M6 - Cross-Optimization Testing

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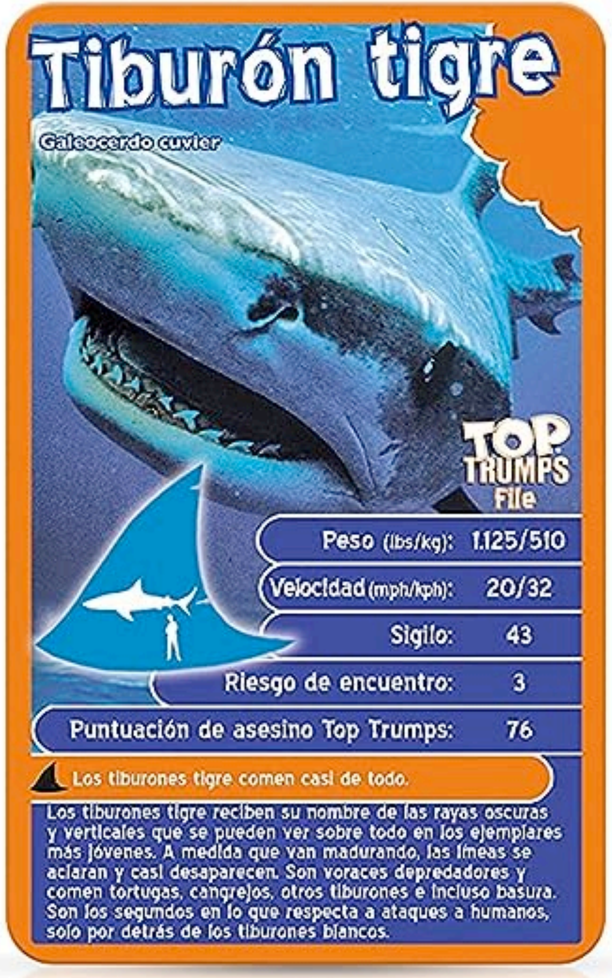
Goals

- Differential testing for compilers:
  - Across different compilers fro the same language
  - Across different variants of the same compiler

- Optimization invariants
  - Cross-optimization differential testing
  - Cross-architecture differential testing

Remember Differential Testing

80 km/h



32 km/h

What if we don’t have two things to compare?

80 km/h

32 km/h

What if we don’t have two things to compare?

80 km/h

After Lunch

Before Lunch

75 km/h

What if we don’t have two things to compare?

In Nature

In Captivity

80 km/h

67 km/h

How can we obtain

variations of the same compiler?

Optimization Invariants

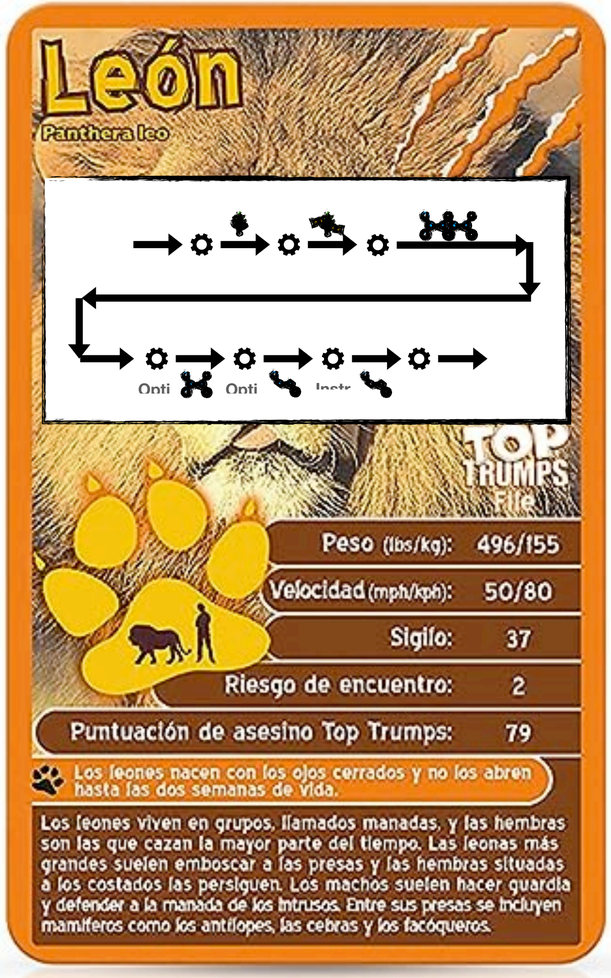
- Insight: optimizations should not break the program

