Semantic Tooling at Twitter

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Please use the Scala Days app to rate sessions.

Agenda

- State of developer tools at Twitter
- Vision of nextgen semantic tooling
- Proposed technology stack

twitter

State of the code

- Monorepo
- Consistent build
  - Now: retain agility!
- Persistent rumor: “Twitter is writing less Scala”
  - False.
  - JDK8 landed in Source about 1 year ago. In that period:
    - Scala codebase grew by 35%
    - Java codebase grew by 19%

Rewind: Monorepos? Monorepos.

- No diamonds
- Atomic cross-project changes
- Top-to-bottom continuous integration testing
- Linear change history
- No binary incompatibilities except at the boundary
    - ...although really just an argument for source distributions...?

Achieving the promise of a monorepo

- Requires tooling!
  - Previous talk: Pants (ref).
  - Previous talk: dependency hygiene (ref).
  - Today: semantic tooling!
- "Avoid deprecations in the common case"
  - Dead code in a monorepo is not like dead code in polyrepos!
- Rewriting `Future.get` to `Await.result` (last year) required a custom compiler plugin →

```
0899f3e util-core: Remove deprecated method Future.get(Duration)
 28 files changed, 293 insertions(+), 210 deletions(-)
60b8b21 util-core: Remove deprecated Future.get
 53 files changed, 403 insertions(+), 299 deletions(-)
6ed301d Replace calls to Future.get with Await.result
 116 files changed, 1113 insertions(+), 956 deletions(-)
7deee17 Replace calls to Future.get with Await.result
 131 files changed, 923 insertions(+), 760 deletions(-)
2855fa4 Replace calls to Future.get with Await.result
 174 files changed, 1476 insertions(+), 1222 deletions(-)
dfe0002 Replace calls to Future.get with Await.result
 51 files changed, 991 insertions(+), 688 deletions(-)
da6f09c Replace calls to Future.get with Await.result
 80 files changed, 815 insertions(+), 535 deletions(-)
```

State of semantic tooling

- Very coarse via target level dependencies:
  - ~2^16 targets, ~2^14 roots (tests+binaries)
- Slightly finer (class-level) semantic information via zinc analysis
  - ~2^22 class files
- Very fast text/regex based indexes
- Symbol level information available only in IDEs
- Very old Sourcegraph install recently deprecated
  - Legacy code for both companies: missing features, fragile integration
    - Compiler plugin specific to 1) Sourcegraph, 2) a compiler version
      - *but are moving toward using LSP extensions (ref)
  - But great direction! Not ruling out future open source collaboration.

vision

Code comprehension

- Table stakes; must be:
  - Orders of magnitude faster than grep
  - Find references-to
  - Find definition-of a symbol
- Going further toward understanding with:
  - Inheritance relationships
  - Documentation
  - Type awareness

Code review

- Context available for a patch
  - Warnings/errors from the compiler
  - Definitions/references

Code evolution

- Deprecations should be completely unnecessary for code that doesn’t escape the closed world!
- Decide whether to refactor…
  - Explore class/trait relationships
  - Filter calls by the call graph
- Then execute.
  - Scalafix!
  - Generic rewrite tools possible?

Executing the vision

- High resolution, antifragile semantic extraction...
- Distributed, language-agnostic* semantic index...
- Integration with language-agnostic tools...

scalameta

http://scalameta.org/

Nextgen metaprogramming library for Scala

- Syntactic API (2014-)
  - Tokens
  - Abstract syntax trees
  - Parsers
  - Quasiquotes
- Semantic API (2017-)
  - An independent open-source foundation for semantic tools
  - Already used at Twitter and at the Scala Center
  - Recently published technology preview within scalameta 1.6.0

Old-school semantic tooling for Scala

- Write a compiler plugin that runs after typer
- import global._
- Fight with compiler internals
- Rewrite your tool when a new minor version of Scala is released

Why old school didn’t work

Huge surface of the compiler API

- Tens of thousands LOC
- Dozens of different modules
- Thousands of different methods

First attempt (scalareflect, 2011)

- Reduce the API surface to several hundred most popular methods
- Guarantee stability across minor and even major Scala releases

Second attempt (scalameta, 2014)

