Indexing Large, Mixed-Language Codebases

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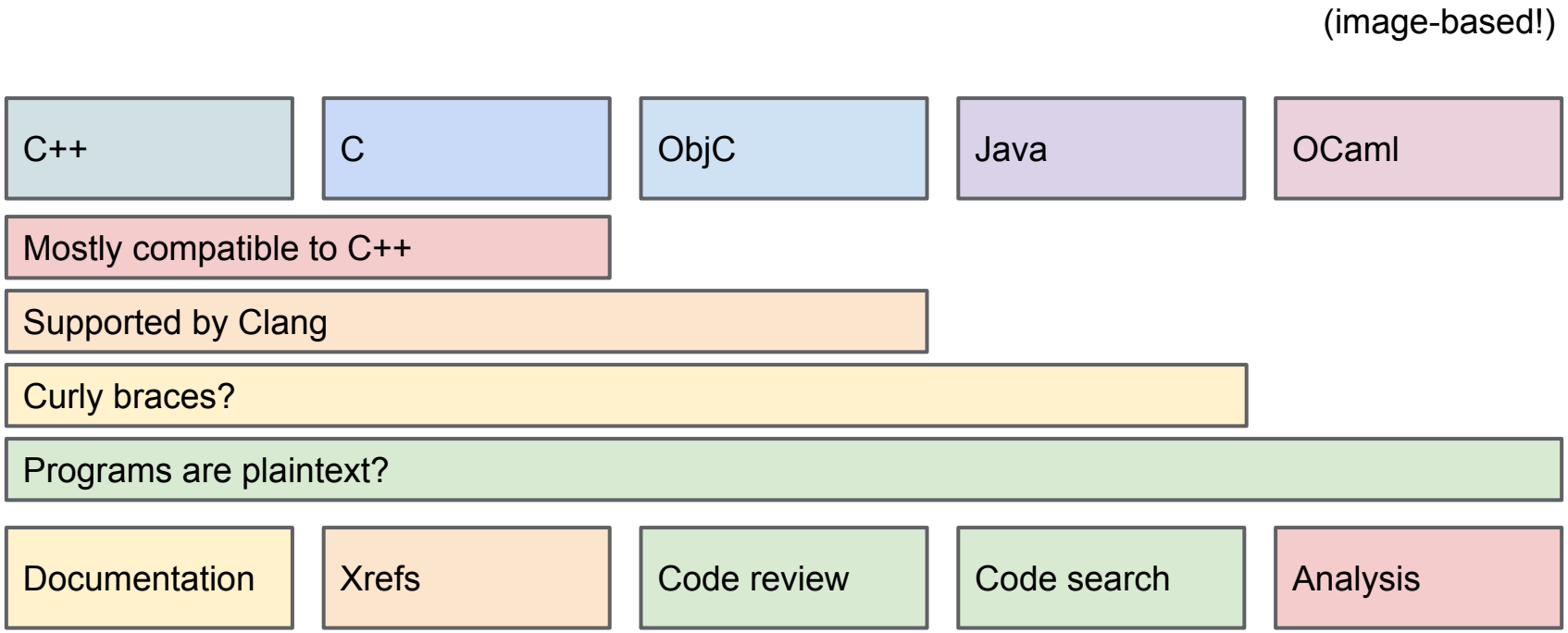
The Kythe project aims to establish *open data formats* and *protocols* for *interoperable* developer tools.

