Sulong

An experience report of using the "other end" of LLVM in GraalVM

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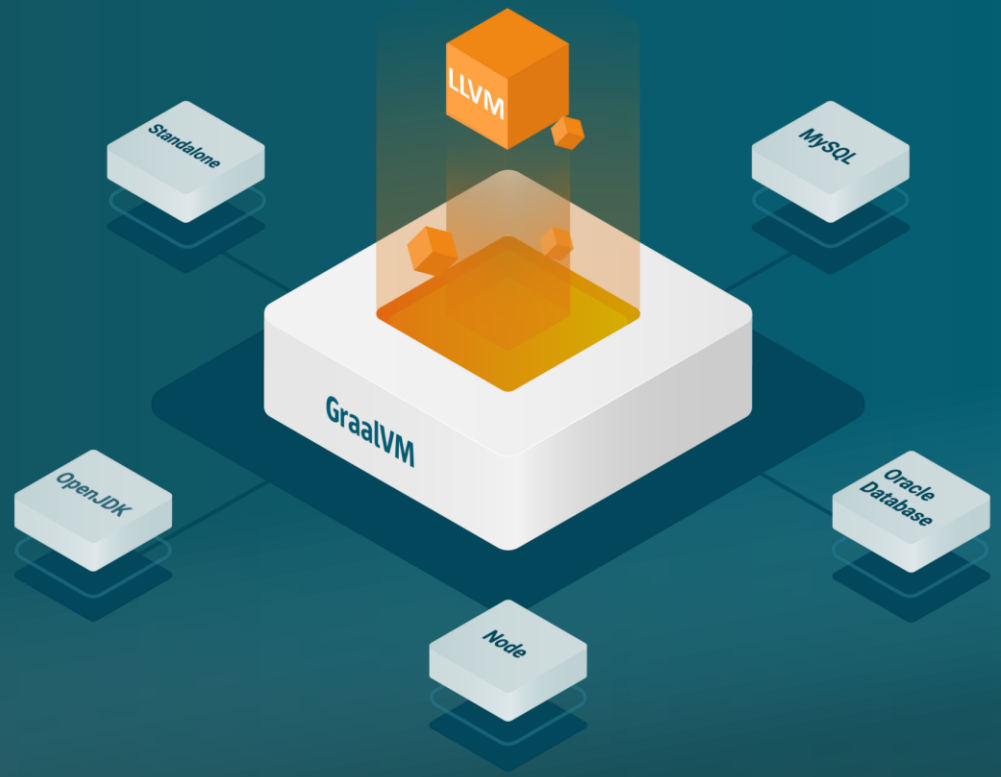
April 9, 2019



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What is Sulong?