- Further “compress” the API surface to several dozen most popular methods
- New data structures to enable new “compressed” APIs
- Convert back and forth between compiler and new data structures

Why these attempts didn’t work

Still using compiler data structures

- Immense data schema
- Very involved pre- and postconditions
- Require a running compiler
- Not serializable

Third attempt (scalameta, 2017)

- Dumb data schema to represent semantic information
- Give up on bidirectional interop with compiler data structures
- Still use the significantly reduced API surface from the second attempt

Semantic database

- Extremely simple data schema
- ~50 lines of protobuf code
- Supports resolved names, compiler messages and symbol denotations
- Technology preview for Scala 2.11.11 and Scala 2.12.2

example

Live demo: semantic db for an example Scala file

```scala
package com.example

class Printer {
  def print(msg: String): Unit =
    println(msg)
}

object Example {
  def main(args: Array[String]): Unit = {
    val msg = "Hello World"
    // Comment.
    new Printer().print(msg)
  }
}
```

Early feedback

- Semantic databases are extremely hackable
- Spawned a family of semantic tools that run outside the compiler
- Great potential for portability
- Great potential for scalability
- Simplicity of data schemas is seriously underrated

kythe

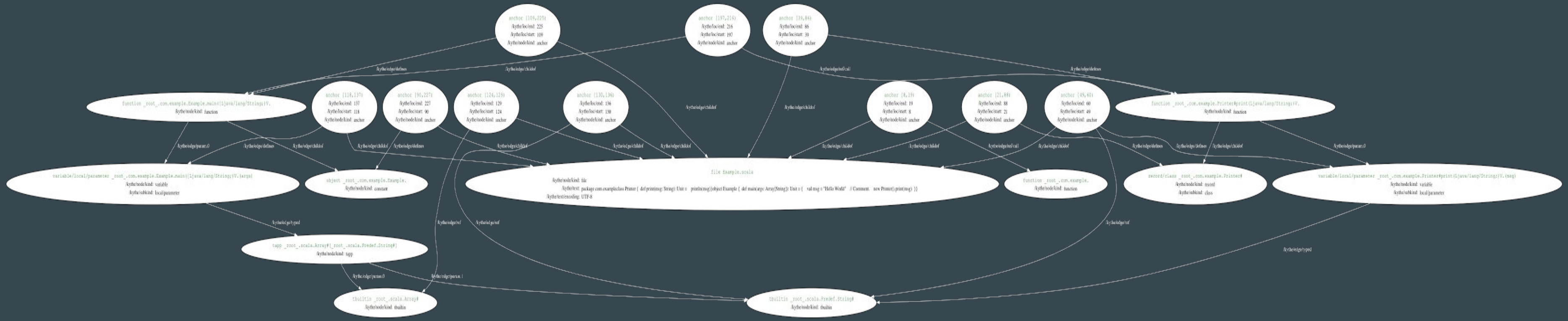
https://kythe.io/

Kythe: What is it?

- Common interchange/schema for semantic information about code
  - Symbol definitions/references
  - Callgraphs
  - Inheritance relationships
  - Generic/templated type information
- An index containing lots of relationships and kinds
  - ie: more than just “ref” and “def” (as found in most symbol indexes)
- ...how many relationships?

Kythe: A schema for a graph...

aliases
aliases/root
annotatedby
bounded/{upper,lower}
childof
childof/context
completes
completes/uniquely
defines
defines/binding
depends
documents
extends
generates
instantiates
instantiates/speculative
overrides
overrides/root
overrides/transitive
param
ref
ref/call
ref/doc
ref/expands
ref/expands/transitive
ref/imports
ref/includes
ref/queries
satisfies
specializes
typed
undefines
code
doc/uri
abs
absvar
anchor
constant
doc
file
interface
function
lookup
macro
meta
package
process
record
sum
talias
tapp
tbuiltin
tnominal
tsigma
variable
vcs
...