Outline

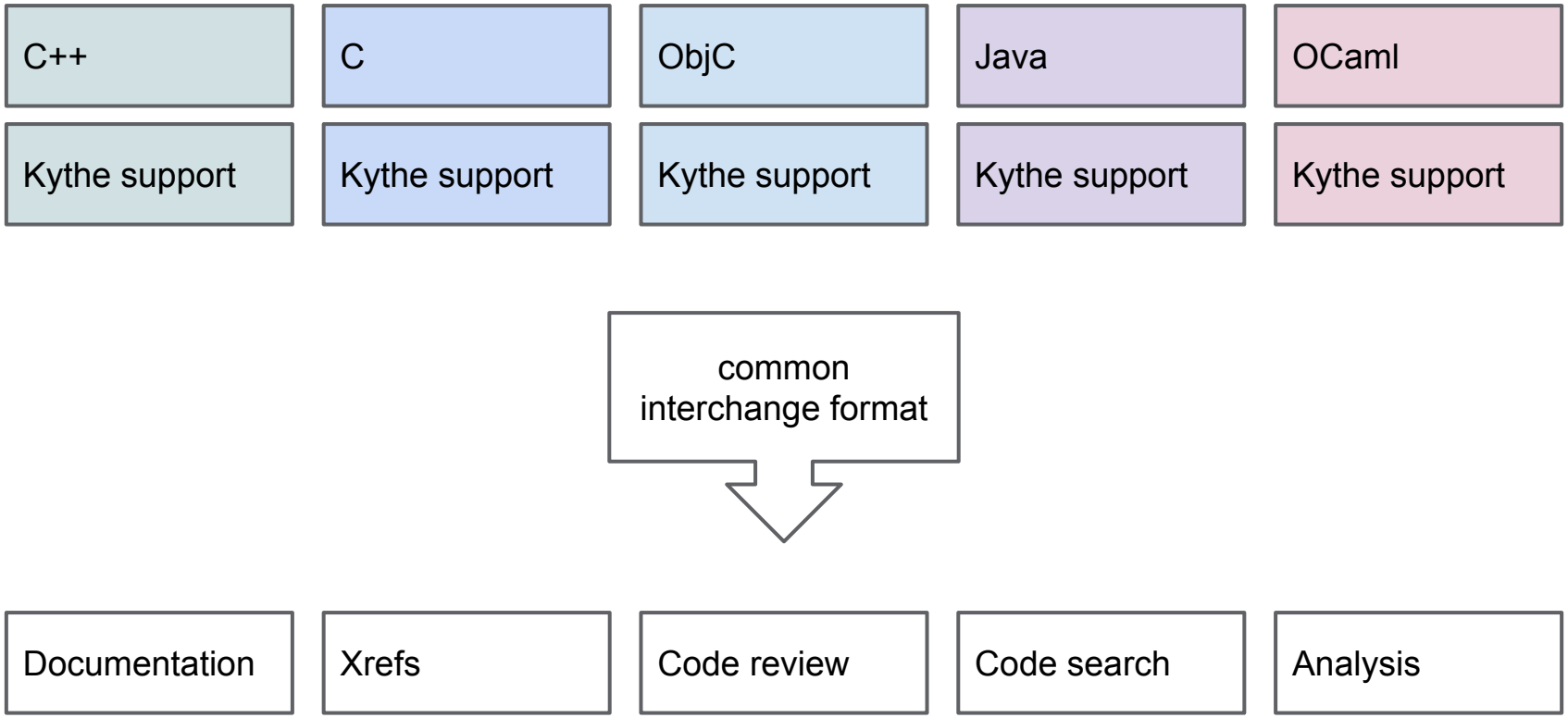
- **Introduction**
- System structure
- C++ support via Clang
  - What does Kythe get?
  - What does Kythe propose to give back?
- Future work