- Optimizations work in a *if proof then transform* fashion
- If no proof of correctness can be done, no transformation happens

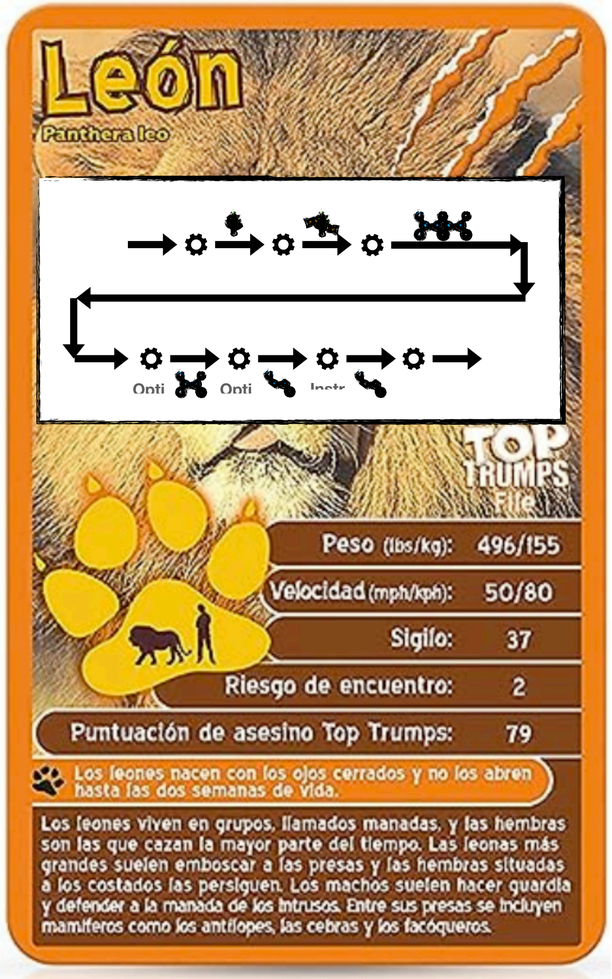
- Thus, If optimizations break the program output we have a *bug*

Cross-Optimization Differential Testing

O2 level



O0 level



Compiling with Optimizations

```
| program objectProgram result |
program := SmiParser parse: 'function main(){
  x := 7;
  return x + 1;
}'.

compiler := SmiCompiler new.

objectProgram := compiler compile: program.
result := self runProgram: objectProgram.
```

Compiling with Optimizations

```
| program objectProgram result |
program := SmiParser parse: 'function main(){
  x := 7;
  return x + 1;
}'.

compiler := SmiCompiler new.
compiler o1.
objectProgram := compiler compile: program.
result := self runProgram: objectProgram.
```

Smic optimization levels

- O0: no optimizations [DEFAULT]
- O1: stable optimizations
- O2: unstable optimizations

```
“Compiler starts in o0”
compiler := SmiCompiler new.

compiler o1.
compiler o2.

“Put it back to o0”
compiler o0.
```

Getting insights of a single optimization

- Testing a single optimization at a time
- Differential: single optimization vs no optimizations