anchor [109,225)
/kythe/loc/end: 225
/kythe/loc/start: 109
/kythe/node/kind: anchor
anchor [197,216)
/kythe/loc/end: 216
/kythe/loc/start: 197
/kythe/node/kind: anchor
anchor [39,86)
/kythe/loc/end: 86
/kythe/loc/start: 39
/kythe/node/kind: anchor
function _root_.com.example.Example.main([Ljava/lang/String;)V.
/kythe/node/kind: function
anchor [118,137)
/kythe/loc/end: 137
/kythe/loc/start: 118
/kythe/node/kind: anchor
anchor [90,227)
/kythe/loc/end: 227
/kythe/loc/start: 90
/kythe/node/kind: anchor
anchor [124,129)
/kythe/loc/end: 129
/kythe/loc/start: 124
/kythe/node/kind: anchor
anchor [130,136)
/kythe/loc/end: 136
/kythe/loc/start: 130
/kythe/node/kind: anchor
anchor [8,19)
/kythe/loc/end: 19
/kythe/loc/start: 8
/kythe/node/kind: anchor
anchor [21,88)
/kythe/loc/end: 88
/kythe/loc/start: 21
/kythe/node/kind: anchor
anchor [49,60)
/kythe/loc/end: 60
/kythe/loc/start: 49
/kythe/node/kind: anchor
function _root_.com.example.Printer#print(Ljava/lang/String;)V.
/kythe/node/kind: function
variable/local/parameter _root_.com.example.Example.main([Ljava/lang/String;)V.(args)
/kythe/node/kind: variable
/kythe/subkind: local/parameter
object _root_.com.example.Example.
/kythe/node/kind: constant
file Example.scala
/kythe/node/kind: file
/kythe/text: package com.exampleclass Printer { def print(msg: String): Unit = println(msg)}object Example { def main(args: Array[String]): Unit = { val msg = "Hello World" // Comment. new Printer().print(msg) }}
/kythe/text/encoding: UTF-8
function _root_.com.example.
/kythe/node/kind: function
record/class _root_.com.example.Printer#
/kythe/node/kind: record
/kythe/subkind: class
variable/local/parameter _root_.com.example.Printer#print(Ljava/lang/String;)V.(msg)
/kythe/node/kind: variable
/kythe/subkind: local/parameter
tapp _root_.scala.Array#[_root_.scala.Predef.String#]
/kythe/node/kind: tapp
tbuiltin _root_.scala.Array#
/kythe/node/kind: tbuiltin
tbuiltin _root_.scala.Predef.String#
/kythe/node/kind: tbuiltin
/kythe/edge/defines
/kythe/edge/childof
/kythe/edge/ref/call
/kythe/edge/param.0
/kythe/edge/param.1
/kythe/edge/typed
/kythe/edge/ref

A Graph.

Viz courtesy of Benjy Weinberger

Kythe: Value proposition

- Hub-and-spoke
  - Write once, run on any codebase
- Multi-language/platform
  - C++, Go, Java, Protobuf, Common Lisp
  - In-progress implementations for: Python, ES6, Typescript… Scala
- Support for very large graphs
  - Index for Chromium (~2^24 LOC) is ~50GB
- From Twitter's perspective:
  - Java, Scala on the "same" platform
  - Python, Go, Javascript on their own platforms
  - thrift and protobuf on all the platofmrs

Kythe: Language-agnostic tooling?

- Included:
  - xrefs server and API
  - Complex graph queries with, eg. Cayley.io
  - Simple-but-powerful cli tool
  - Import/export as triples/quads/ctags/etc
  - Example call-graph analyses
  - Toy code browser UI
- Possible:
  - Documentation browser?
  - Code Analytics?
  - Incremental compilation?
  - Dead code elimination via call-graph analysis?

Kythe: Adding Scala support

- Most “functional” of the supported languages
  - …but similarly abstraction-rich to C++, which also supports HKT.
- Necessary to integrate with Java
  - ie: have a uniform “key” for a symbol defined by Java
  - …ideally without a dependency on javac.

scalameta-kythe

- Implementation
  - Uses a scalameta Mirror to consume semantic dbs
  - Walks the scalameta AST and consumes Symbols and Denotations to index
  - Uses Kythe's Java API to emit "entries" (essentially: triples)
- Supported so far:
  - A few definition nodes and their anchors
    - class, object, def, parameters, type application
  - A few relationships
    - childof, defines, ref(erences), param.0-N, typed