I use languages with property **X** and I'd like to do **Y**

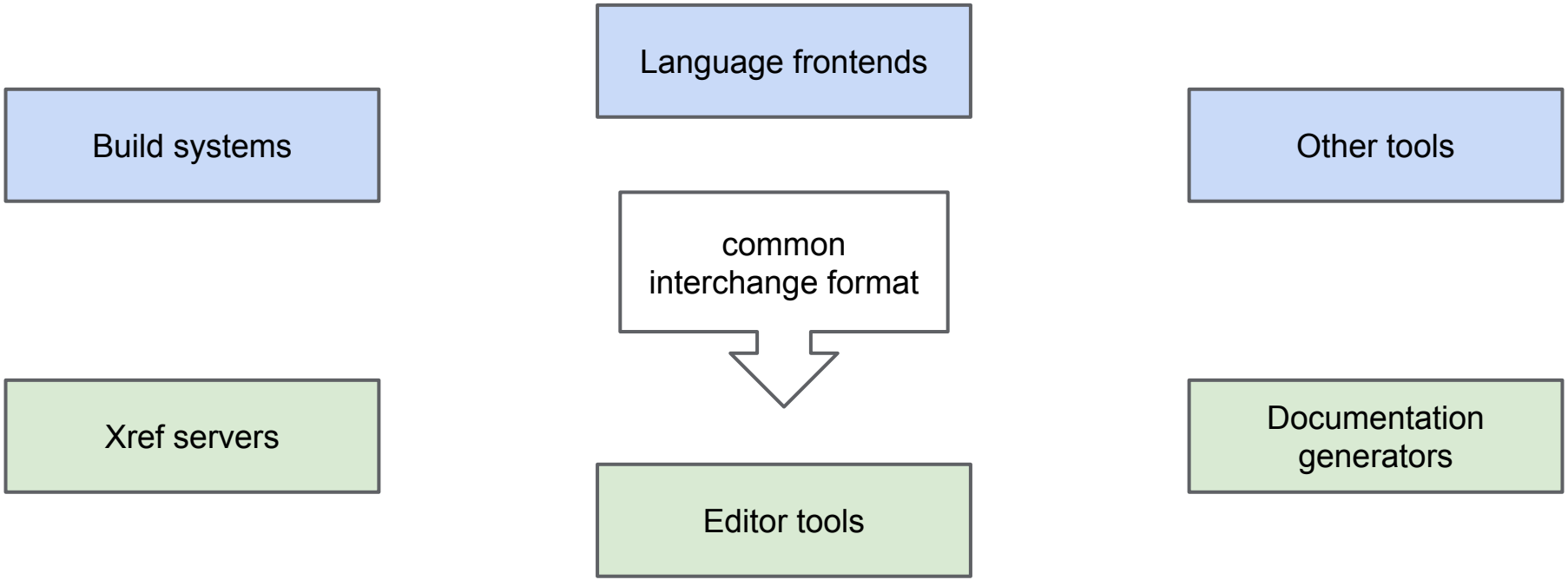


I also use source code generator X, build system Y, repo Z

protobuf	cmake	git
thrift	gmake	svn
cap’n proto	omake	cvs
yacc	mvn	company filer
antlr	a bunch of shell scripts	local disk
jni?	ant?	someone’s :80?


C++
C
ObjC
Java
OCaml
Kythe support
Kythe support
Kythe support
Kythe support
Kythe support
common interchange format
Documentation
Xrefs
Code review
Code search
Analysis

I use tools that support Kythe data



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- **System structure**
- C++ support via Clang
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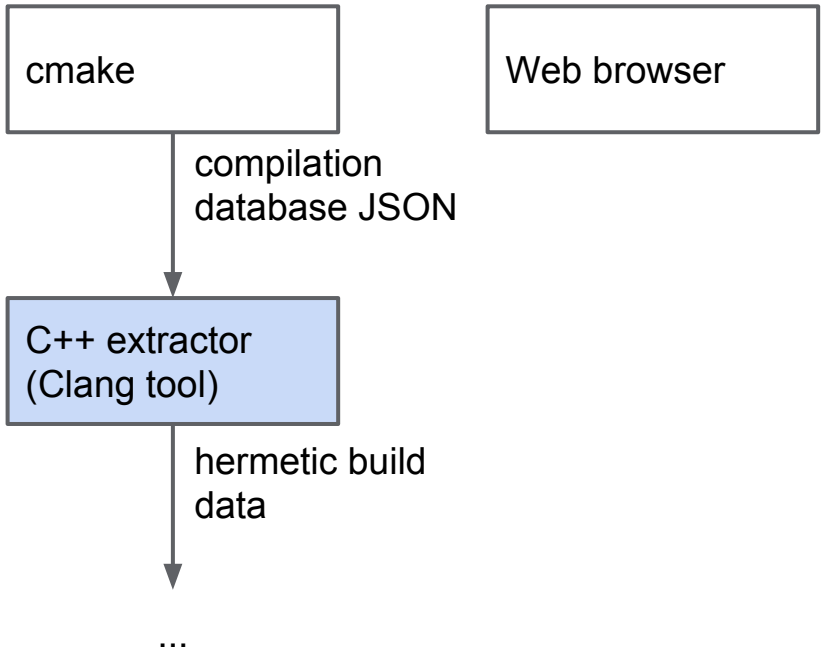
A Kythe system