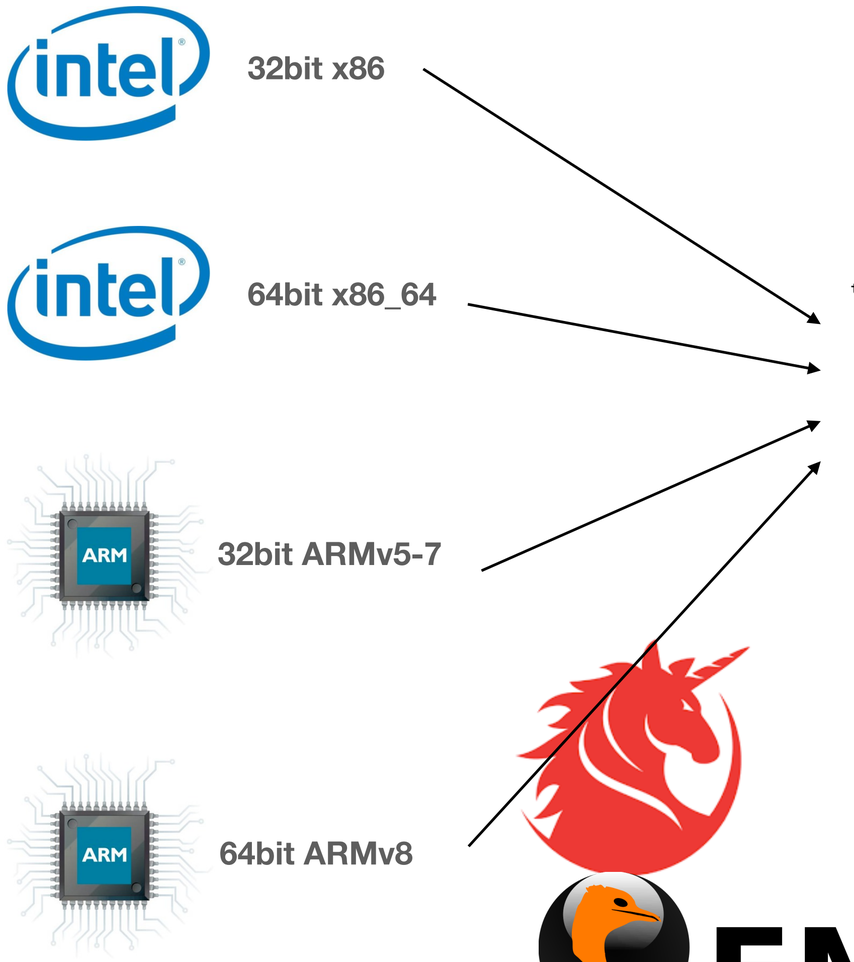
```
“Compiler starts in o0”
compilerA := SmiCompiler new.

compilerB := SmiCompiler new.
compilerB optimizations: { testedOptimization }
```

Obtaining all possible optimizations in Smic

```
SmiCompiler supportedOptimizations
>> anArray(
  a DRBranchCollapse
  a DRCopyPropagation
  a DRPhiSimplication
  a DROptimisationSequence
  a DRCleanControlFlow
  a DROptimisationSequence
  a DRGlobalValueNumbering
  a DRCogitCanonicaliser
  a DROptimisationSequence)
```

Cross-architecture testing




```
testProgramAddOne

    | program objectProgram result |
    program := SmiParser parse: 'function main(){
        x := 7;
        return x + 1;
    }'.

    objectProgram := self compile: program.
    result := self runProgram: objectProgram.

    self assert: result equals: 8
```

```
compilerA := SmiCompiler new.
compilerA architecture: #X64.

compilerB := SmiCompiler new.
compilerB architecture: #aarch64.
```

Full Example

- Two compiler variants
- Differential runner

```
runnerA := PzBlockRunner on: [ :e | | p |
  p := compilerA compile: program.
  smiRunner run: p
].

runnerA := PzBlockRunner on: [ :e | | p |
  p := compilerB compile: program.
  smiRunner run: p
].

diffRunner := PzDifferentialRunner new
  runnerA: runnerA;
  runnerB: runnerB;
  yourself.

diffRunner value: ‘function main(){ … }’
```

Possible Extensions and Next Steps

- Combine with grammar fuzzing!
- What should the runner compare?
  - The default differential runner compares exit statuses
  - Should they compare return values?
  - Exceptions?

Takeaways

- Optimizations keep program semantics
- Compilers could be modified to generate compiler versions
  - Cross-optimization
  - Cross-architecture

- Different observed behavior is evidence of bugs

Material

- An Empirical Comparison of Compiler Testing Techniques. ICSE’16 Junjie Chen et al.