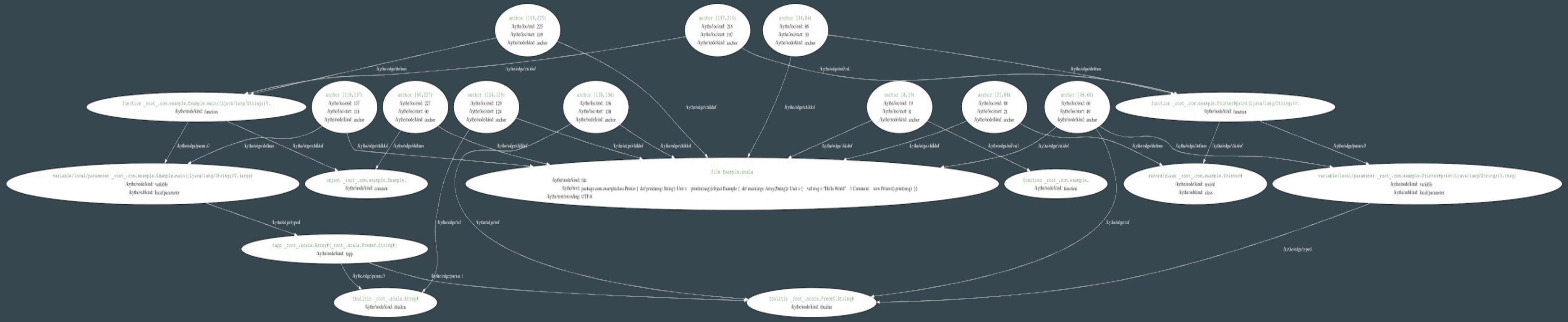
example

```scala
package com.example

class Printer {
  def print(msg: String): Unit =
    println(msg)
}

object Example {
  def main(args: Array[String]): Unit = {
    val msg = "Hello World"
    // Comment.
    new Printer().print(msg)
  }
}
```

Take that same Scala file...

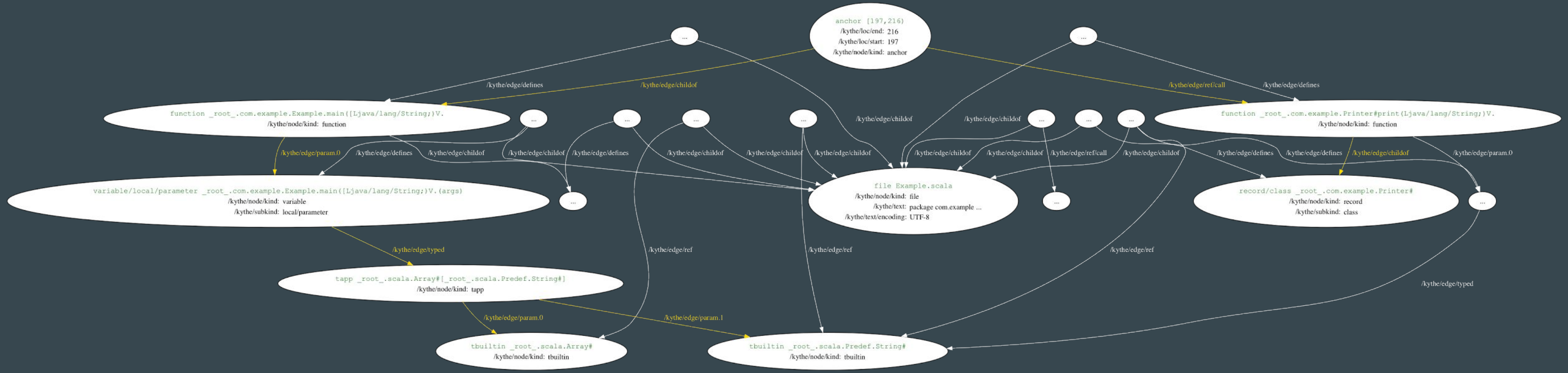
...Build using the scalahost compiler plugin...

...Emit kythe “entries” using the scalameta-kythe indexer...