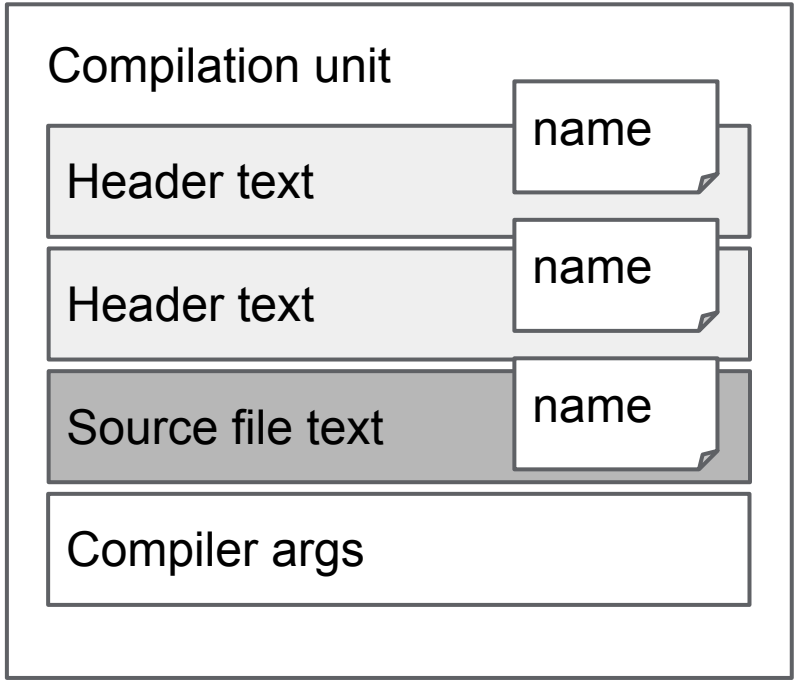
A Kythe system

- Extractors pull compilation information from the build system



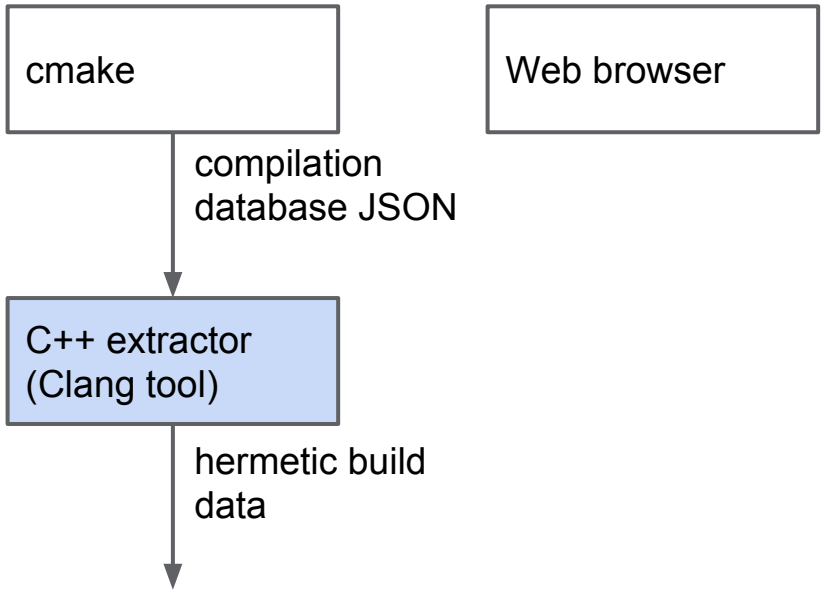
Hermetic build data

- Contains every dependency the compiler needs for semantic analysis
- Gives files identifiers that can be used to locate them in repositories
- Allows for distribution of analysis tasks



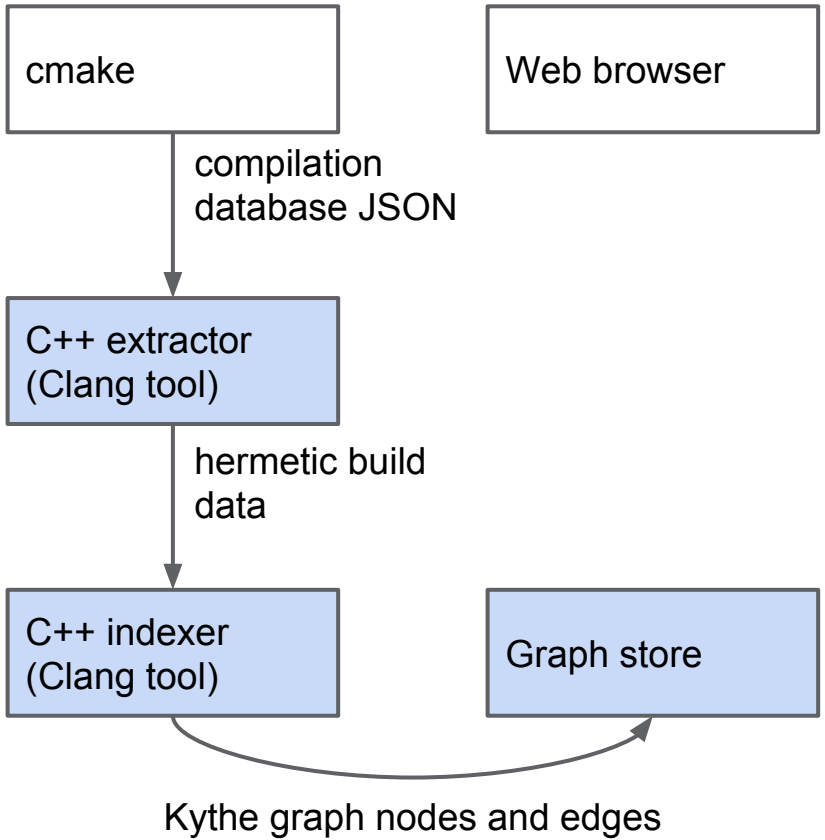
A Kythe system

- Extractors pull compilation information from the build system



A Kythe system

- Extractors pull compilation information from the build system
- Indexers use this information to construct a persistent graph



