Modular Development of Certified Concurrent Code

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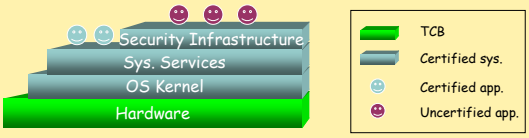
http://flint.cs.yale.edu

Goal: Building Reliable Software!



We have NO security guarantee without reliable implementation!

Low-level program verification allows us to have:

- Highly efficient and dependable OS and libraries
- Reliable security infrastructure
- Certified applications for mission-critical systems

First Step:

Modular-Verification of Low-Level Concurrent Code!

Our Approach:

Modular Verification of Low-Level Multi-Threaded Code (CMAP)

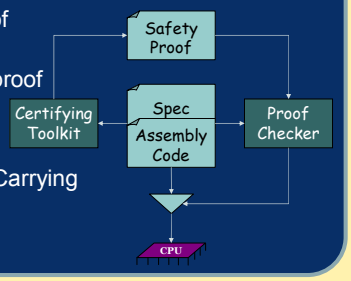
Assume-Guarantee + Dynamic Thread Creation

Logic-based specification

Semi-automatic proof construction

Formal Mechanical proof

Foundational Proof-Carrying Code (FPCC)



Comparison to state of the art

Current approaches	New approach
• higher-level, cobegin/coend	• low-level + fork/join/exit
• PCC for sequential code	• PCC for concurrent code
• not modular or thread modular only	• thread modular and procedural modular
• type systems for specific properties	• logic system for general properties

Concurrency Verification

Assume-Guarantee Method

- Thread spec: (A, G)
- Non-interference: $\forall i,j.\ i\neq j \Rightarrow G_i \Rightarrow A_j$

Challenges for low-level code cert.

- Changing Environment
  - Unbounded Dynamic Thread Creation/Termination
- Modularity Issues
  - Thread Modularity + Procedural Modularity

```
Global data: int data[100];
main:
  int i:=0;
  while (i<100){
    data[i]:=f(i);
    fork child(i);
    i++;
  }
```

The CMAP Approach

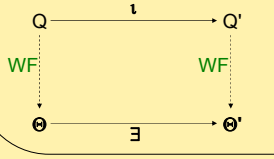
INV: dynamic threads do not interfere

Queue: **Q**, Spec: **Θ**,

$WF(Q, \Theta) \equiv \forall t_i, t_j \in Q. t_i \neq t_j \Rightarrow (G_i \Rightarrow A_j)$

Borrow the invariant-based proof in TAL

Initial condition: $\exists \Theta_0.\ WF(Q_0, \Theta_0)$



ι ::= add | sub | jd …

| exit | fork | yield

The CMAP Approach

Queue Update

WF(Q∪{t}, Θ∪{(A, G)})

↓ A⇒A', G'⇒G; t: (A', G')

WF(Q∪{t}, Θ∪{(A', G')})

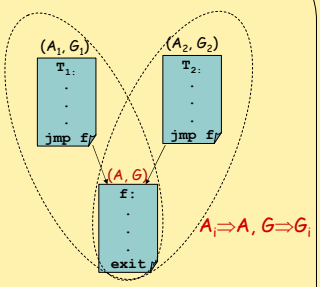
Queue Extension

WF(Q∪{t}, Θ∪{(A, G)})

↓ fork f(a)

↓ A ⇒ A", G" ⇒ G

WF(Q∪{t',t}, Θ∪{(A", G"), (A∨G", G∧A")})



Certify once, use everywhere!

Conclusions and Future Work

What we have done so far:

CMAP: Abstract Machine + Verification Logic

Certified Code:

- Unbounded dynamic thread creation
- Readers-writers problems with sync. primitives
- Lock-free concurrent programs (GCD)

Coq Implementation

Future Work

Certified thread library and sync. primitives

Surface languages and certifying compilation

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The FLINT Project
Systems Software for Advanced Languages