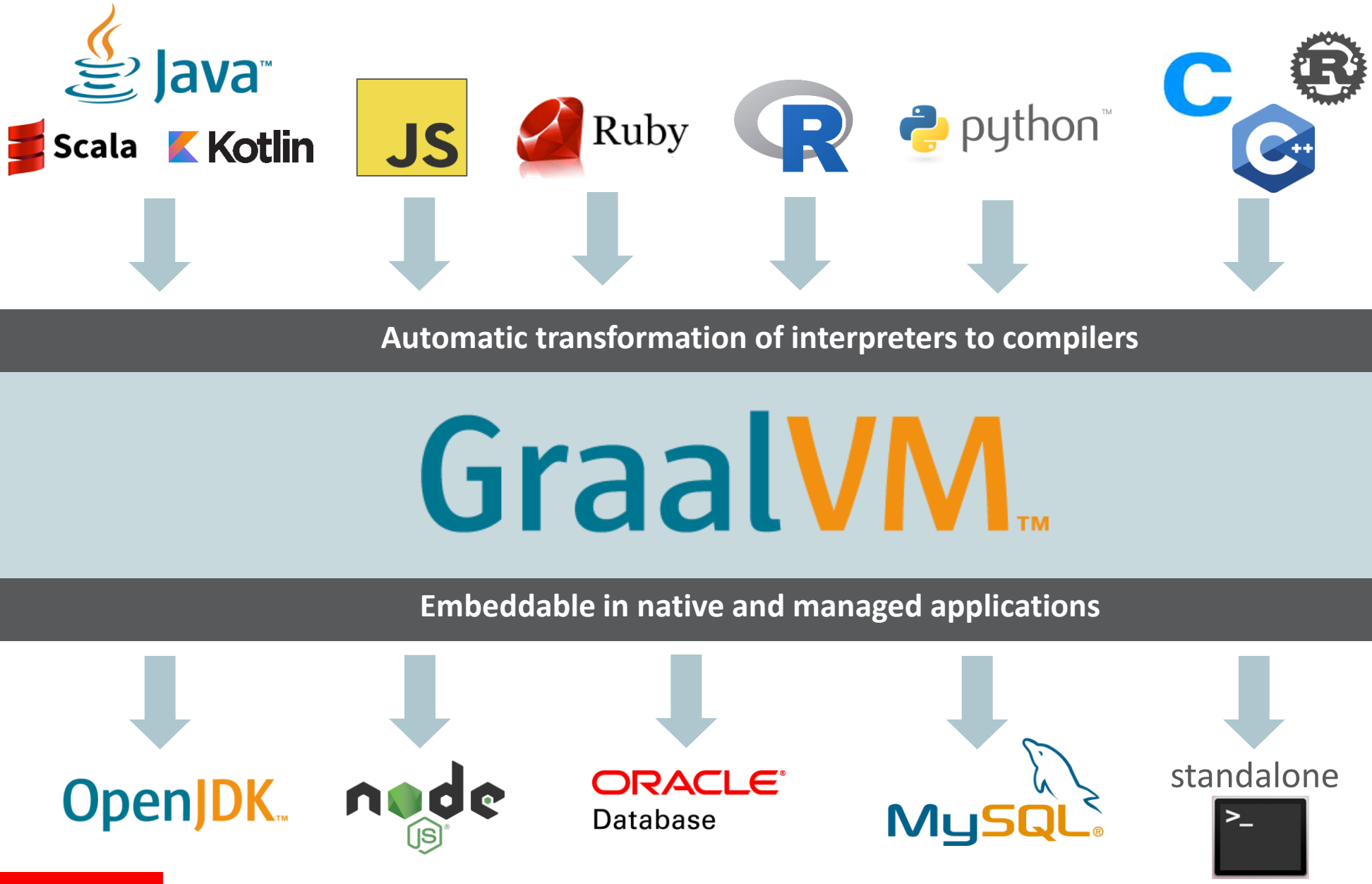
LLVM Bitcode execution engine

- Think: `lli`
- Interpretation and JIT-compilation

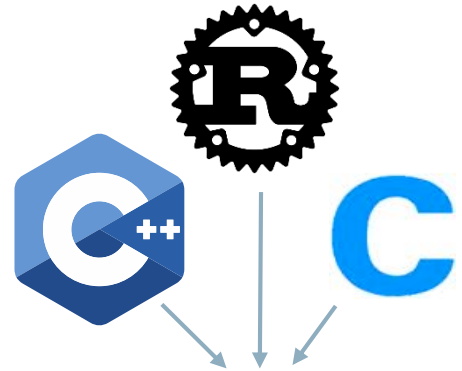
What is the Goal of Sulong?

Execute “low-level/unsafe” languages on GraalVM

- C, C++, Fortran, Rust, (Swift?)



GraalVM Stack



Truffle Framework

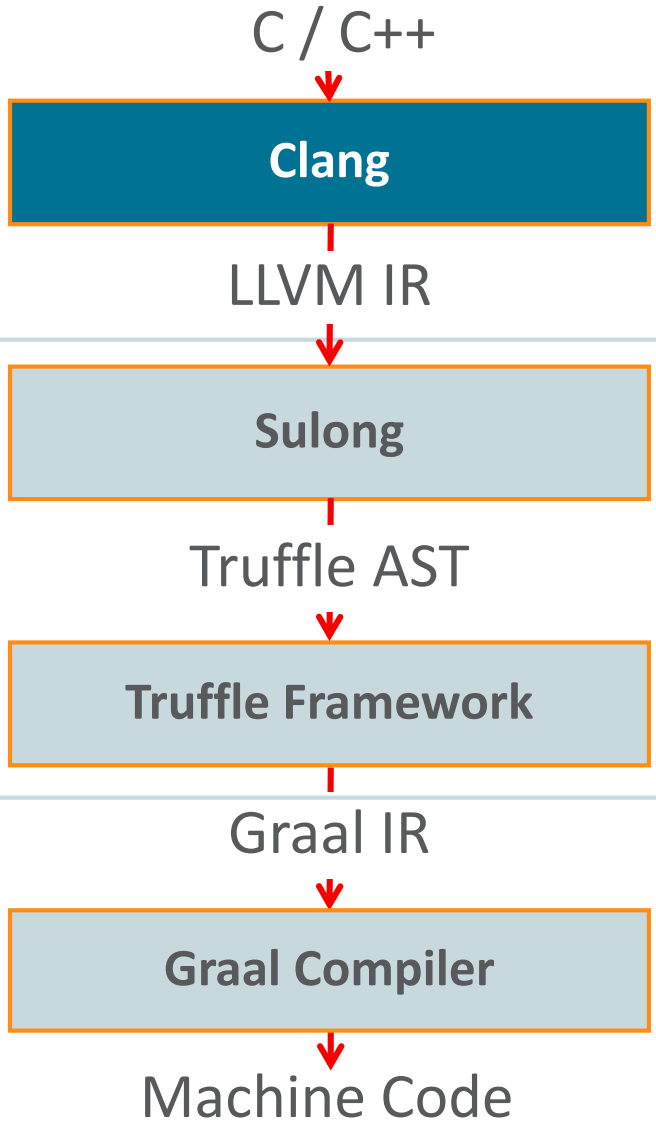
Graal Compiler

Sulong Pipeline

Ahead of Time

Run Time

Just in Time
(hot code only)



