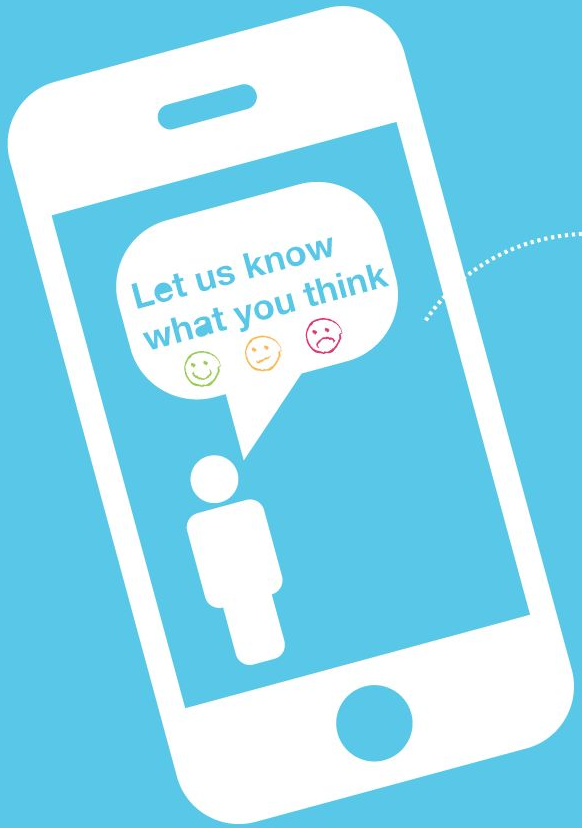
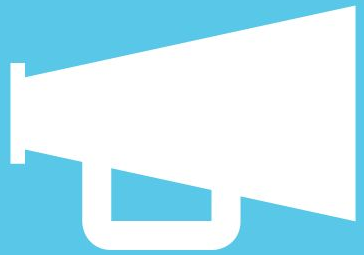
Semantic Tooling at Twitter

Eugene Burmako, Stu Hood





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Agenda

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

twitter

State of Source

- 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!

A day in the life of a core lib dev

- Not a bad environment!
  - Pre-commit unit and integration testing of all dependents
  - Atomic commit of changes to libraries and their consumers
  - Thousands of examples of usage of most APIs
  - Users sit right down the hall
- But not perfect.
  - How do I remove an API?

“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 (post codegen)
- Very fast text/regex based indexes
  - ~2^25 loc (pre codegen)

State of semantic tooling (continued)

- 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): great direction!
  - Not ruling out future open source collaboration.
- Pants support for scalafix (new!) and scalafmt
  - Not yet widely used internally
  - Big bang rewrite likely coming soon.

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/types on hover

Code evolution

- Deprecations should be completely unnecessary for code that doesn't escape the closed world!
- Decide whether to refactor by...
  - ...exploring class/trait relationships
  - ...filtering calls by scope or 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 1.8.0

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 language-version-specific 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, symbol denotations and sugars
- Technology preview for Scala 2.11.11 and Scala 2.12.2