Indexer implementation

1. Load hermetic build data into memory with `mapVirtualFile`
2. First pass: recover parent relationships for naming

Nameless decls and shadowed names

- Clang omits parent edges in the AST because it doesn't need them
- As best we can, we want to give stable names to any Decl we see referenced at any point
- We also want to distinguish between shadowed names
- Solution: build a map from AST nodes to `(parent, visitation-index)*`

```
void foo() {
  x:0:0:foo
  int x;
  x:0:1:0:foo
  { int x; }
  x:0:2:0:foo
  { int x; }
}
```

Indexer implementation

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Indexer implementation

1. Load hermetic build data into memory with `mapVirtualFile`
2. First pass: recover parent relationships for naming
3. Second pass: notify a `GraphObserver` about abstract program relationships

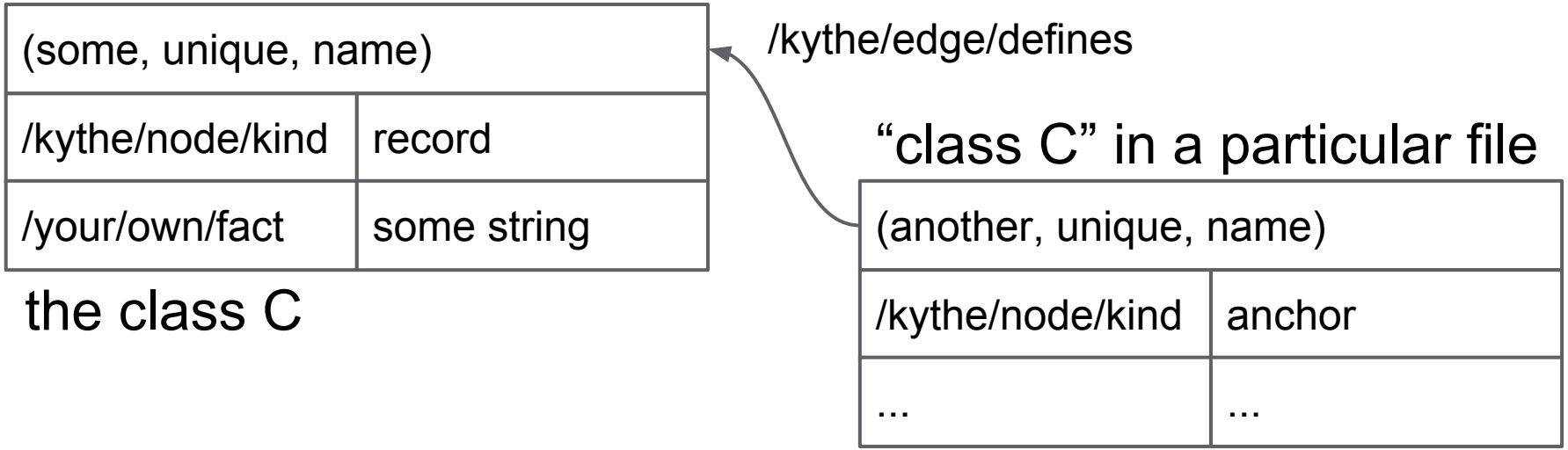
The Kythe graph

All programs in Kythe are abstracted away to nodes and edges.

(some, unique, name)	
/kythe/node/kind	record
/your/own/fact	some string

The Kythe graph

Nodes represent semantic information as well as syntactic information.