Interpreter execution

Compiled Code execution

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Sulong on Github

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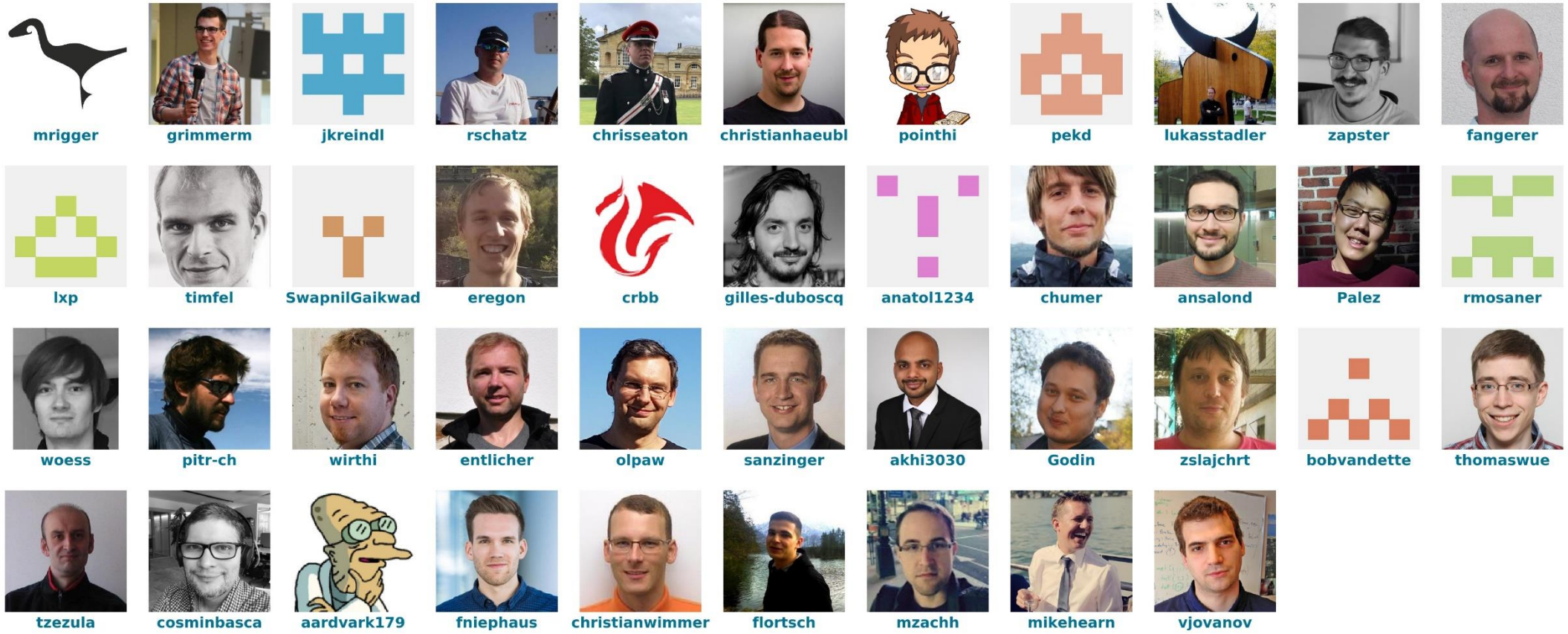

https://github.com/oracle/graal/tree/master/sulong

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Sulong on Github

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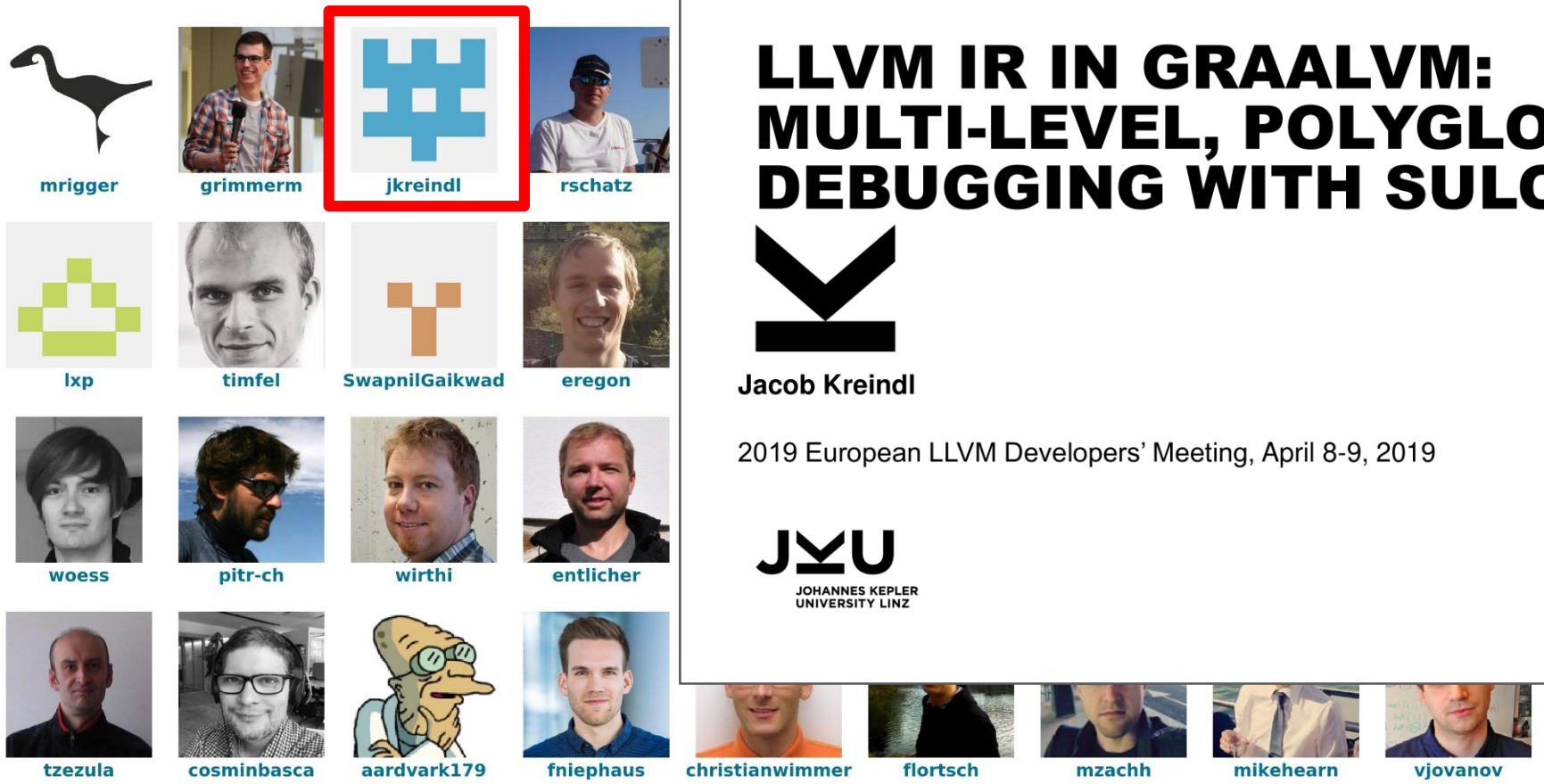