example

Live demo: semantic db for an example Scala file

```
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

language-agnostic* semantic index?

kythe

kythe.io

Kythe: What is it?

- Common interchange/schema for semantic information about code
  - Symbol definitions/references
  - Callgraphs
  - Inheritance relationships
  - Generic/templated type information
- A scalable semantic index/graph for 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 semantic 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

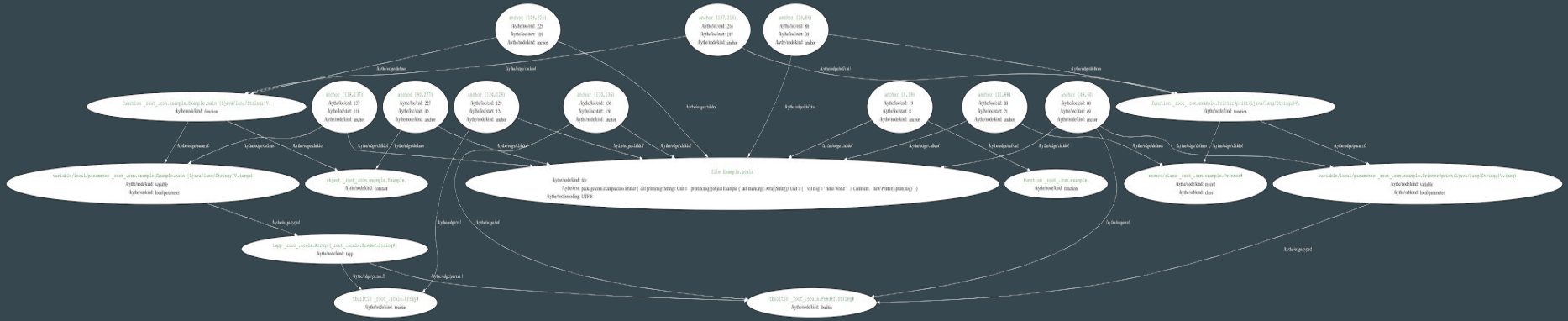
tnominal

tsigma

variable

vcs

...



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 platforms

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++ (already implemented), 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.
- We’ve started this.

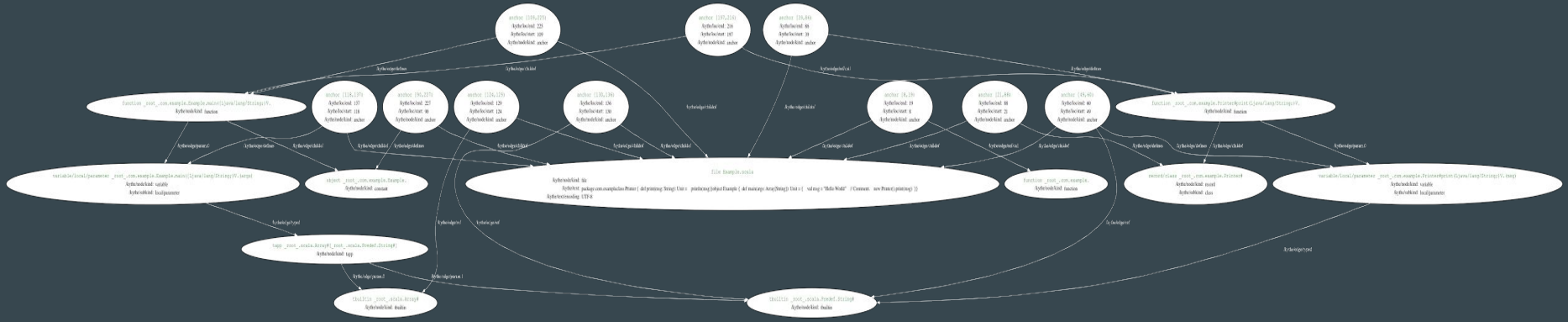
example

```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...

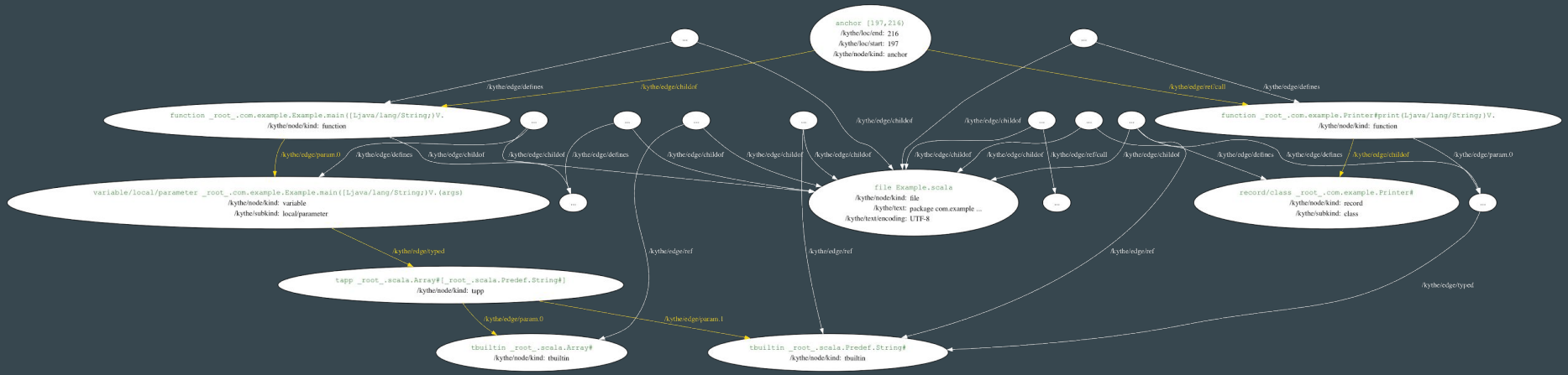
...Build using the scalahost compiler plugin...

