Sulong

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

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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?)
Automatic transformation of interpreters to compilers

GraalVM™

Embeddable in native and managed applications

OpenJDK™, node.js, Database, MySQL, standalone
GraalVM Stack

Truffle Framework

Graal Compiler
Sulong Pipeline

**Ahead of Time**

**Run Time**

**Just in Time**

*(hot code only)*
Sulong on Github

https://github.com/oracle/graal/tree/master/sulong
Sulong on Github

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

Jacob Kreindl

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

https://github.com/oracle/graal/tree/master/sulong
Fast Cross-language Interoperability

• The world is polyglot!

• Shared *Interoperability Interface*
  – “Implement once, talk to many!”

![Image of a mobile phone and various programming languages and frameworks]

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Truffle Framework
Live Demo
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

```javascript
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

C / C++

Clang

LLVM IR

Sulong

Truffle AST

Truffle Framework

Graal IR

Graal Compiler

Machine Code
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?

```python
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'])
```

Clang

LLVM IR

C / C++
Native Build Systems

NumPy’s setup is parsing object files

`setup_common.py`

```python
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

- \texttt{wllvm, gllvm wrappers} \texttt{o/}
  - Compiler flags fiddling is cumbersome
  - \texttt{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
    
    ```java
    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

GraalVM.
Run Programs Faster Anywhere

High-performance polyglot VM

GraalVM is a universal virtual machine for running applications written in JavaScript, Python, Ruby, R, JVM-based languages like Java, Scala, Kotlin, Clojure, and LLVM-based languages such as C and C++.

https://www.graalvm.org
Integrated Cloud
Applications & Platform Services