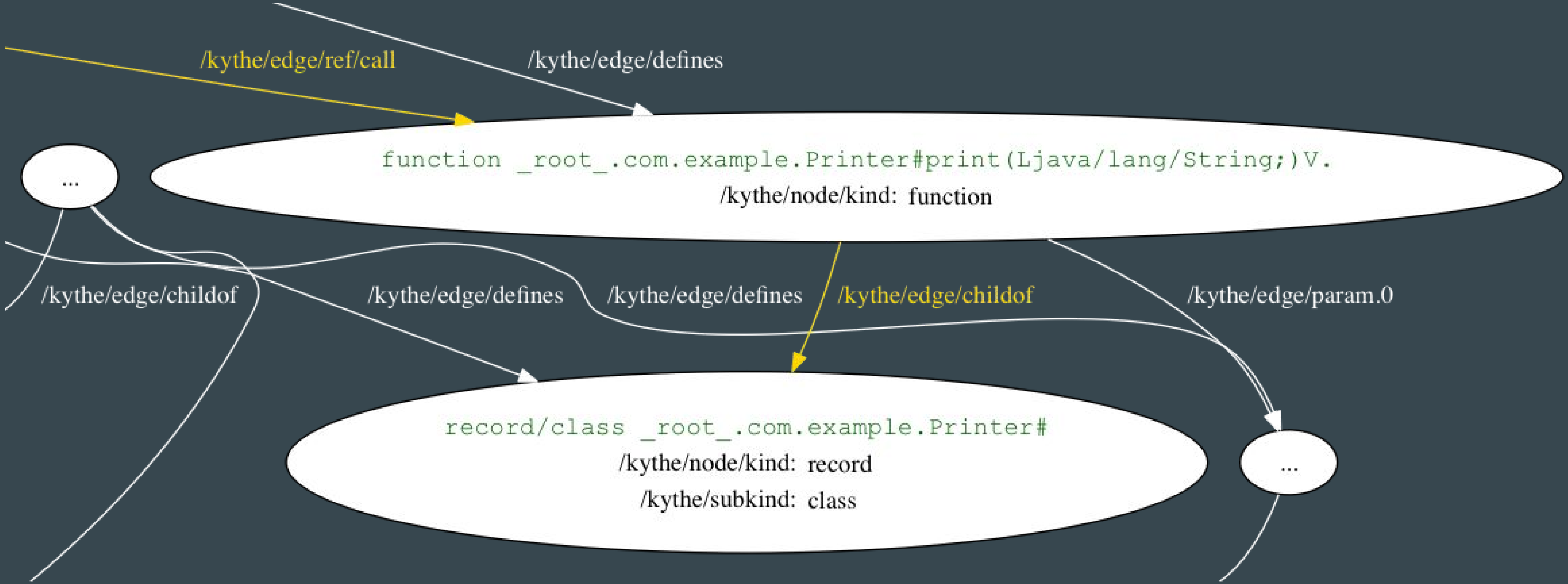


Render the resulting graph.