LLVM IR IN GRAALVM: MULTI-LEVEL, POLYGLOT DEBUGGING WITH SULONG

Jacob Kreindl

2019 European LLVM Developers' Meeting, April 8-9, 2019

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https://github.com/oracle/graal/tree/master/sulong

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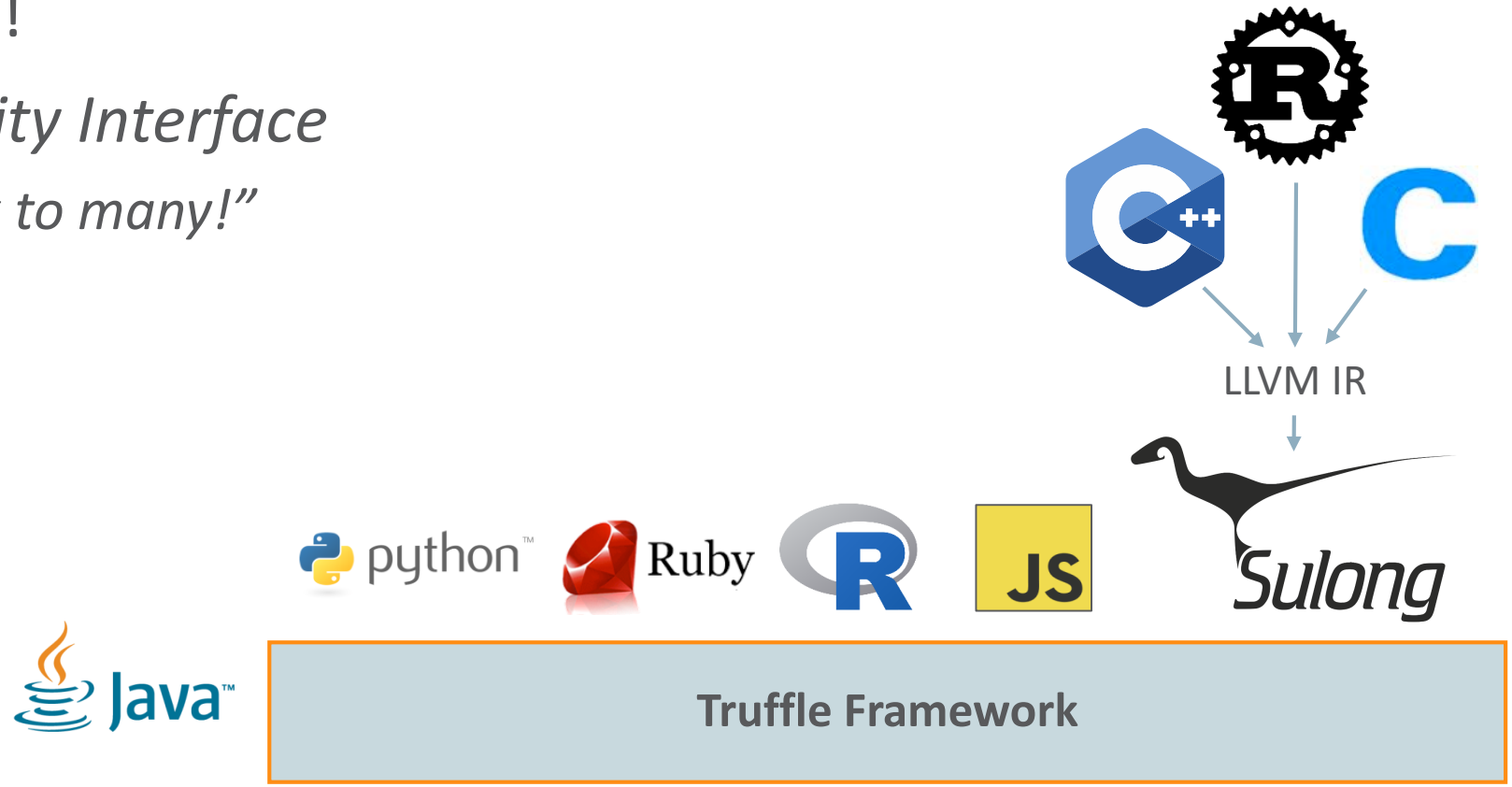
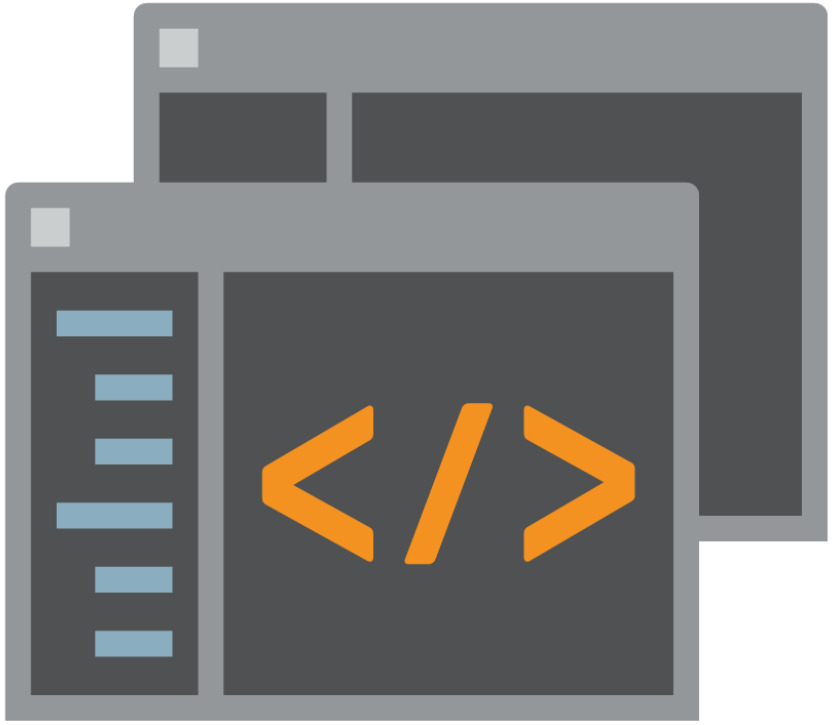
Fast Cross-language Interoperability