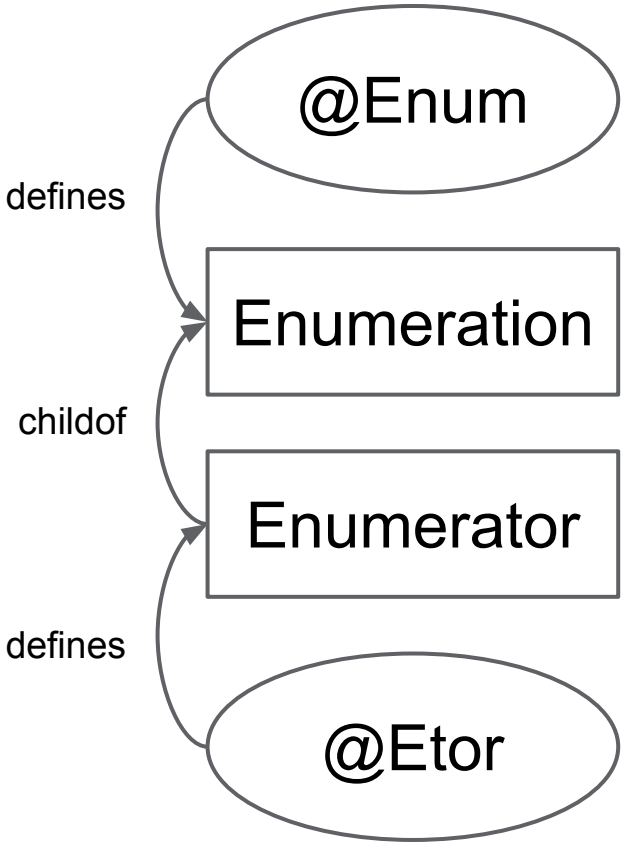


The Kythe schema

- We provide a base set of nodes and edges
- We also provide rules for naming certain kinds of nodes
- It is extensible: you're free to use your own node and edge kinds
- "Be conservative in what you send, be liberal in what you accept"
  - some data may be missing
  - there may be more data than you can understand
  - others may produce incorrect data

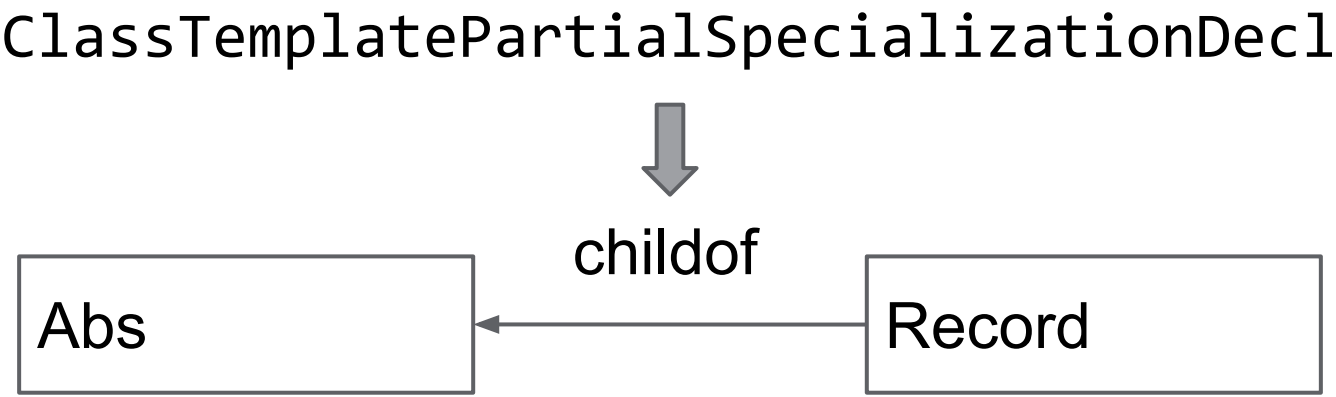
The schema provides checked examples

```
//- @Enum defines Enumeration
enum class Enum {
//- @Etor defines Enumerator
  Etor
};
//- Enumerator childof Enumeration
```



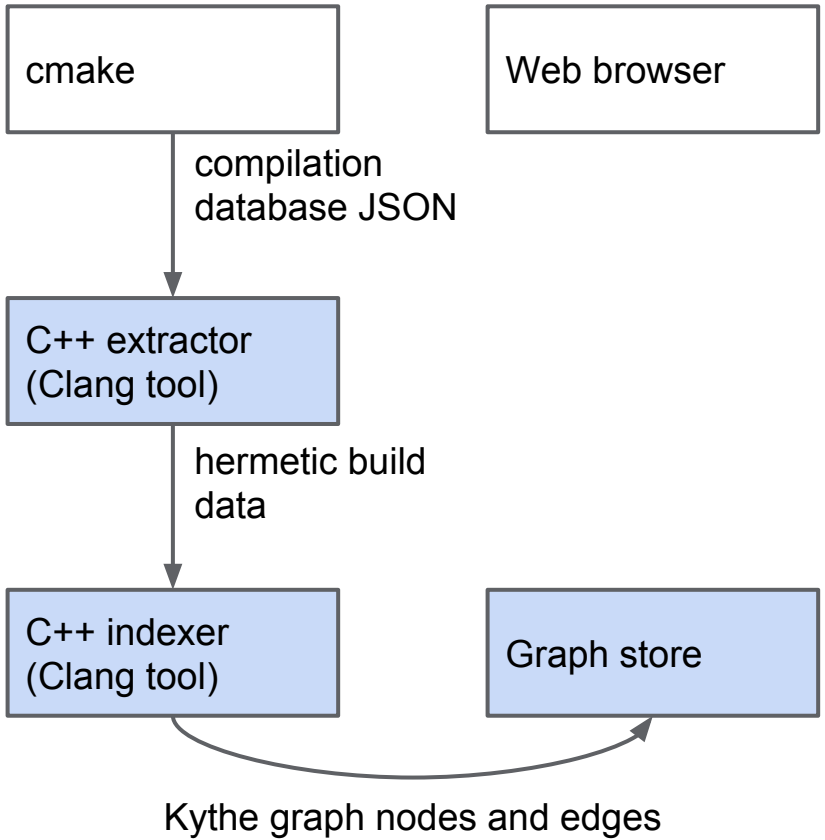
The GraphObserver is notified about program structure

