The BINCOA Framework for Binary Code Analysis

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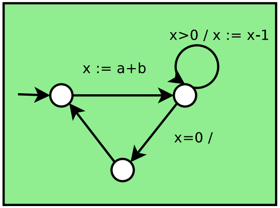
Binary code analysis

Model



Source code

```
int foo(int x, int y) {
 int k= x;
 int c=y;
 while (c>0) do {
   k++;
   c--;}
 return k;
}
```

Assembly

```
_start:
  load  A 100
  add B A
  cmp B 0
  jle label

label:
  move @100 B
```

Executable

```
ABFFF780BD70696CA101001BDE45
145634789234ABFFE678ABDCF456
5A2B4C6D009F5F5D1E0835715697
145FEDBCADACBDAD459700346901
3456KAHA305G67H345BFFADECAD3
00113456735FFD451E13AB080DAD
344252FFAADBDA457345FD780001
FFF22546ADDAE989776600000000
```

Binary code analysis at a glimpse

Recent research field

[Codesurfer/x86, SAGE, Jakstab, Osmose, TraceAnalyzer, McVeto, Vine, BAP]

Many promising applications

- off-the-shelf components (including libraries)
- mobile code (including malware)
- third-party certification

Advantages over source-code analysis

- always available
- no “compilation gap”
- allows precise quantitative analysis (ex : wcet)

Very challenging

- conceptual challenges
- practical issues

Practical issues

Engineering issue : many different (large) ISAs

- supporting a new ISA : time-consuming, error-prone, tedious
- consequence : each tool support only a few ISAs (often one !)

Semantic issue : each tool comes with its own formal(?) model

- exact semantics seldom available
- modelling hypothesises often unclear

Consequences

- lots of redundant engineering work between analysers
- difficult to achieve empiric comparisons
- difficult to combine / reuse tools

The BINary COde Analysis project

French research project (CEA, Uni. Bordeaux 1, Uni. Paris 7)

Propose a common formal model for low-level programs

- Dynamic Bitvector Automata (DBA)

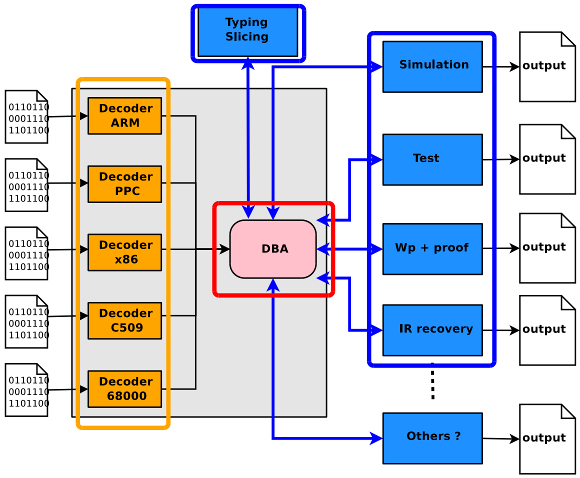
Provide basic open-source tool support

- basic DBA manipulation
- *(future) front-ends from x86, PPC, ARM*

Develop (complementary) binary-level analysers

- OSMOSE (CEA), TraceAnalyzer (CEA), Insight (LABRI)

Long-term objective



- Mutualize engineering work
- Common semantic
- Ease collaboration between analyses

Dynamic Bitvector Automata

Main design ideas

- small set of instructions
- concise and natural modelling of common ISAs
- low-level enough to allow bit-precise modelling

Can model : instruction overlapping, return address smashing, endianness, overlapping memory read/write

Limitations : (strong) no self-modifying code, (weak) no dynamic memory allocation, no FPA

Dynamic Bitvector Automata (2)

Extended automata-like formalism

- bitvector variables and arrays of bytes
- all bv sizes statically known, no side-effects
- standard operations from BVA

Feature 1 : Dynamic transitions

- for dynamic jumps

Feature 2 : Directed multiple-bytes read and write operations

- for endianness and word load/store

Feature 3 : Memory zone properties

- for (simple) environment

Dynamic Bitvector Automata (2)

Feature 1 : Dynamic transitions

- some nodes are labelled by an address
- dynamic transitions have no predefined destination
- destination computed dynamically via a target expression

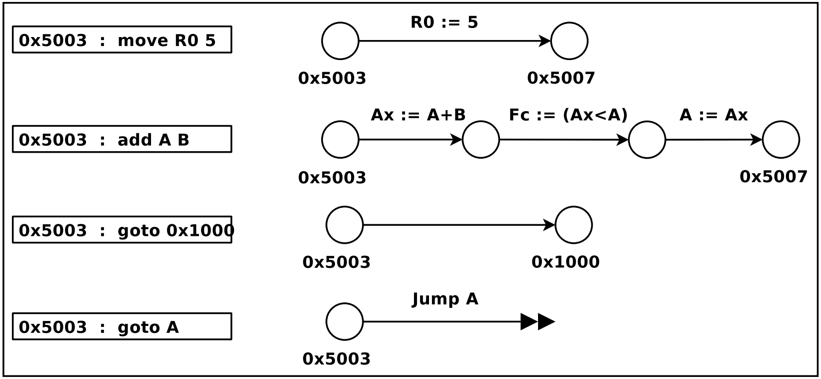
Feature 2 : Directed multiple-bytes read and write operations

- $\mathrm{array}[\mathit{expr}; k^{\#}]$, where $k \in \mathbb{N}$ and $\# \in \{\leftarrow, \rightarrow\}$

Feature 3 : Memory zone properties

- specify special behaviour for some segments of memory
- volatile, write-aborts, write-ignored, read-aborts

Modelling with DBA



Procedure calls / returns : encoded as static / dynamic jumps

Memory zone properties, a few examples : ROM *(write-ignored)*, memory controlled by env *(volatile)*, code section *(write-aborts)*

DBA toolbox

Open-source Ocaml code for basic DBA manipulation

Features

- a datatype for DBAs
- basic “typing” (size checking) over DBAs
- import (export) from (to) a XML format
- DBA simplification (see next)

GPL license, based on xml-light, $\approx$ 3 kloc

DBA toolbox - simplifications

Goal : simplify unduly complex DBAs typically obtained from instruction-wise translation

- useless flag computations / auxiliary variables / etc.

Inspired by standard compilation techniques [peephole, dead code, etc.]

- beware of partial DBAs and dynamic jumps !
- rethink these standard techniques in a partial CFG setting

Results : size reduction of -50% (all instrs), and between -30% and -50% (non-goto instrs)

Binary-level analysers

Osmose (CEA) [ICST-08, STVR-11]

- automatic test data generation (dynamic symbolic execution)
- 75 kloc of OCaml, front-ends : PPC, M6800, Intel c509
- case-studies : programs from aeronautics and energy

> negotiations to become open-source

TraceAnalyzer (CEA, with Franck Védrine) [VMCAI-11]

- safe CFG reconstruction (refinement-based static analysis)
- 29 kloc of C++, front-end : PPC
- case-studies : programs from aeronautics

Insight (LABRI, with Emmanuel Fleury)

- abstract interpretation and weakest precondition
- C++, front-end : x86
- case-studies (on-going) : polymorphic virus analysis

> aims at being open source when the API stabilizes

Conclusion

Current state

- DBAs are a nice formalism to work with
  [improve our former model]
- common semantics allows exchange of information
  [OSMOSE - Traceanalyzer]
- basic DBA support

Ongoing and future work

- open-source front-ends
- extensions of DBAs : support for dynamic memory allocation