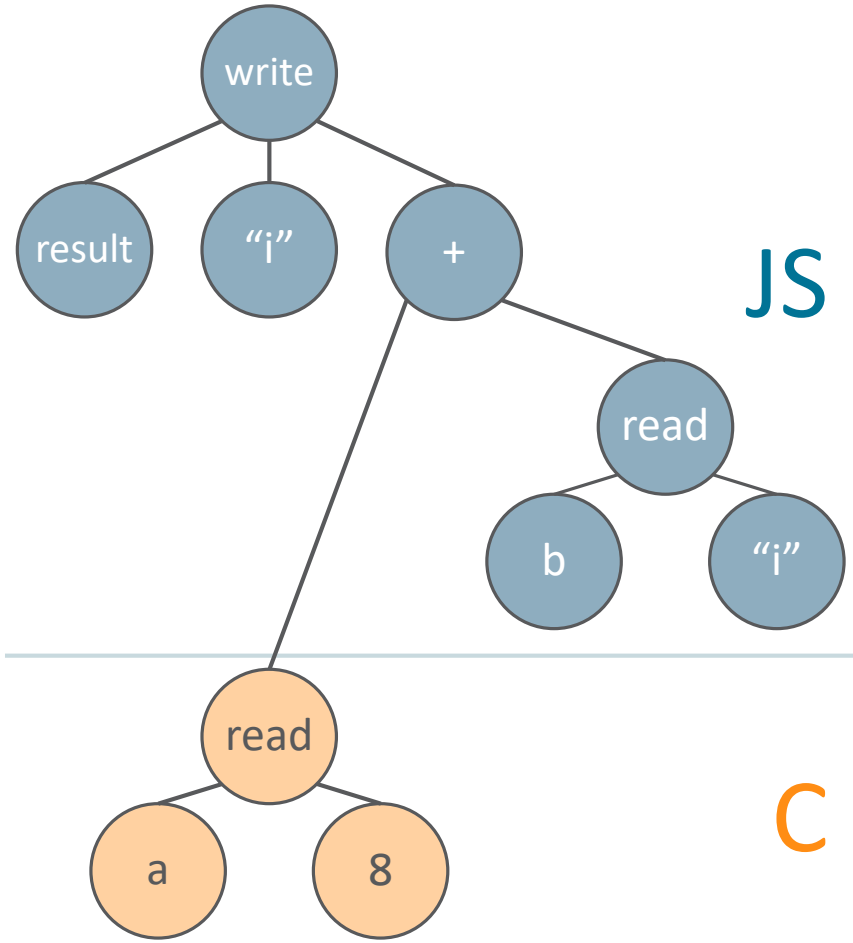
- The world is polyglot!
- Shared *Interoperability Interface*
  - *"Implement once, talk to many!"*



Live Demo



Interoperability (Truffle Approach)