- The GraphObserver interface sees an abstract view of a program
- There is not a 1:1 mapping between AST nodes and program graph nodes



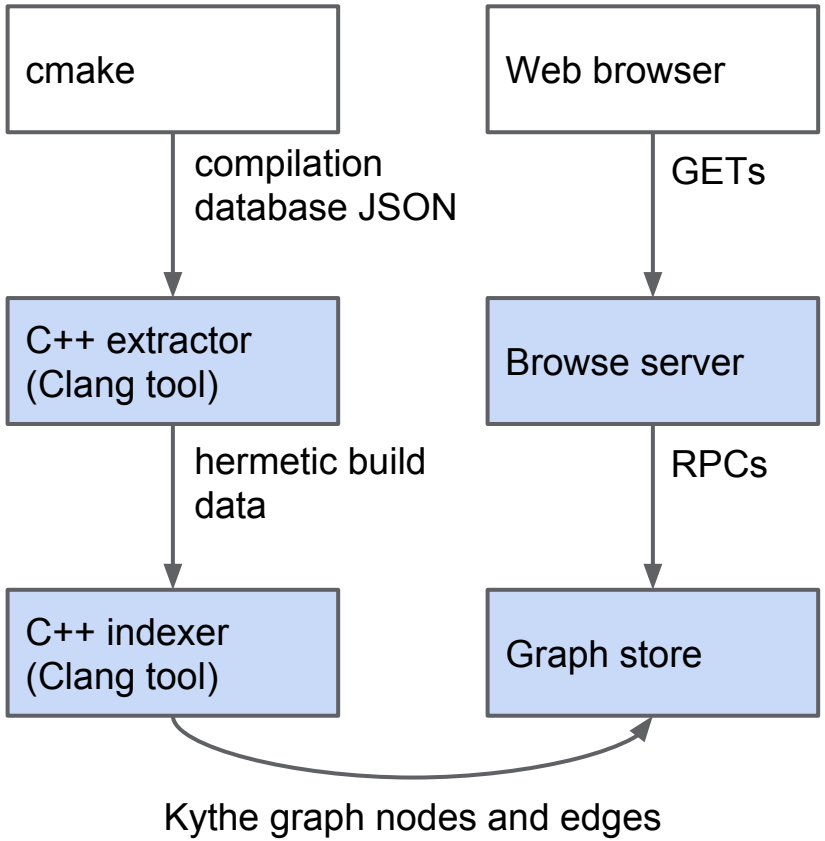
A Kythe system

- Extractors pull compilation information from the build system
- Indexers use this information to construct a persistent graph



A Kythe system

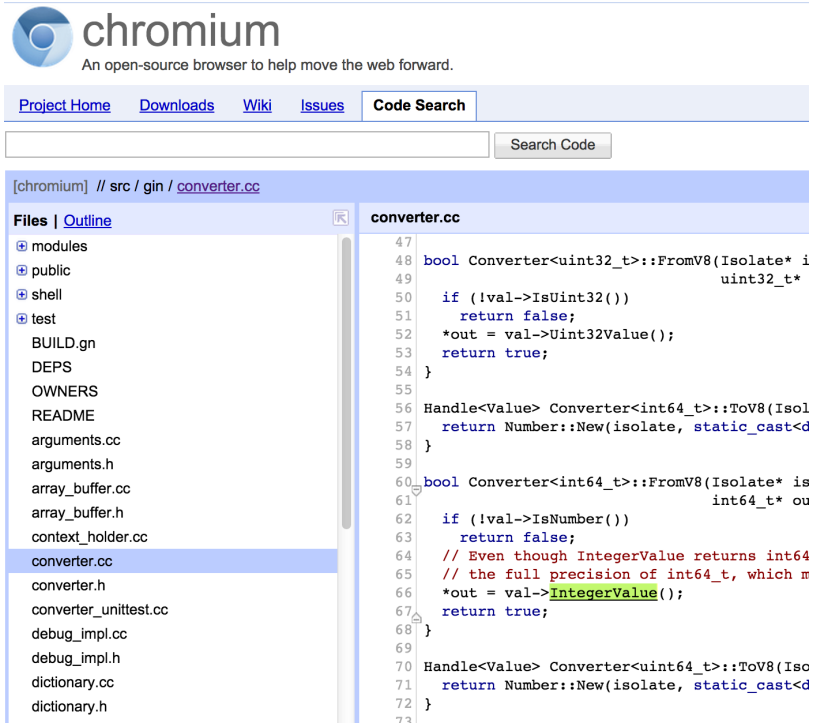
- Extractors pull compilation information from the build system
- Indexers use this information to construct a persistent graph
- Services use the graph to answer queries
  - code browsing
  - code review
  - documentation generation



