# status report

# JSR-305: Annotations for Software Defect Detection

# Why annotations?

- Static analysis can do a lot
  - can even analyze interprocedural paths
- Why do we need annotations?
  - they express design decisions that may be implicit, or described in documentation, but not easily available to tools

# Where is the bug?

```
if (spec != null) fFragments.add(spec);
if (isComplete(spec)) fPreferences.add(spec);
```

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```

```
boolean isComplete(AnnotationPreference spec) {
    return spec.getColorPreferenceKey() != null
        && spec.getColorPreferenceValue() != null
        && spec.getTextPreferenceKey() != null
        && spec.getOverviewRulerPreferenceKey() != null;
}
```

# Finding the bug

- Many bugs can only be identified, or only localized, if you know something about what the code is supposed to do
- Annotations are well suited to this...
  - e.g., @Nonnull

# JSR-305

- At least two tools already have defined their own annotations:
  - FindBugs and IntelliJ
- No one wants to have to apply two sets of annotations to their code
  - come up with a common set of annotations that can be understood by multiple tools

# JSR-305 target

- JSR-305 is intended to be compatible with JSE 5.0+ Java
- Hoped to have usable drafts and preliminary tool support out by the end of the summer
  - missed that, but close

# JSR-308

- Annotations on Java Types
- Designed to allow annotations to occur in many more places than they can occur now
  - ArrayList<@Nonnull String> a = ...
- Targets JSE 7.0
- Will add value to JSR-305, but JSR-305 cannot depend upon JSR-308

# Nullness

- Nullness is a great motivating example
- Most method parameters are expected to always be nonnull
  - some research papers support this
- Not always documented in JavaDoc

# Documenting nullness

- Want to document parameters, return values, fields that should always be nonnull
  - Should warn if null passed where nonnull value required
- And which should not be presumed nonnull
  - argument to equals(Object)
  - Should warn if argument to equals is immediately dereferenced

# Only two cases?

- What about Map.get(...)?
- Return null if key not found
  - even if all values in Map are nonnull
- So the return value can't be @Nonnull
- But lots of places where you "know" that the value will be nonnull
  - you know key is in table
  - you know value is nonnull

# 3 cases?

- May need to have 3 cases for nullness
  - @Nonnull
  - @NullFeasible
  - @UnknownNullness
- Would *love* better name suggestions
  - might use @Nullable for one of last two these
    - but which one?

# @Nonnull

- Should not be null
  - For fields, interpreted as should be nonnull after object is initialized
- Tools will try to generate a warning if they see a possibly null value being used where a nonnull value is required
  - same as if they see a dereference of a possibly null value

# @NullFeasible

- Code should always worry that this value might be null
  - e.g., argument to equals
- Tools should flag any dereference that isn't preceded by a null check

# @UnknownNullness

- Same as no annotation
  - Needed because we are going to introduce default and inherited annotations
  - Need to be able to get back to original state
- Null under some circumstances
  - might vary in subtypes, or depend on other parameters or state
- Interprocedural analysis might give us better information

# @NullFeasible requires work

- If you mark a return value as @NullFeasible, you will likely have to go make a bunch of changes
  - kind of like const in C++
- My experience has been that there are lots of methods that could return null
  - but that in a particular calling context, you may know that it can't

# Type Qualifiers

- Many of the JSR-305 annotations will be type qualifiers: additional type constraints on top of the existing Java type system
  - aka Pluggable type system

# @Nonnegative and friends

- Fairly clear motivation for @Nonnegative
- More?
  - @Positive
- Where do we stop?
  - @NonZero
  - @PowerOfTwo
  - @Prime

# Three-way logic again

- If we have @Nonnegative, do we also need:
  - @Signed
    - similar to @NullFeasible
    - returned by hashCode(), Random.nextInt()
  - @UnknownSign
    - similar to unknown nullness

# User defined type qualifiers

- In (too many) places, Java APIs use integer values or Strings where enumerations would have been better
  - except that they weren’t around at the time
- Lots of potential errors, uncaught by compiler