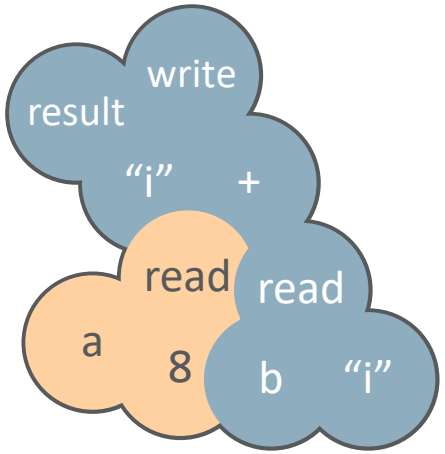


JS AST Nodes

C AST Nodes

```
function add(a, b) {
   var result = {r:0, i:0};

   result.r = a->r  +   b.r;

   result.i = a->i  +   b.i;

   return result;
}
```

Interoperability (Truffle Approach)



Single machine code function

```
function add(a, b) {
   var result = {r:0, i:0};

   result.r = a->r  +   b.r;

   result.i = a->i  +   b.i;

   return result;
}
```

Foreign Function Interfaces (FFI)

- Most non-trivial languages have an FFI
  - Usually native code (C/C++/Fortran)
- Accessing interpreter data structures
  - Implementation details become API ☹
- Sulong to the rescue!
  - Access language objects instead of C structs


```c
/* Dictionary object type */
typedef struct {
    PyObject_HEAD

    Py_ssize_t ma_used;

    uint64_t ma_version_tag;

    PyDictKeysObject *ma_keys;

    PyObject **ma_values;
} PyDictObject;
```

What is the Goal of Sulong? (cont.)

Execute “low-level/unsafe” languages on GraalVM

- C, C++, Fortran, Rust, (Swift?)

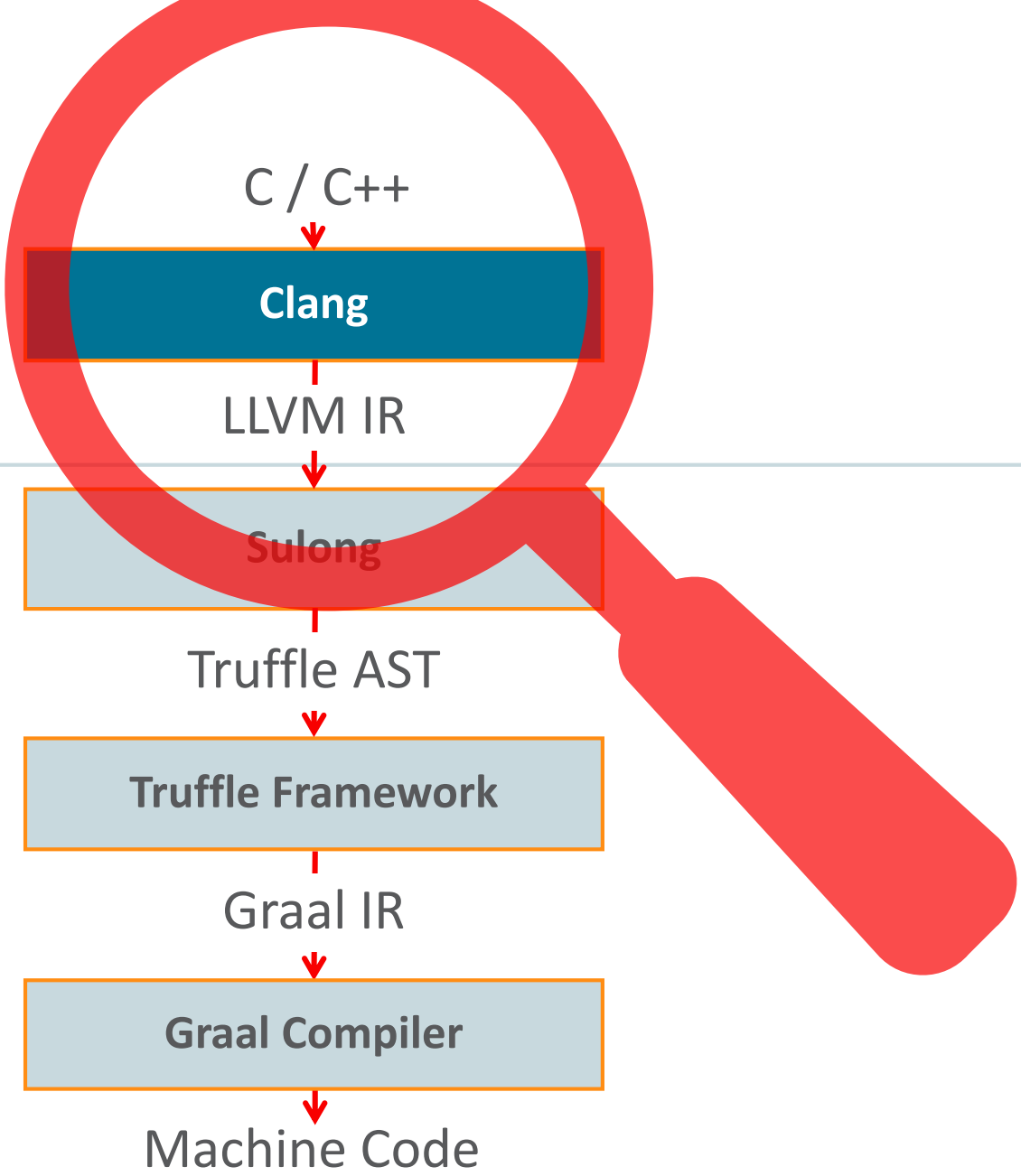
Support native language extensions

- Python, Ruby, NodeJS, R, ...