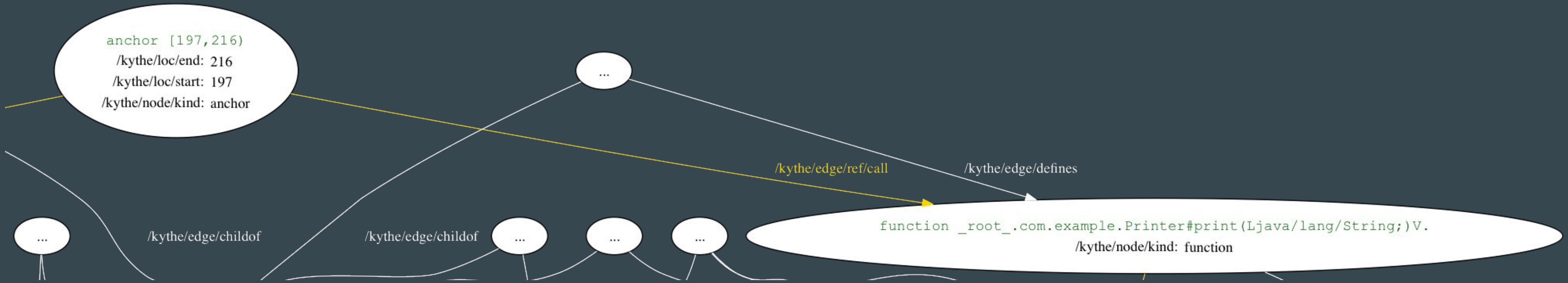
Viz courtesy of Benjy Weinberger


anchor [197,216)
/kythe/loc/end: 216
/kythe/loc/start: 197
/kythe/node/kind: anchor
function _root_.com.example.Example.main([Ljava/lang/String;)V.
/kythe/node/kind: function
function _root_.com.example.Printer#print(Ljava/lang/String;)V.
/kythe/node/kind: function
variable/local/parameter _root_.com.example.Example.main([Ljava/lang/String;)V.(args)
/kythe/node/kind: variable
/kythe/subkind: local/parameter
file Example.scala
/kythe/node/kind: file
/kythe/text: package com.example ...
/kythe/text/encoding: UTF-8
record/class _root_.com.example.Printer#
/kythe/node/kind: record
/kythe/subkind: class
tapp _root_.scala.Array#[_root_.scala.Predef.String#]
/kythe/node/kind: tapp
tbuiltin _root_.scala.Array#
/kythe/node/kind: tbuiltin
tbuiltin _root_.scala.Predef.String#
/kythe/node/kind: tbuiltin
/kythe/edge/defines
/kythe/edge/childof
/kythe/edge/ref/call
/kythe/edge/param.0
/kythe/edge/param.1
/kythe/edge/typed
/kythe/edge/ref
...

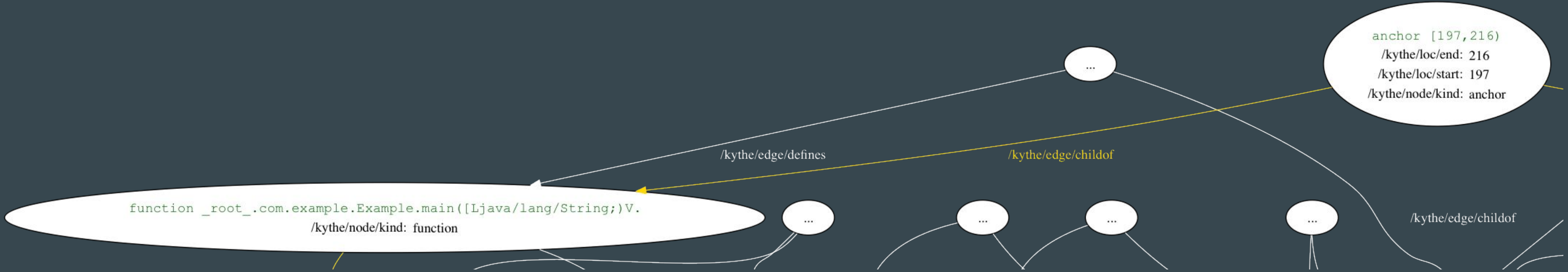
Highlight nodes along an interesting path...



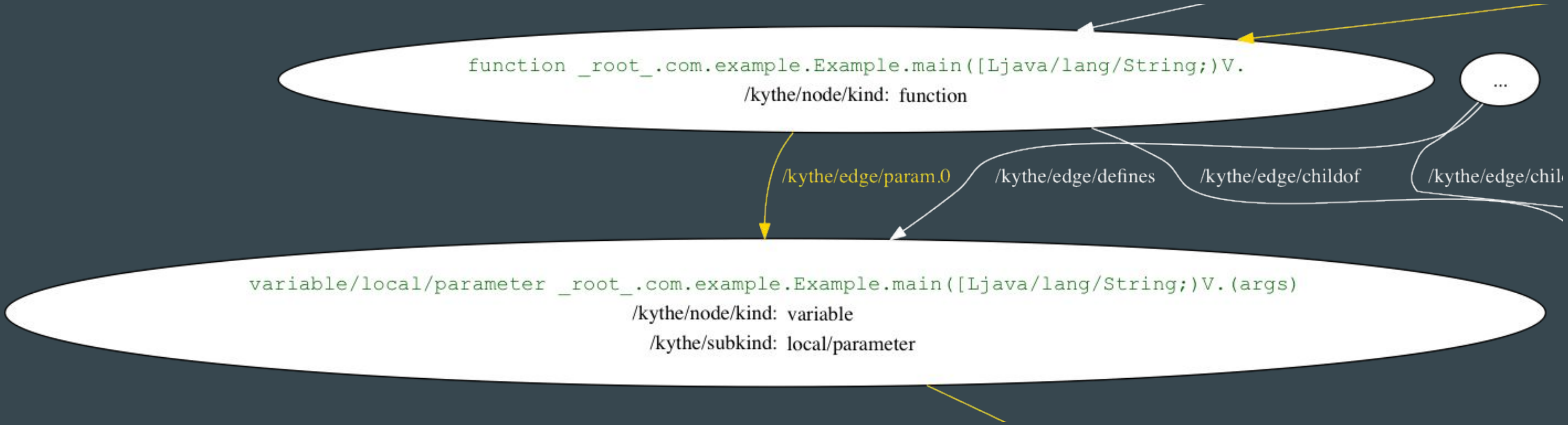
A function is a childof a class...



