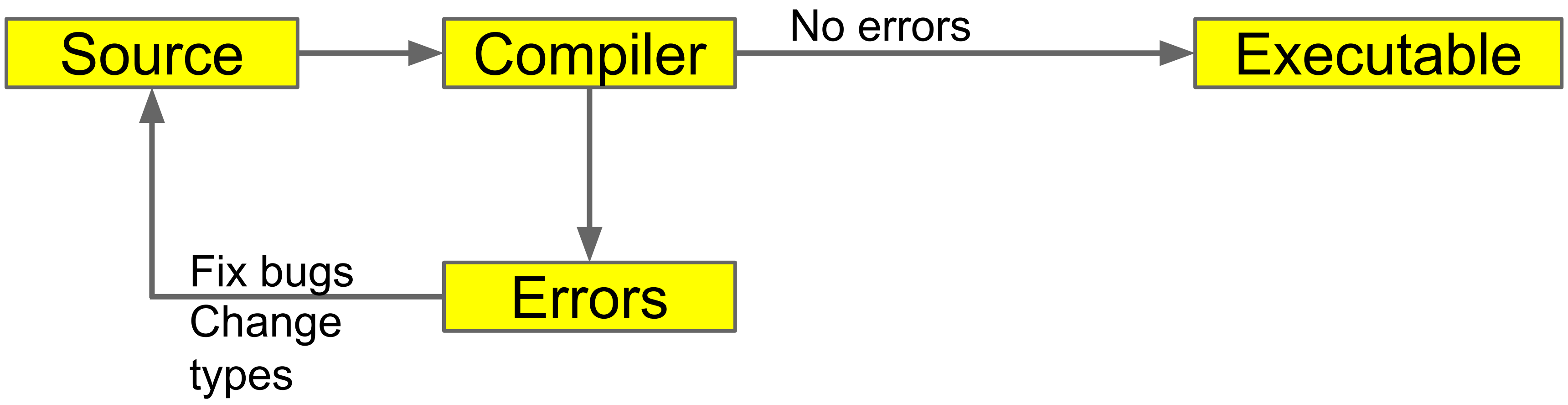
```
@Immutable Date date = new Date();
date.setSeconds(0);  // compile-time error
```

3. Type checker warns about violations (bugs)

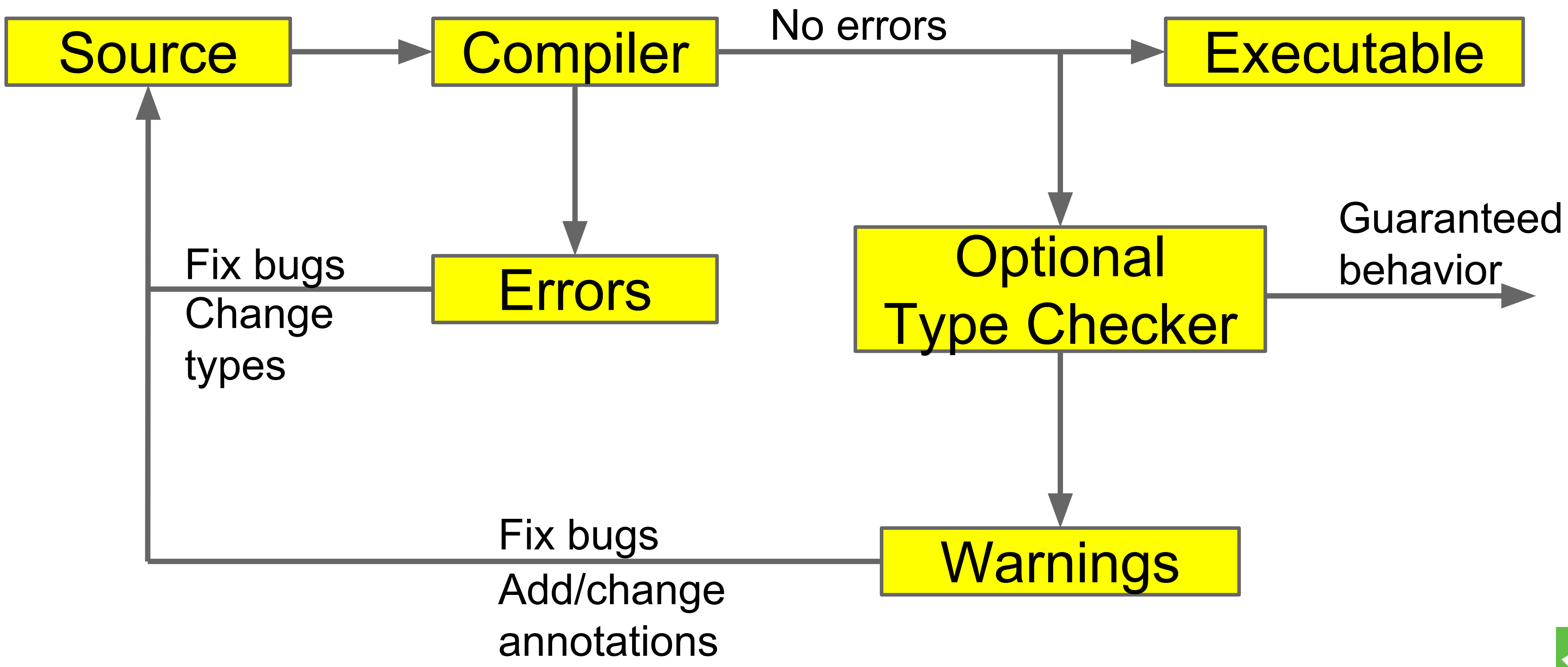
```
% javac -processor NullnessChecker MyFile.java

MyFile.java:149: dereference of possibly-null reference bb2
      allVars = bb2.vars;
                  ^
```

