Symbolic Execution in Selfie - a first step
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Symbolic Execution in Selfie
- a first step -

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**INTRODUCTION**

Our project consists in designing and implementing a low-level symbolic emulator following selfie's philosophy: simplicity. More precisely, we tackle the question of how to implement a fully, sound and complete symbolic emulator capable of deducing properties for any machine code sequence given in input. Our first goal being to have no loss of information for at least the selfie code and define clearly the subset of RISC-U language it imply. This particular challenge is made possible thanks to the simple languages handled by this independent software, alleging and preventing us from the usual assumptions in numerical analysis. All in all, we aim at using selfie's self-property to symbolically verify the selfie compilation and emulation.

**LANGUAGES**

<table>
<thead>
<tr>
<th>High-level</th>
<th>RISC-U: Low-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>C*</td>
<td>RISC-U</td>
</tr>
</tbody>
</table>

C* a tiny subset of C, supports only two data types: uint64_t and uint64_t*. RISC-U a tiny subset of 64-bit RISC-V, contains 14 instructions for unsigned arithmetic only.

**SELFIE**

Selfie is an independent 64-bit implementation of (1) a self-compiling compiler written in C* targeting RISC-U, (2) a self-executing RISC-U emulator, and (3) a self-hosting hypervisor that virtualizes the emulated RISC-U machine. Selfie is implemented in a single 8k-line file and can compile, execute, and virtualize itself any number of times. Selfie has originally been developed for educational purposes but has recently become a research platform as well.

**SYMBOLIC EXECUTION**

The symbolic execution emulates a given RISC-U binary, analysing numerically the instructions over abstract domains and operations. A current version implements w-intervals and initializes read system calls' return value as every possible value. The implementation logs each emulated instruction in a trace recording a triple \( \langle \text{inst}, \text{prev}, \text{value} \rangle \) of the instruction binaries, the previous destination register value and the new abstract one. Moreover, each register and memory records the trace index of its last store. This data-structure allows us to apply constraints and back-propagation algorithms when the branch on equal instruction (beq) is emulated by simply moving backward or forward through the trace. An abstract domain for a complete and sound numerical analysis is still in investigation for the selfie binary, its simplicity allows us to avoid the usual over-approximations and fit exactly the possible values of each variable for all paths.

**LOGGING TRACE**

<table>
<thead>
<tr>
<th>tc</th>
<th>pc</th>
<th>prev</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>n</td>
<td>addi</td>
<td>n+2</td>
</tr>
<tr>
<td>n+1</td>
<td>addi</td>
<td>n+3</td>
</tr>
<tr>
<td>n+2</td>
<td>addi</td>
<td>n+4</td>
</tr>
<tr>
<td>n+5</td>
<td>addi</td>
<td>n+6</td>
</tr>
<tr>
<td>n+7</td>
<td>addi</td>
<td>n+8</td>
</tr>
<tr>
<td>n+9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>V_{start}</th>
<th>V_{end}</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>MAX</td>
</tr>
<tr>
<td>...</td>
<td>2</td>
</tr>
<tr>
<td>...</td>
<td>MAX</td>
</tr>
<tr>
<td>...</td>
<td>MAX</td>
</tr>
<tr>
<td>...</td>
<td>MAX</td>
</tr>
</tbody>
</table>

|x = read();
y = x + 2;
if(x == 10) return y;
return x;|

then

x[10,10] y[12,12]

else

x[11,9] y[13,11]

RISC-U binaries

onto RISC-U binaries

\( \text{ld} \ $t0 \ -$8(\text{sp}) \)
\( \text{addi} \ $t1 \ 2 \)
\( \text{addi} \ $t1 \ 1 \)
\( \text{add} \ $t0 \ $t0 \ $t1 \)
\( \text{sd} \ $t0 \ -$16(\text{sp}) \)
\( \text{beq} \ $t0 \ $zero \ #f \)

\( \text{ecall} \)

\( \text{ld} \ $t0 \ -$8(\text{sp}) \)
\( \text{addi} \ $t1 \ 10 \)
\( \text{addi} \ $t1 \ 1 \)
\( \text{sltu} \ $t0 \ $t1 \)
\( \text{beq} \ $t0 \ $zero \ #f \)

**REFERENCES**

- http://selfie.cs.uni-salzburg.at

Risc-U outputs symbolic emulation selfie

w = interval 2^{-63}

def use (11,9) [1, M] [0, 0] true

1, M [0, 0] true