Google

This design is known to scale

- Small dataset (Chromium)
  - ~22,600 C++ compilations
  - ~31G of serving data
- Internal code search is much larger
  - 100 million lines of code
- Other internal tools make use of build data for analysis



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Clang made C++ tooling possible

- A tooling-friendly compiler leads to an ecosystem of software tools
  - ASan, TSan, MSan
  - clang-format, clang-tidy
  - Doxygen libclang integration
- Clang's code is eminently hackable
  - The interface to the typed AST is clean
  - The preprocessor is easy to tool as well

Clang has excellent template support

```
template <typename T> class C
{ typename T::Foo foo; };      // ClassTemplateDecl (of CXXRecordDecl)

template <typename S> class C<S*>
{ typename S::Bar bar; };   // ClassTemplatePartialSpecializationDecl

template <> class C<int> { };      // ClassTemplateSpecializationDecl

C<X> CX;
C<X*> CPX;
C<int> CI;                  // implicit ClassTemplateSpecializationDecl
```

Clang has excellent template support

```
template <typename T> class C
{ typename T::Foo foo; };

template <typename S> class C<S*>
{ typename S::Bar bar; };
```

= *getSpecializedTemplate*

= *getSpecializedTemplateOrPartial*

```
C<X> CX;
C<X*> CPX;
C<int> CI;
```

.getTemplateArgs
=> { X }*
“template <X=T> class C”*
.getTemplateInstantiationArgs
=> { X }
“template <X=S> class C<X>”*

Clang makes macros manageable

```
#define M1(a,b) ((a) + (b))
int f() {

  int x = 0, y = 1;

  return M1(x, y);
}
```

located at

expands to

```
((x) + (y))
```

parses to

Result AST

```
| ...
`- DeclRefExpr(x)

| ...
`- DeclRefExpr(y)
```

Clang supports other compilers' extensions: GCC

- We want to index real world code!
- Just some of the GCC extensions clang supports:
  - **indirect-goto** (`goto *bar;`)
  - **address-of-label** (`void *bar = &&foo;`)
  - **statement-expression**
    `(string s("?"); ({for(;;); s;}).size();)`
  - **conditional expression without middle operand** (`f() ? : g()`)
  - **case labels with ranges** (`case 'A' ... 'Z':`)
  - **ranges in array initializers**
    `int a[] = { [0 ... 9] = 1, [10 ... 99] = 2, [100] = 3 };`

Clang can build extension-heavy software

- Building the Linux kernel works (modulo some patches: http://llvm.linuxfoundation.org/index.php/Main_Page)
- Hairiest GCC “feature” unsupported: variable length arrays in structs

```
struct {struct shash_desc shash;
        char ctx[crypto_shash_descsize(tfm)];} desc;
```

- Support for MSVC extensions (and ABI…) is developing too; some success with Chromium on Windows (https://code.google.com/p/chromium/wiki/Clang)

Kythe adds to Clang's tooling support

- Persistence for abstract program data: records, not `CXXRecordDecls`.
- Hermetic storage of compilation units
- Unambiguous naming for more program entities
- Abstract AST traversal

C++ is a first-class citizen

- The Kythe schema is intended to support all of C++14 (templates, (generic) lambdas, auto, …)
- We expect support for Concepts Lite will not be difficult
- To get this into Clang:
  - **Nothing Kythe-specific goes into the LLVM tree**
  - Just a library in clang/tools/extra that calls appropriate members on an abstract `GraphObserver`
  - The Kythe indexer is a particular implementation of `GraphObserver`

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Things left to do

- UI/IDE integration
- Support for other languages
  - Including one or two that are supported by Clang already
- Other analyses that work over or contribute to the graph
  - Use Kythe information as sparse data to drive whole-project analysis
- Adding more build information (eg, who links to whom)
- Quick incremental updates

Summary

- The open Kythe data format enables interoperable tooling
- The Kythe pipeline is designed to scale
- C++ support is possible thanks to the work done on Clang tooling
- Simpler languages (Go, Java) aren’t necessarily easier to tool
- The code we will propose to upstream does not depend on Kythe
- There are lots of opportunities for community development

Mailing list

https://groups.google.com/forum/#!forum/kythe-early-interest