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

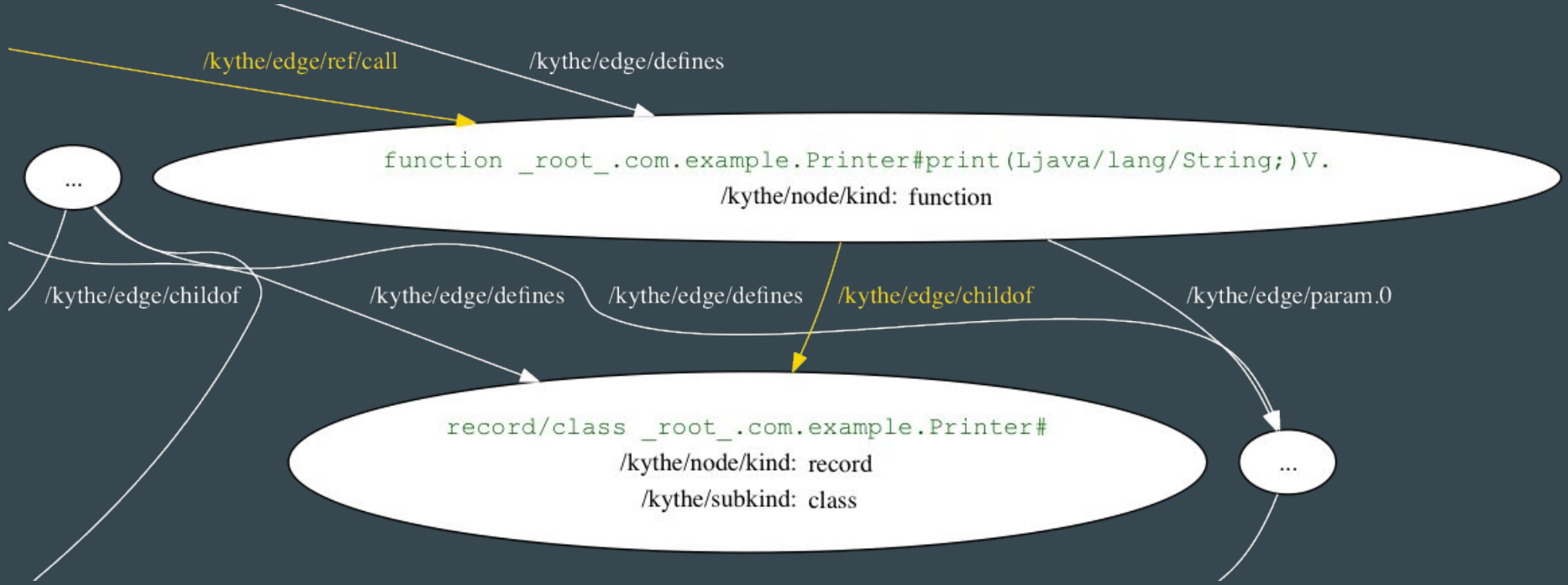


Render the resulting graph.