Sulong Pipeline

Ahead of Time

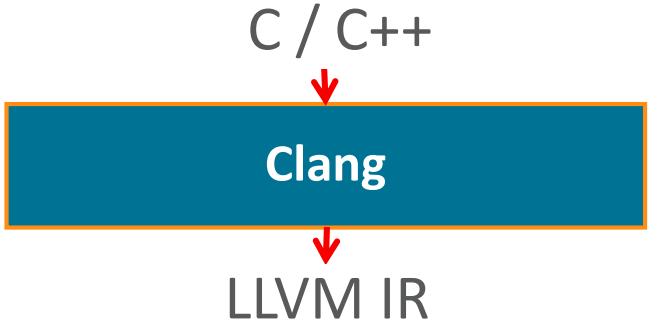
Run Time



Compile Native Projects to Bitcode

Single-file programs

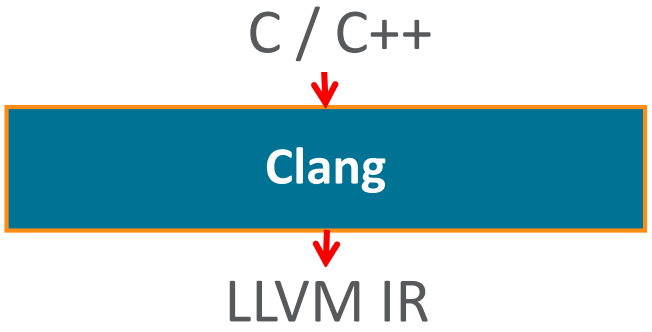
```
clang -c -emit-llvm main.c
```



Compile Native Projects to Bitcode

Mutli-file programs

```
$ clang -emit-llvm main.c foo.c

clang: error: -emit-llvm cannot be used when linking
```




```
$ clang -c -emit-llvm main.c
$ clang -c -emit-llvm foo.c

$ llvm-link main.bc foo.bc -o out.bc
```

Native Build Systems

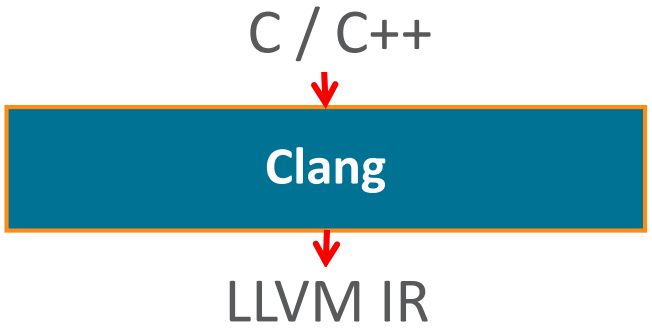
Native build systems are manifold and not under our control

- Makefile

  `CC=clang CFLAGS=-emit-llvm LD=llvm-link (?)`

- How about Python native extensions?

```
from distutils.core import setup, Extension

module1 = Extension('demo',
        define_macros = [('MAJOR_VERSION', '1'),
        ('MINOR_VERSION', '0')],
        include_dirs = ['/usr/local/include'],
        libraries = ['tcl83'],
        library_dirs = ['/usr/local/lib'],
        sources = ['demo.c'])
```

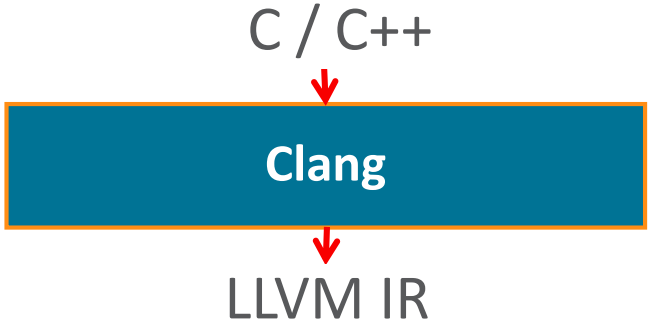


Native Build Systems

NumPy's setup is parsing object files

`setup_common.py`

```
def long_double_representation(lines):
    """Given a binary dump as given by GNU od -b,
    look for long double representation."""
```

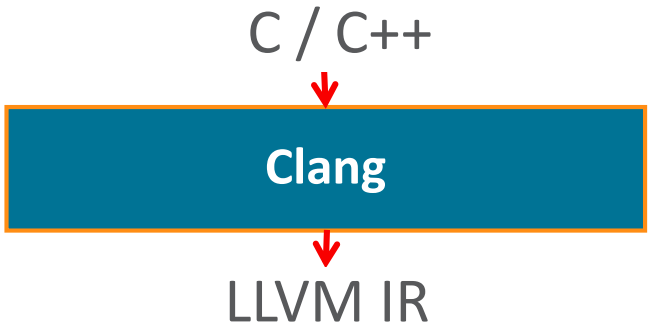


https://github.com/numpy/numpy

Compile Native Projects to Bitcode

Mutli-file programs

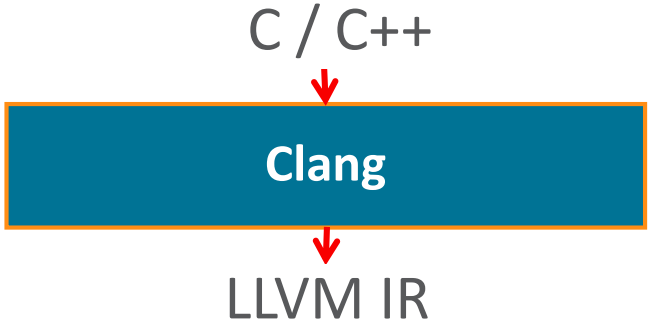
```
$ clang -c -fembed-bitcode foo.c
$ clang -c -fembed-bitcode main.c
$ clang -fembed-bitcode main.o foo.o -o a.out
$ objcopy -O binary -j .llvmbc a.out out.bc
$ lli out.bc
lli: out.bc: error: Malformed block
# bitcode section concatenated, not llvm-linked ☹
```



