# Bringing Low-Level Languages to the JVM: Efficient Execution of LLVM IR on Truffle

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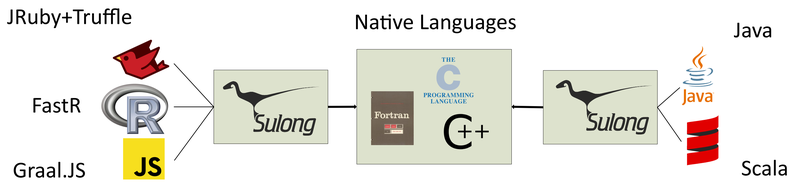
## Motivation

- To execute low-level languages (C, Fortran, C++, …) from JVM languages, one has to ***resort to native interfaces*** such as the Java Native Interface (JNI)
- JNI ***incurs overhead***, makes ***native interoperability complicated***, and ***contradicts Java's memory safety guarantees***
- **Language boundaries** are an obstacle for optimizations; compilers cannot optimize across language boundaries

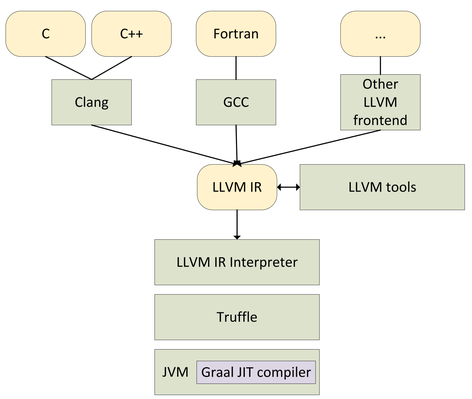
## Our Solution: Execute Native Languages on the JVM

- ***Interpreter for native languages*** on top of the JVM
  - to implement ***dynamic language's native interfaces***
  - to run ***native languages on the JVM***
- Having several languages on the same platform allows ***optimizations across language boundaries***



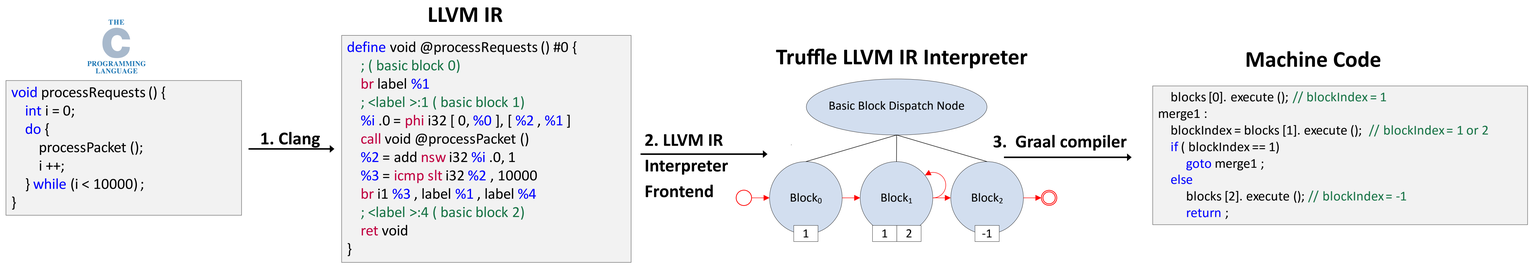

## System Overview: Bringing LLVM and the JVM together

- ***Clang and GCC*** compile ***native languages to LLVM IR***
- ***LLVM IR*** is a machine-specific, low-level intermediate format
- ***LLVM IR interpreter*** bases on the Truffle language implementation framework
- Truffle interpreters are ***Abstract Syntax Tree (AST) interpreters***
- Truffle uses ***the Graal JIT compiler*** for efficient compilation




## Interpretation and Dynamic Compilation of LLVM IR

1. ***Compile C/C++/Fortran Program*** to LLVM IR
2. Execute ***LLVM IR*** with the ***Truffle LLVM IR Interpreter***
3. Compile frequently executed functions to machine code by ***unrolling the interpreter loop***



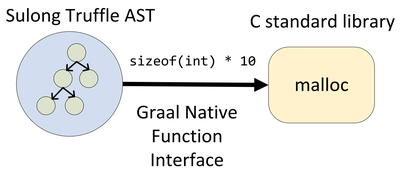

```
void processRequests () {
   int i = 0;
   do {
      processPacket ();
      i ++;
   } while (i < 10000) ;
}
```

```
define void @processRequests () #0 {
  ; ( basic block 0)
  br label %1
  ; <label >:1 ( basic block 1)
  %i .0 = phi i32 [ 0, %0 ], [ %2 , %1 ]
  call void @processPacket ()
  %2 = add nsw i32 %i .0, 1
  %3 = icmp slt i32 %2 , 10000
  br i1 %3 , label %1 , label %4
  ; <label >:4 ( basic block 2)
  ret void
}
```

```
   blocks [0]. execute (); // blockIndex = 1
merge1 :
   blockIndex = blocks [1]. execute ();  // blockIndex = 1 or 2
   if ( blockIndex == 1)
      goto merge1 ;
   else
      blocks [2]. execute (); // blockIndex = -1
      return ;
```

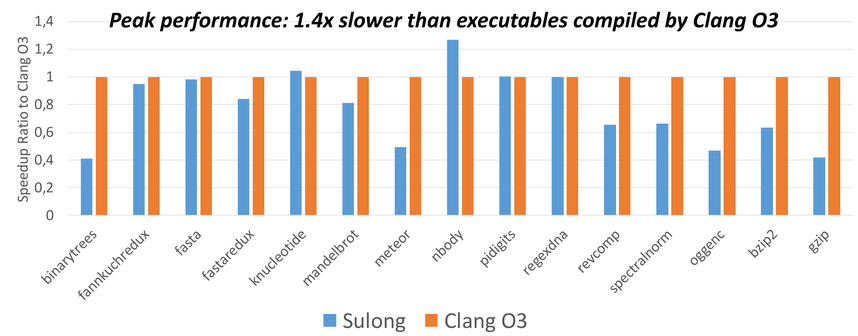
## Native Calls

- ***Graal Native Function Interface*** (NFI) to call native functions
  ***Direct calls*** from compiled Java code to native functions!
- Sulong allocates and accesses ***unmanaged memory to avoid conversion*** and marshalling of data




Grimmer, M., et al. "An efficient native function interface for Java." *Proceedings of PPPJ'13.*

## Performance Evaluation: C Benchmarks

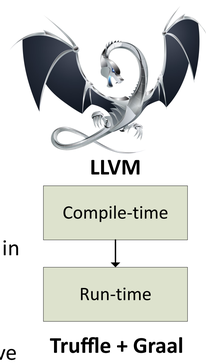



## Static Optimizations

- **Problem**: Java compilers do not optimize accesses to unmanaged memory
- **Solution**: Use LLVM's static optimization tool to promote memory accesses to local variables

## Dynamic Optimizations

- **Problem**: Static compilers cannot react to changes in program behavior
- **Solution**: Profile in the interpreter and exploit profiling data during compilation through speculative optimizations

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Sulong

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