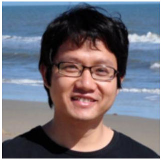
Verifying Absence of Side Channels using Cartesian Hoare Logic


Işıl Dillig


Yu Feng


Jia Chen


M. Heule

THE UNIVERSITY OF TEXAS AT AUSTIN

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$$\boxed{\exists H_1, H_2, L.\ R_P(H_1, L) \neq R_P(H_2, L)}$$

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- If difference in resource usage is very small, vulnerability may not be **exploitable**
- To relax this definition, we propose **bounded non-interference:**

$$\forall H_1, H_2, L.\ |R_P(H_1, L) - R_P(H_2, L)| < \epsilon$$

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- To verify bounded non-interference, need technique for verifying k-safety

Self-composition

- Simplest technique to verify k-safety is **self-composition (SC)**
- Given 2-safety property F, self composition sequentially composes two alpha-renamed copies of the program

```
Verify(P, F) {
  P[x1/x];
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Unfortunately, self-composition does not work well in practice

Why Self-composition Doesn't Work

- To see why SC doesn't work, consider this program

```
f(int[] secret,
  int k, int n) {

 i:=0;
 while(i<n){
   if(secret[i])
     foo(); //r+=c
   else
     bar(); //r+=c
  i:=i+k;
 }

}
```

Why Self-composition Doesn't Work

- To see why SC doesn't work, consider this program
- With SC, we obtain this new program

```
 i1:=0;
 while(i1<n){
   if(secret1[i1])
     foo(); //r1+=c
   else
     bar(); //r1+=c
  i1:=i1+k;
 }
i2:=0;
while(i2<n){
   if(secret2[i2])
     foo(); //r2+=c
   else
     bar(); //r2+=c
  i2:=i2+k;
 }
assert(r1 - r2 < b);
```

Why Self-composition Doesn't Work

- To see why SC doesn't work, consider this program
- With SC, we obtain this new program
- Unfortunately, need to know precise values of r1, r2 after each loop to prove assertion, but this is very difficult

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 i1:=0;
 while(i1<n){
   if(secret1[i1])
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  i1:=0;i2:=0;
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  i2:=i2+k;
}
assert(r1 - r2 < b);
```

Easy to infer r1=r2!

Cartesian Hoare Logic (CHL)

- Our PLDI'16 paper introduces **Cartesian Hoare Logic (CHL)** for verifying k-safety

$$\text{(Expand)}\quad \frac{\vdash \langle\Phi\rangle\ \boxed{\circledast} S^n\ \langle\Psi\rangle}{\vdash \|\Phi\|\ S\ \|\Psi\|}$$

$$\text{(Lift)}\quad \frac{\vdash \{\Phi\}\ S\ \{\Psi\}}{\vdash \langle\Phi\rangle\ S\ \langle\Psi\rangle}$$

$$(\flat\text{−intro 1})\quad \frac{\vdash \langle\Phi\rangle\ S;\flat \circledast \chi\ \langle\Psi\rangle}{\vdash \langle\Phi\rangle\ S \circledast \chi\ \langle\Psi\rangle}$$

$$(\flat\text{−intro 2})\quad \frac{\vdash \langle\Phi\rangle\ \chi \circledast \flat\ \langle\Psi\rangle}{\vdash \langle\Phi\rangle\ \chi\ \langle\Psi\rangle}$$

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$$\text{(Assoc)}\quad \frac{\vdash \langle\Phi\rangle\ \chi_1 \circledast (\chi_2 \circledast \chi_3)\ \langle\Psi\rangle}{\vdash \langle\Phi\rangle\ (\chi_1 \circledast \chi_2) \circledast \chi_3\ \langle\Psi\rangle}$$

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$$\text{(Step)}\quad \frac{\vdash \{\Phi\}\ S_1\ \{\Phi'\} \quad \vdash \langle\Phi'\rangle\ S_2 \circledast \chi\ \langle\Psi\rangle}{\vdash \langle\Phi\rangle\ S_1; S_2 \circledast \chi\ \langle\Psi\rangle}$$

$$\text{(Havoc)}\quad \frac{V = \text{vars}(\chi)}{\vdash \langle\Phi\rangle\ \chi\ \langle\exists V.\Phi\rangle}$$

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- CHL proof rules allow synchronization between loops

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- CHL proof rules allow synchronization between loops
- Easy to automate reasoning in CHL

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Cartesian Hoare Logic (CHL)

- Our PLDI'16 paper introduces **Cartesian Hoare Logic (CHL)** for verifying k-safety
- CHL proof rules allow synchronization between loops
- Easy to automate reasoning in CHL
- More scalable and precise than prior techniques

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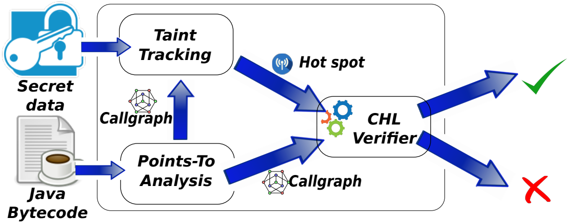
- However, combines CHL verifier with taint analysis for better scalability



Results

- Using this technique, we solved several benchmarks from engagements (e.g., GabFeed, SnapBuddy, TourPlanner)
- Furthermore, we were able to find vulnerabilities in real Java applications, such as Tomcat, Jetty, JBoss, and SpringSecurity
- In addition, we also used technique to analyze other k-safety properties (e.g. transitivity, associativity, symmetry etc.)

Demo Time!