# Example in java.sql.Connection

createStatement(int resultSetType, int resultSetConcurrency, int resultSetHoldability)

Creates a Statement object that will generate ResultSet objects with the given type, concurrency, and holdability.

resultSetType: one of the following ResultSet constants: ResultSet.TYPE_FORWARD_ONLY, ResultSet.TYPE_SCROLL_INSENSITIVE, or ResultSet.TYPE_SCROLL_SENSITIVE

resultSetConcurrency: one of the following ResultSet constants: ResultSet.CONCUR_READ_ONLY or ResultSet.CONCUR_UPDATABLE

resultSetHoldability: one of the following ResultSet constants: ResultSet.HOLD_CURSORS_OVER_COMMIT or ResultSet.CLOSE_CURSORS_AT_COMMIT

# The fix

- Declare
  - public @TypeQualifier @interface ResultSetType {}
  - public @TypeQualifier @interface ResultSetConcurrency {}
  - public @TypeQualifier @interface ResultSetHoldability {}
- Annotate static constants and method parameters

# User defined Type Qualifiers

- JSR-305 won’t define @ResultSetType
- Rather JSR-305 will define the meta-annotations
  - that allow any developer to define their own type qualifier annotations
  - which they can apply and will be interpreted by defect detection tools

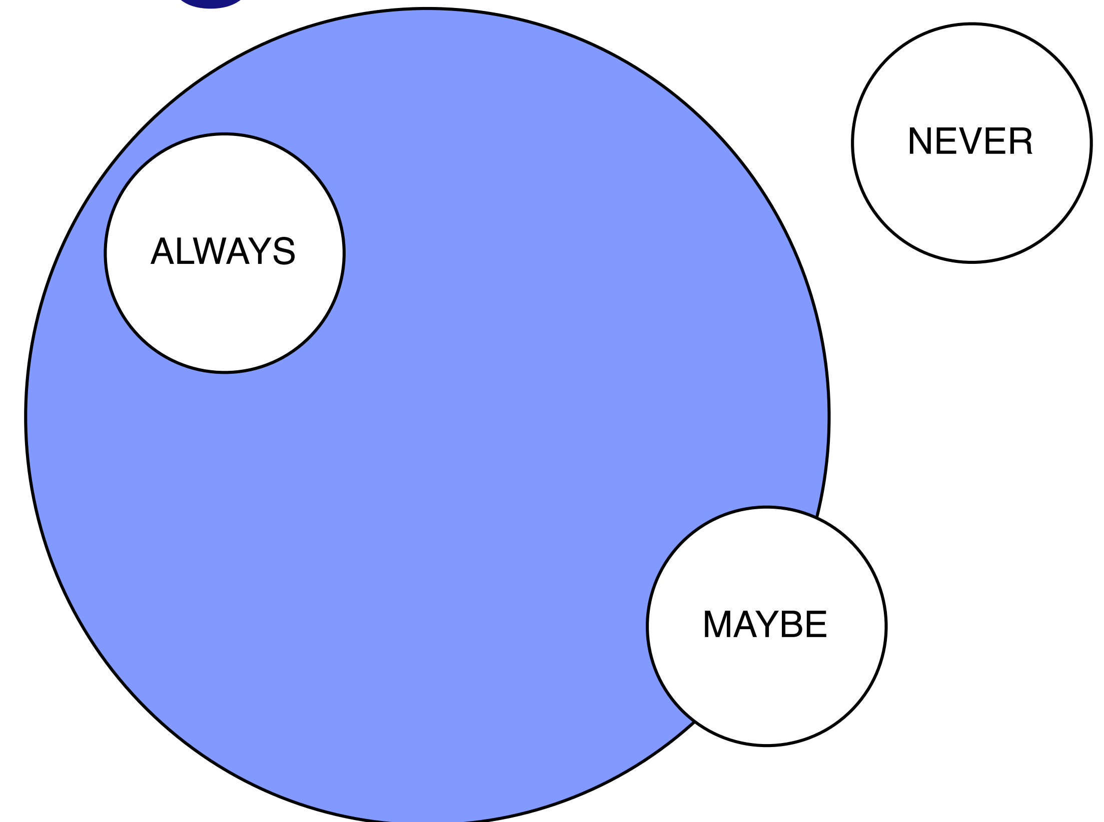
# Defining a type qualifier

```
@Documented
@TypeQualifier
@Retention(RetentionPolicy.RUNTIME)
public @interface Nonnull {
    When when() default When.ALWAYS;
    }
```