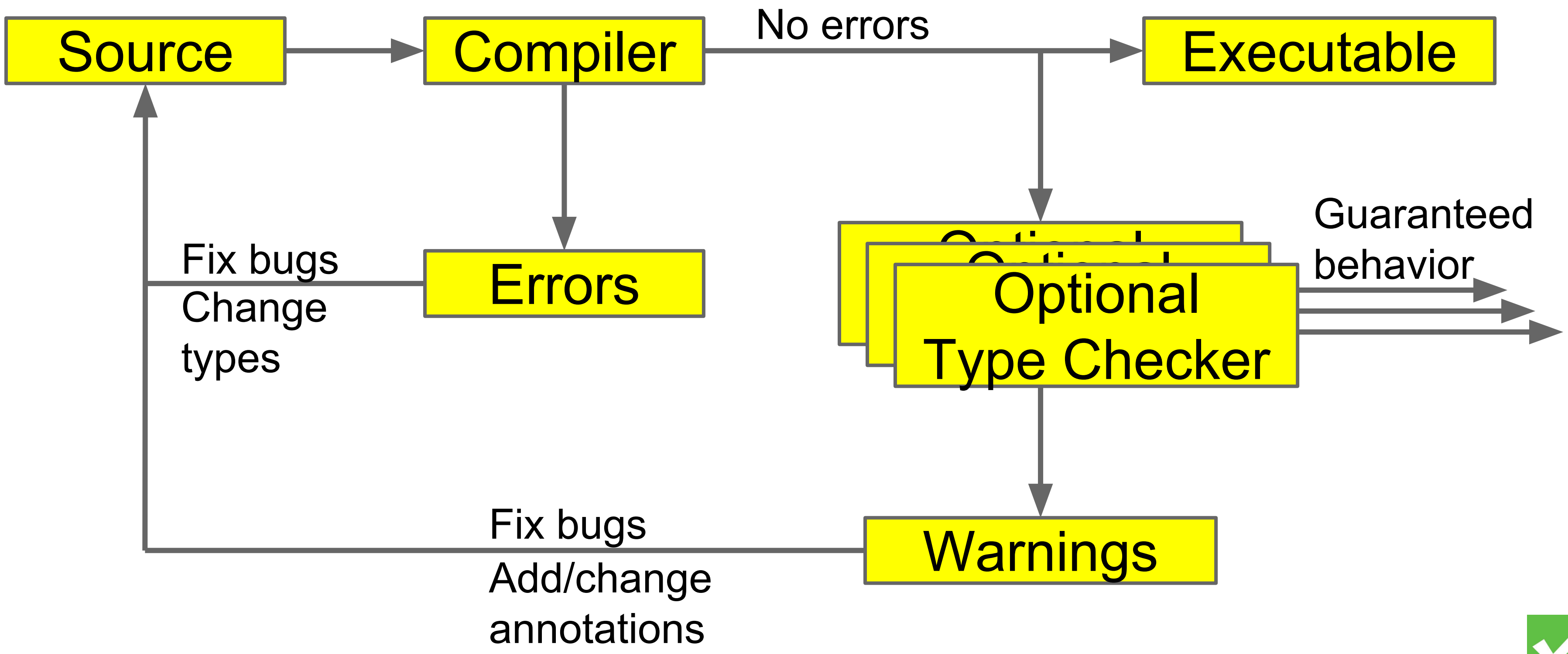
Type Checking



Optional Type Checking



Optional Type Checking



Example type systems

Null dereferences (`@NonNull`)

Equality tests (`@Interned`)

Concurrency / locking (`@GuardedBy`)

Command injection vulnerabilities (`@OsTrusted`)

Privacy (`@Source`)

Regular expression syntax (`@Regex`)

printf format strings (`@Format`)

Signature format (`@FullyQualified`)

Compiler messages (`@CompilerMessageKey`)

Fake enumerations (`@Fenum`)

You can write your own checker!

