allvm - Binary Decompilation

Sandeep Dasgupta
University of Illinois Urbana Champaign

March 30, 2016

Outline

Goal & Motivation

Possible Approaches

Our Approach

Present Status

Research Goal

- Obtain “richer” LLVM IR than native machine code.
- Enable advanced compiler techniques (e.g. pointer analysis, information flow tracking, automatic vectorization)

Why “richer” LLVM IR

- Source code analysis not possible
    - IP-protected software
    - Malicious executable
    - Legacy executable
- Source code analysis not sufficient
    - What-you-see-is-not-what-you-execute
- Platform aware and dynamic optimizations

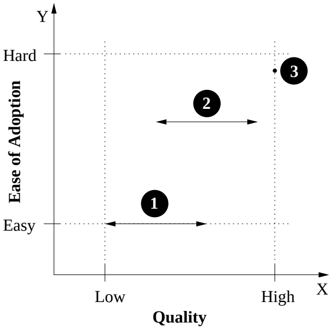
Outline

3 Possible Approaches

Research Goal: Obtain “richer” LLVM IR than native machine code.

Possible Approaches

1. Decompile Machine Code → LLVM IR
2. "Annotated" Machine Code → LLVM IR
3. Ship LLVM IR



Decompile `Machine Code` → `LLVM IR`

Benefits	Challenges
• Easy to adopt • No compiler support needed	• Reconstructing code and control flow • Variable recovery • Type recovery • Function & ABI rules recovery

- Tools Available: QEMU, BAP, Dagger, Mcsema, Fracture

“Annotated” `Machine Code` → `LLVM IR`

Benefits	Challenges

• Effective reconstruction
• Minimal compiler support needed
	• Annotations to be
	  • Minimal
	  • Compiler & IR independent
	• Adoption

- Tools Available: None

Ship `LLVM IR`

Benefits	Challenges
• *No loss* of information	• Adoption in Non LLVM based compilers • Code size bloat

- Tools Available: Portable Native Client, Renderscript, iOS, watchOS, tvOS apps, ThinLTO

Outline

Goal & Motivation

Possible Approaches

Our Approach

Present Status

Our Approach

Long term goal

Minimal compiler-independent annotations to reconstruct high-quality IR

Short term goals

1. Experiment with `Machine Code` $\rightarrow$ `LLVM IR`, to **understand** the challenges better
   - To select from existing decompilation frameworks.
   - Experiment with different variable and type recovery strategies
2. Design suitable annotations for what cannot be inferred without them

Outline

Goal & Motivation

Possible Approaches

Our Approach

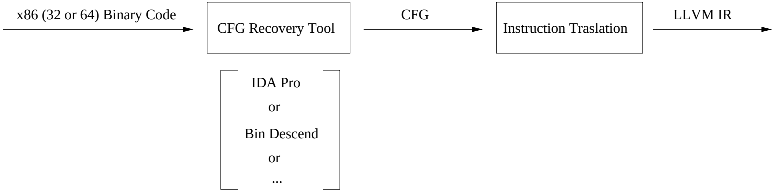
Present Status

Present Status

- Selected “mcsema” among the existing `Machine Code` $\longrightarrow$ `LLVM IR` solution.
  - Analysing the quality of IR recovery.
  - Current support and limitations.
- Literature survey on variable & type recovery research
- (Under Progress) Implementing a variable and type recovery model using mcsema

Selecting mcsema

- Actively supported and open sourced
- Well documented
- Functional `LLVM IR`
- Separation of modules: CFG recovery and Instruction translation (`CFG` $\longrightarrow$ `LLVM IR`)



Instruction Translation

- Processor state: Modelled as struct of `ints`
- Processor memory: Modelled as flat array of bytes

```
start:
    mov eax, [esp − 4h]
    add eax, 1
    ret
```

Binary Code

Translation →

```
RECOVERED_FUNC ( struct RegisterContext regctx ) :
    VAR_EAX = regctx.EAX
    VAR_ESP = regctx.ESP

    VAR_EAX = [ VAR_ESP − 4 ]
    VAR_EAX += 1

    regctx.EAX = VAR_EAX
    regctx.ESP = VAR_ESP
END
```

High level view of Recovered Code

mcsema: Demo

Support & Limitations

- What Works
  - Integer Instructions
  - FPU and SSE registers
  - Callbacks, External Call, Jump tables
- In Progress
  - FPU and SSE Instructions: Not fully supported
  - Exceptions
  - Better Optimizations

Variable, Type & Function Parameter Recovery

- Enables
  - Fundamental analysis (Dependence, Pointer analysis)
  - Optimizations (register promotion)
- State of the art
  - Divine
    - State of the art variable recovery
  - Second Write
    - Heuristics for function parameter detection
    - Scalable variable and type recovery
  - TIE
    - Type recovery

Outline

Goal & Motivation

Possible Approaches

Our Approach

Present Status

Questions ?

Outline

What-you-see-is-not-what-you-execute

The following compiler (Microsoft C++ .NET) induced vulnerability was discovered during the Windows security push in 2002

```
memset(password, '\0', len);        ──────>        free(password);
free(password);
```