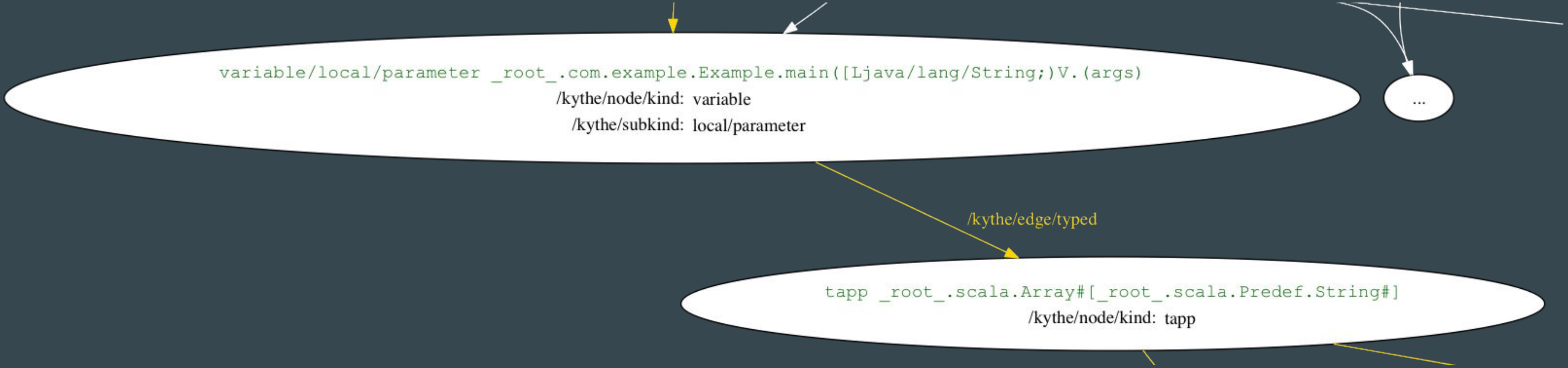
And that function is ref/call’d from a particular anchor.



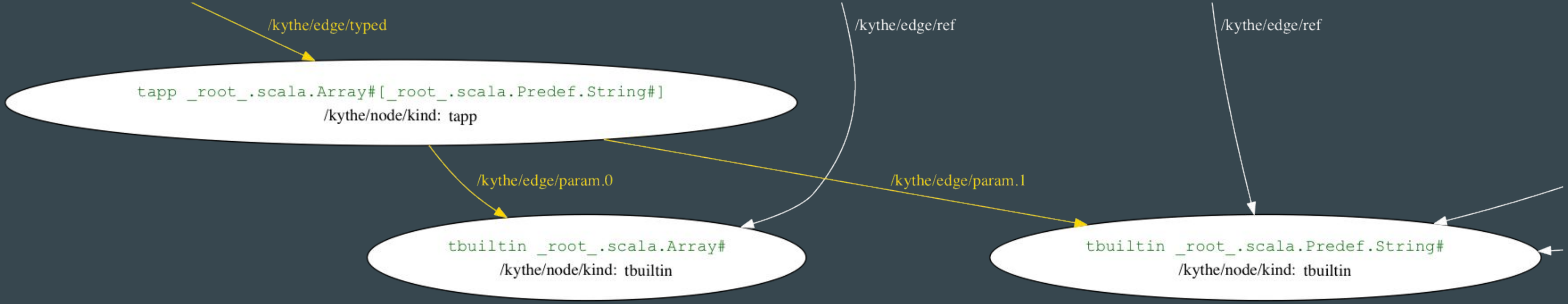
That anchor is childof (ie: a statement in) another function...