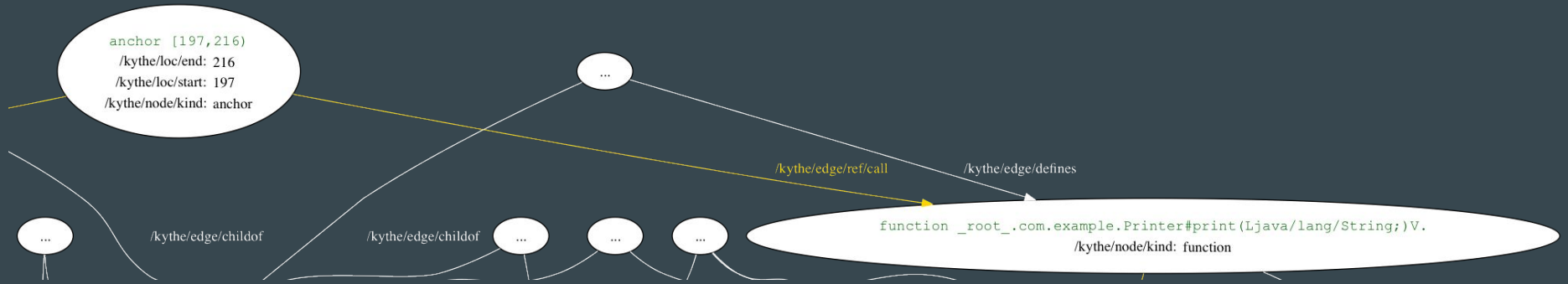
Viz courtesy of Benjy Weinberger



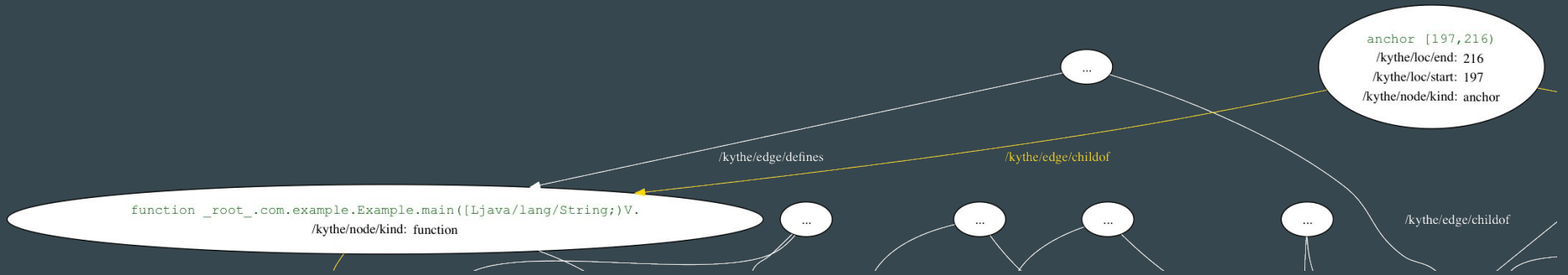
Highlight nodes along an interesting path...



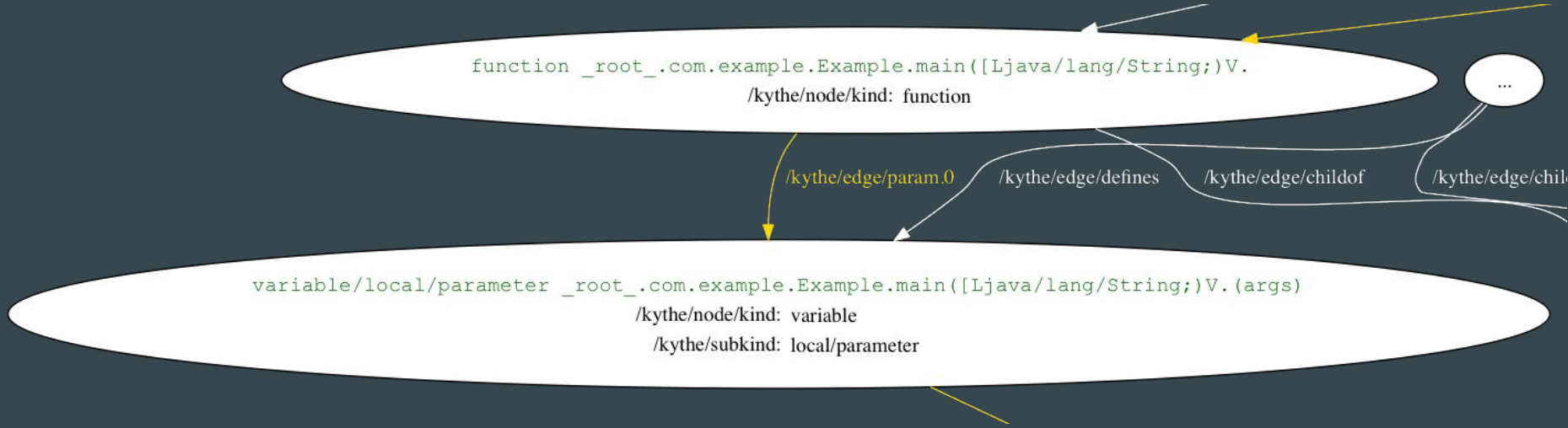
A function is a childof a class...



