Tamarin: Concolic Disequivalence for MIPS

Abel Nieto

A Tale of Two Boxes

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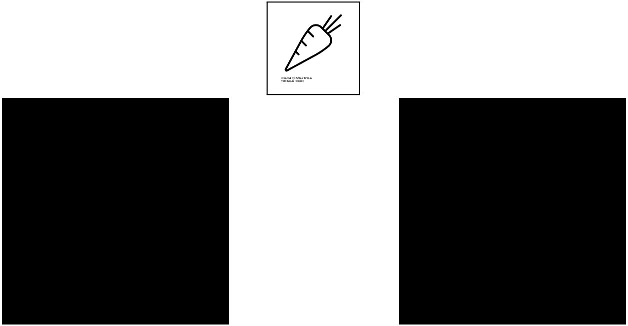

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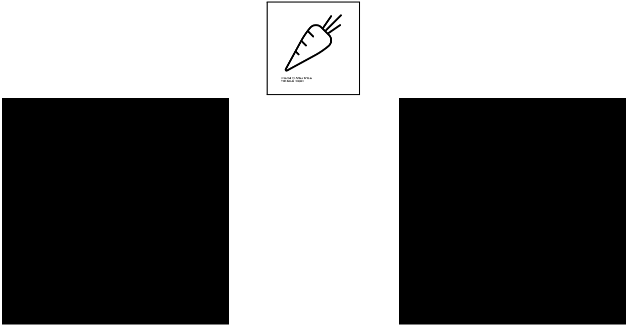

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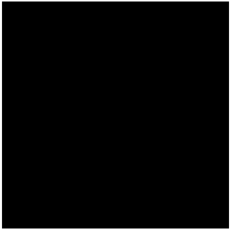

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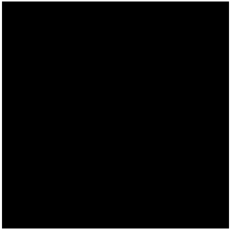

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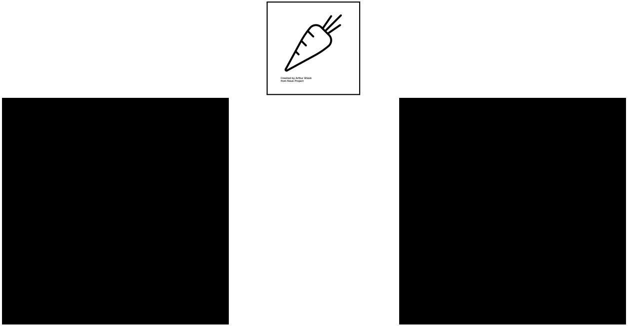

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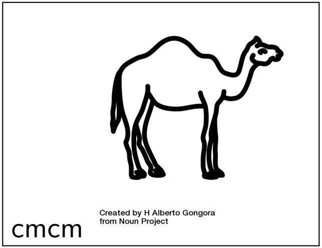

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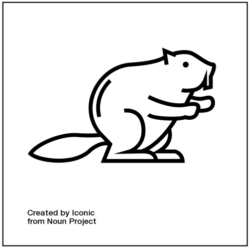

The Problem

Given MIPS program P_1 and P_2, when are they equivalent?

The Problem

Attempt 1: two programs are equivalent if they give the same output (resp.) for all inputs.

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What's an output? Register \$3.

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What's an input? Register \$1 and \$2.
What's an output? Register \$3.

Don't care about (most) CPU interrupts/IO.

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Problem: undecidable via Rice's theorem.

The Problem

Attempt 2: two programs are S-equivalent if they cannot be told apart after S steps.

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S-equivalent (e.g. for $S = 10$), but not equivalent:

```
# P_1
add $3, $1, $2
```

```
# P_2
  add $4, $0, 1  # counter
  add $5, $0, 42 # upper bound
loop:
  slt $6, $4, $5
  beq $6, $0, end
  add $4, $4, 1
  beq $0, $0, loop
end:
  add $3, $1, $1
```

The Problem

Attempt 2: two programs are S-equivalent if they **cannot be told apart** after S steps.

R_1	R_2	S-equiv

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R_1	R_2	S-equiv
v	v	yes

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R_1	R_2	S-equiv
v	v	yes
v	$w \neq v$	no

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R_1	R_2	S-equiv
v	v	yes
v	$w \neq v$	no
v	error	no

The Problem

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R_1	R_2	S-equiv
v	v	yes
v	$w \neq v$	no
v	error	no
error	error	yes

The Problem

Attempt 2: two programs are S-equivalent if they **cannot be told apart** after S steps.

R_1	R_2	S-equiv
v	v	yes
v	$w \neq v$	no
v	error	no
error	error	yes
non-termination	???	yes
...		

The Problem

Lemma

Equivalence implies S-equivalence.

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Equivalence implies S-equivalence.

Corollary (Soundness)

If two programs are not S-equivalent (for any S), then they are not equivalent.

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Try some inputs by hand: low coverage, fast (unit tests)

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Try all 2^{64}values of \$1 and \$2: high coverage, slow (but decidable)

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Which inputs?

Try some inputs by hand: low coverage, fast (unit tests)

Try all 2^{64}values of $1 and $2: high coverage, slow (but decidable)

Tamarin: use concolic execution: higher coverage(?), not too slow(?)

Idea

Alternating concolic execution

```
# P_1
  bne $1, 42, end
  add $3, $3, $0
end:
  add $3, $1, $2
```

```
# P_2
  add $3, $1, $2
  bne $2, 100, end
  add $3, $3, $2
end:
```

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Run	Driver	Verifier	\$1	\$2	Path	R_D	R_V

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# P_2
  add $3, $1, $2
  bne $2, 100, end
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end:
```

Run	Driver	Verifier	\$1	\$2	Path	R_D	R_V
1	P_1	P_2	1	1	$\$1 \neq 42$	2	2

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2	P_2	P_1	1	1	$\$2 \neq 100$	2	2

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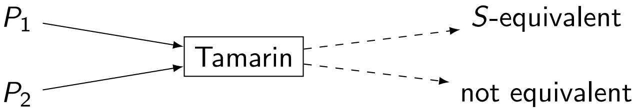
Run	Driver	Verifier	\$1	\$2	Path	R_D	R_V
1	P_1	P_2	1	1	$\$1 \neq 42$	2	2
2	P_2	P_1	1	1	$\$2 \neq 100$	2	2
3	P_1	P_2	42	1	$\$1 = 42$	2	2
4	P_2	P_1	1	100	$\$2 = 100$	201	2

Tamarin (Overview)



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