function _root_.com.example.Example.main([Ljava/lang/String;)V.
/kythe/node/kind: function
...
/kythe/edge/param.0
/kythe/edge/defines
/kythe/edge/childof
/kythe/edge/chil
variable/local/parameter _root_.com.example.Example.main([Ljava/lang/String;)V.(args)
/kythe/node/kind: variable
/kythe/subkind: local/parameter

That function has a parameter named `args`...


variable/local/parameter _root_.com.example.Example.main([Ljava/lang/String;)V.(args)
/kythe/node/kind: variable
/kythe/subkind: local/parameter
...
/kythe/edge/typed
tapp _root_.scala.Array#[_root_.scala.Predef.String#]
/kythe/node/kind: tapp

Which is typed as a tapp (type application) of...


/kythe/edge/typed
/kythe/edge/ref
/kythe/edge/ref
tapp _root_.scala.Array#[_root_.scala.Predef.String#]
/kythe/node/kind: tapp
/kythe/edge/param.0
/kythe/edge/param.1
tbuiltin _root_.scala.Array#
/kythe/node/kind: tbuiltin
tbuiltin _root_.scala.Predef.String#
/kythe/node/kind: tbuiltin

...two params: the builtins Array and String. Array[String].

Kythe: With Pants

- Integration with JVM languages supported by pants
  - Emit directly to a kythe API server?
    - ./pants --kythe-api=$servers index ::
  - Send to a DFS and then aggregate?
    - ./pants --kythe-out=$file index ::
  - Scalafix all targets owning files matching a query?
    - ./pants --kythe-api=$servers --kythe-query=$query fmt
- Initial support landed this week!
  - github.com/pantsbuild/pants/pull/4457

Kythe: Complexity / generality

- Adapting all languages to fit a particular schema is a monumental challenge
- Likely to never contain specific enough information for certain relationships
- But appears to be useful for 5-6 languages so far.

E

summary

Vision

Scalable semantic tooling for Scala and beyond:

- Code comprehension
- Code review
- Code evolution
- ...

Technology stack

- Extraction of semantic information (scalameta!)
  - Standalone data schema independent from a particular compiler
  - Portable across Scala implementations (Scala 2.x, Scala 3, IDEs)
  - Consumers are abstracted from compiler internals
- Indexing of semantic information (kythe?)
  - Distributed graph storage and indexes
  - Integration with all relevant languages
- Integration with language-agnostic tools

Status

- Draft specification of semantic dbs
  - Data schema that includes positions, symbols and denotations
  - Uses compiler-independent formulations of these concepts
- Technology preview of scalameta extraction into semantic dbs
  - Available in scalameta since 1.6.0
  - Supports Scala 2.11.11 and 2.12.2
  - Ongoing project to support Dotty
- Prototype of kythe indexing for semantic dbs
  - Using snapshot builds of scalameta 1.8.0
  - Technology preview will be open-sourced soon

Future work

- Integration with Twitter’s internal code search
- Integration with Phabricator
  - via ctags
- Further collaboration with Scalafix
- Keep an eye on TASTY
- Keep an eye on Sourcegraph

Credits

- Ólafur Páll Geirsson who co-designed the API and battle-tested it in Scalafix
- Fengyun Liu who influenced our design and started integration with Dotty
- Benjy Weinberger whose explanations of his pet project finally clicked
- pants, scala, scalameta, and kythe contributors ... like you!

Twitter is hiring!

- One of the largest Scala shops in the world
- Exciting research into developer tools
- Build team
  - Distributed compilation and testing
  - Semantic Indexing
  - IDE Integrations
  - (definitely more than just configuration wrangling!)

Questions?

SCALA DAYS CHICAGO 2017

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Thank you!

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