# The When element

- An enum that describes the relationship between
  - the values S allowed at a location and
  - the set T of values described by the type qualifier
- values: ALWAYS, NEVER, MAYBE, UNKNOWN

# Meanings




- ALWAYS: $S \subseteq T$
- NEVER: $S \subseteq \overline{T}$
- MAYBE: $\neg$ ALWAYS $\wedge$ $\neg$ NEVER
- UNKNOWN: true

# Applied to Nonnull

- Say we start by defining @Nonnull
- @Nonnull(when=When.MAYBE)
  - null feasible
- @Nonnull(when=When.UNKNOWN)
  - unknown nullness

# Why so many when's?

- Don't want to bias type qualifiers as to whether you start with the positive or negative version
  - @Nonnull(when=When.NEVER)
  - represents a value that is always null
- But what if we had started by defining @Null
  - @Null(when=When.NEVER)
    - nonnull
  - @Null(when=When.MAYBE)
    - null feasible

# More examples

- Start by defining @Negative
  - @Negative(when=When.NEVER)
    - nonnegative
  - @Negative(when=When.MAYBE)
    - signed

# Checking type qualifiers

- If we detect a feasible path on which a
  - ALWAYS or MAYBE source
  - flows to a NEVER sink
- generate a warning
- And the converse
  - NEVER or  MAYBE source flowing to an ALWAYS sink

# Strict type qualifiers

- If you don’t define a when element, the type qualifier is *strict*
  - applying it is treated as ALWAYS
  - anything else is treated as UNKNOWN
  - report a warning if an UNKNOWN source reaches an ALWAYS sink
- Great for stuff like @ResultSetHoldability

# Type qualifier nicknames

- No one wants to be typing

```
@Nonnull(when=When.MAYBE)
```

  all over the place
- Define a type qualifier nickname

```
@TypeQualifierNickname
@Nonnull(when=When.MAYBE)
public @interface NullFeasible {}
```

# Annotations other than type qualifier

Many of these not yet supported in FindBugs

# Thread/Concurrency Annotations

- Annotations to denote how locks are used to guard against data races
- Annotations about which threads should invoke which methods
- See annotations from *Java Concurrency In Practice* as a starting point

# JCP Annotations

```
@ThreadSafe

@NotThreadSafe

@Immutable

@GuardedBy(“this”)

@GuardedBy(“lock”)

@GuardedBy(...)
```

# What is wrong with this code?

```
Properties getProps(File file)
throws ... {
  Properties props = new Properties();
  props.load(new FileInputStream(file));
  return props;
  }
```

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```

Doesn’t close file

# Resource Closure

- @WillNotClose
  - this method will not close the resource
- @WillClose
  - this method will close the resource
- @WillCloseWhenClosed
  - Usable only in constructors: constructed object decorates the parameter, and will close it when the constructed object is closed

# Miscellaneous

- @CheckReturnValue
- @InjectionAnnotation

# @CheckReturnValue

- Indicates a method that should always be invoked as a function, not a procedure.
- Example:
  - String.toLowerCase()
  - BigInteger.add(BigInteger val)
- Anywhere you have an immutable object and methods that might be thought of a a mutating method return the new value

# @InjectionAnnotation

- Static analyzers get confused if there is a field or method that is accessed via reflection/ injection, and they don't understand it
- Many frameworks have their own annotations for injection
- Using @InjectionAnnotation on an annotation @X tells static analysis tools that @X denotes an injection annotation

# JSR-305 status

- Over the summer, David Hovemeyer and I have largely implemented what is described here for type qualifiers (mostly Dave)
  - not as far as long as we had hoped, but we are getting there