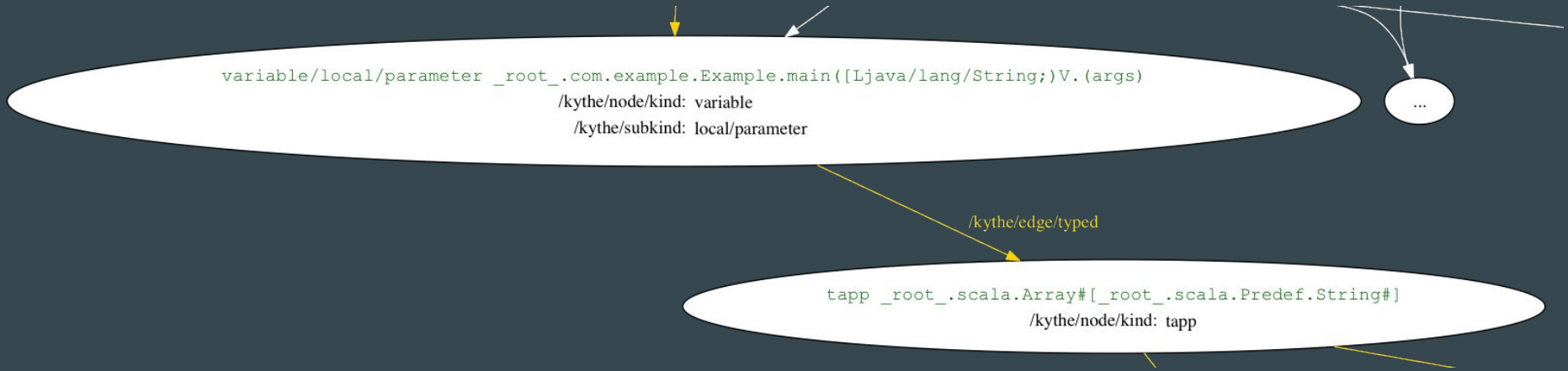
And that function is ref/call'd from a particular anchor.



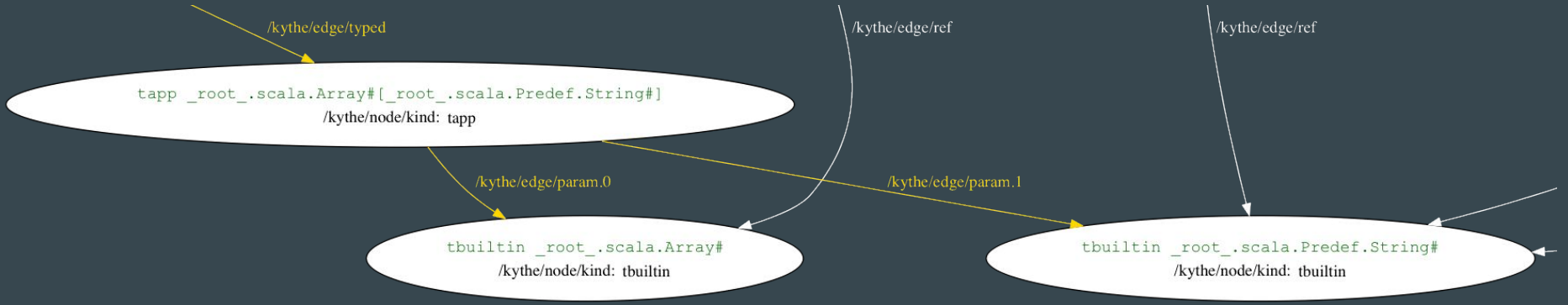
That anchor is childof (ie: a statement in) another function...



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



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



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

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

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
- Direct support for kythe landed last month:
  - 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.

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 recent versions of scalameta
  - 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
  - thin: running queries against a standalone kythe server
- Integration with Phabricator
  - thin: via kythe ctags export
- Further collaboration with Scalafix
- Keep an eye on TASTY
- Keep an eye on Sourcegraph

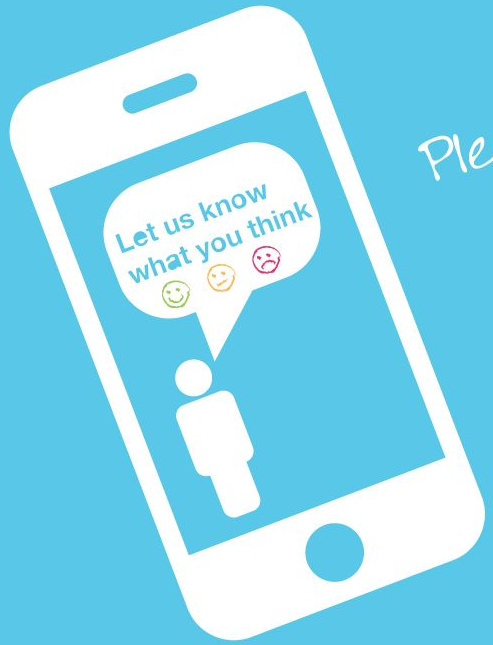
Credits

- 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
  - More than (just) BUILD file wrangling!

Questions?



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