Java 8 extends annotation syntax

Annotations on all occurrences of types:

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@Untainted String query;
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```

Stored in classfile

Handled by javac, javap, javadoc, …

CF: Java 6 & 7 Compatibility

Annotations in comments

```
List</*@NonNull*/ String> strings;
```

Comments for arbitrary source code

```
/*>>> import myquals.TRecv; */
…
int foo(/*>>> @TRecv MyClass this,*/
              @TParam String p) {…}
```

✓

Static type system

Plug-in to the compiler

Doesn’t impact:

- method binding
- memory consumption
- execution

A future tool might affect run-time behavior ✓

Problem: annotation effort

Programmer must write type annotations

- on program code
- on libraries

Very few: 1 per 100 lines, often much less

- depends on the type system

Solution: type inference ✓

Type inference within a method

- Called “flow-sensitive refinement”
- A variable can have different types on different lines of code
- Low overhead
- Always used

Does not affect type signatures

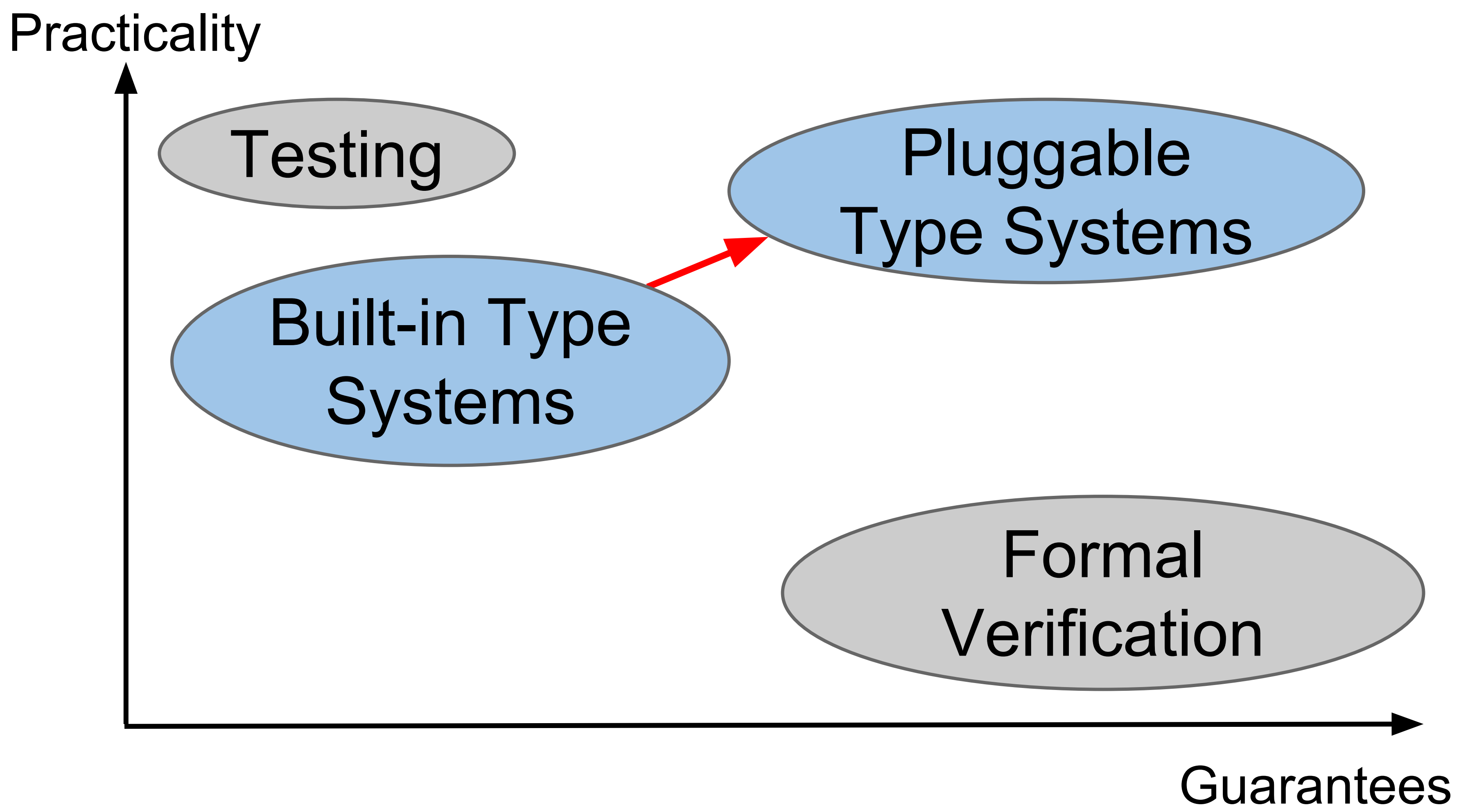
✓

Whole-program type inference

- Analyze **all** the code at once
- Determine the globally optimal annotations

Approach:

- Introduce placeholder for each location
- Use the same type rules to generate constraints
- Use a solver to find a solution


Practicality
Testing
Pluggable Type Systems
Built-in Type Systems
Formal Verification
Guarantees

Conclusions

Type Annotations added in Java 8

Checker Framework for creating type checkers

- Featureful, effective, easy to use, scalable

Prevent bugs at compile time

Improve your code!

`http://CheckerFramework.org/`