Compile Native Projects to Bitcode

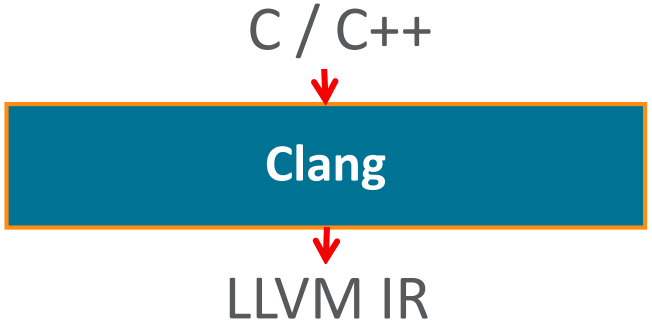
Mutli-file programs

```
$ clang -c -flto main.c

$ clang -c -flto foo.c

$ clang -fembed-bitcode -flto main.o foo.o -o a.out

# no bitcode section ☹
```



3rd Party Solutions for Compiling to Bitcode

- `wllvm`, `gllvm` wrappers \o/
  - Compiler flags fiddling is cumbersome
  - `extract-bc` hard to integrate in build scripts
  - Unsupported corner cases (e.g., cross-compilation)
- Darwin Linker supports embedding bitcodes
  - via embedded bundles
- Custom wrapper code
  - E.g. in our GraalPython

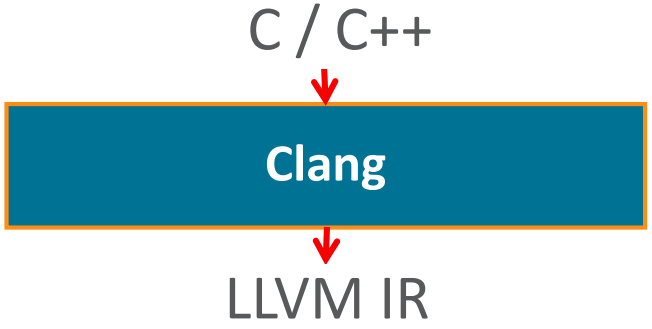



```
public class GraalPythonCC
extends GraalPythonCompiler
{...}
```

RFC: LLD + LTO + --embed-bitcode

- Teach LLD to embed bitcode during LTO

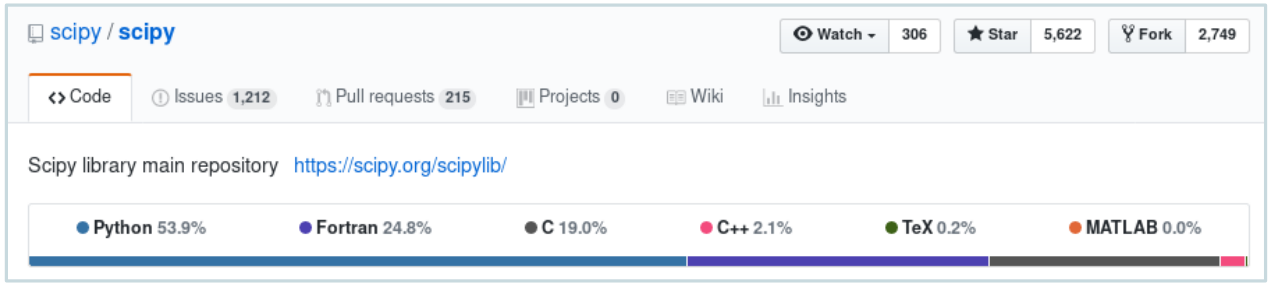
```
$ clang -c -flto main.c

$ clang -c -flto foo.c

$ clang -fuse-ld=lld -Wl,--embed-bitcode main.o
foo.o -o a.out # \o/
```

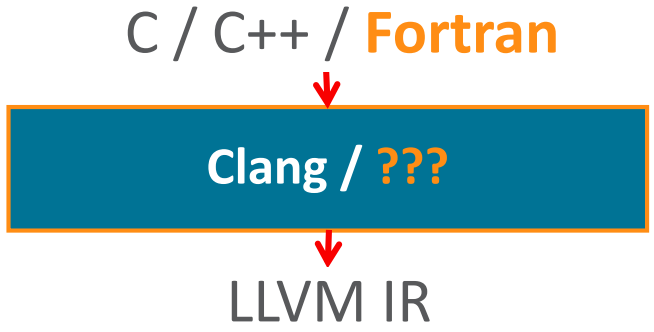


- Patch currently under evaluation
  - Planning to contribute it to upstream (if wanted)

Compiling Fortran to Bitcode

- Fortran is popular in native extensions





- DragonEgg is outdated ☹
- Looking forward to f18 ☺

Conclusion

https://www.graalvm.org

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