StkTokens: Enforcing Well-Bracketed Control Flow and Stack Encapsulation Using Linear Capabilities

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Overview

StkTokens-paper in the big picture

Defining well-bracketed control flow and local state encapsulation

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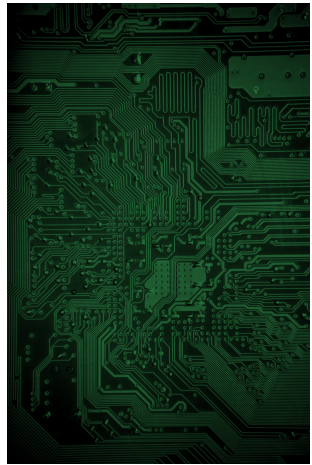
StkTokens-paper in the big picture

Defining well-bracketed control flow and local state encapsulation

Abstractions all the way down



Abstractions all the way down

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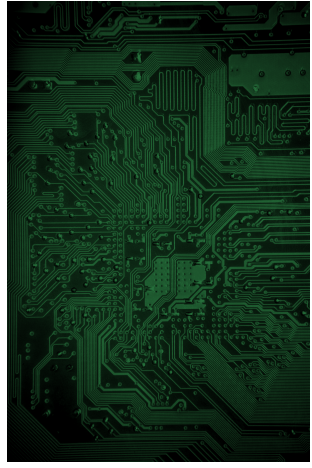

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int main()
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  printf("Hello, World!");
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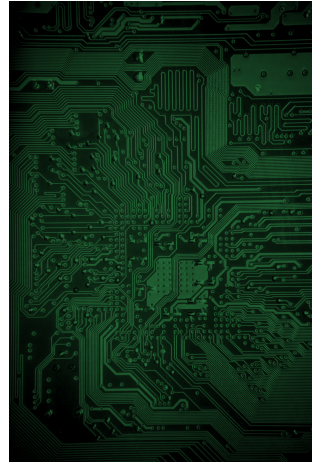

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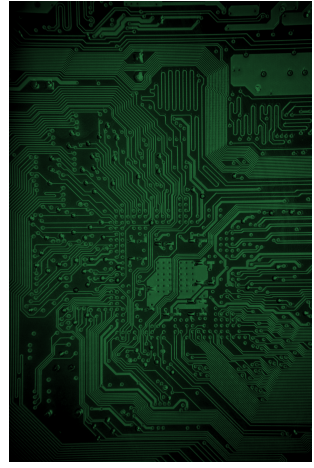

Abstractions all the way down

secure
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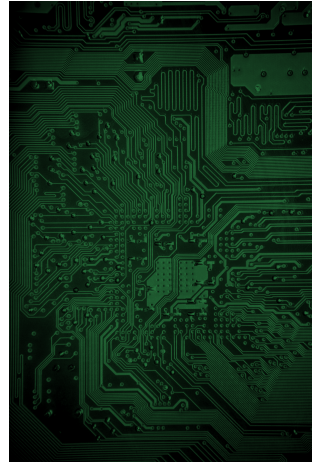

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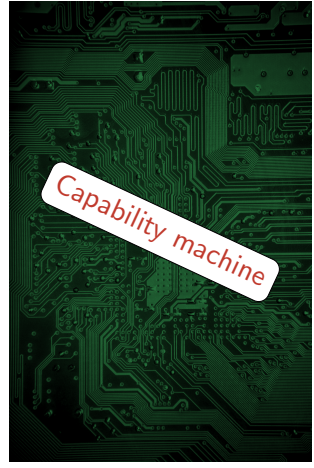

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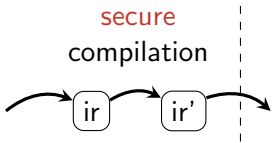


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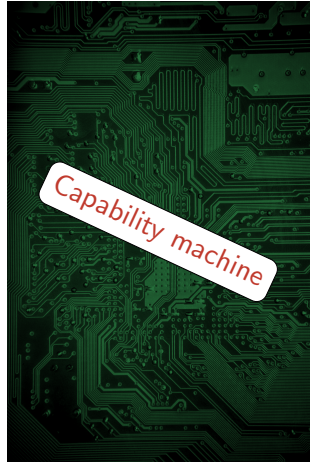

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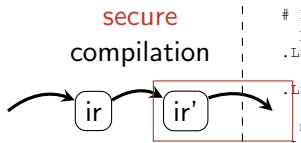


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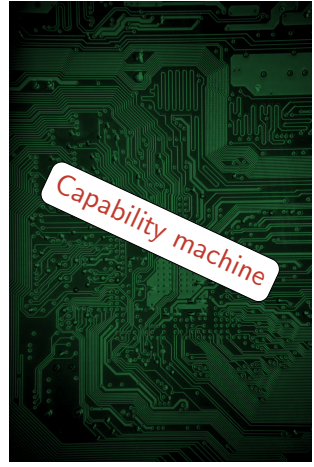

Paper Contents Overview

Formalization of CHERI-like capability machine with linear capabilities

StkTokens a calling convention that provably guarantees local-state encapsulation (LSE) and well-bracketed control-flow (WBCF)

Fully-abstract overlay semantics a novel way to prove LSE and WBCF claims

Overview

StkTokens-paper in the big picture

Defining well-bracketed control flow and local state encapsulation

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```
 void a()
{
    ...
    return;
}

void b()
{
    int x = 5;
    a();
    ...
    a();
    return;
}
```

Defining well-bracketed control flow and local state encapsulation

```
 void a()
{
    ...
    return;
}
```

Function `a` cannot access variable `x`

```
void b()
{
    int x = 5;
    a();
    ...
    a();
    return;
}
```

Local-state encapsulation

Defining well-bracketed control flow and local state encapsulation

```
 void a()
{
    ...
    return;
}

void b()
{
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    a();
    ...
→   a();
    return;
}
```

Well-bracketed control flow

Defining well-bracketed control flow and local state encapsulation

```
→ void a()
  {
      ...
      return;
  }

  void b()
  {
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      ...
      a();
      return;
  }
```

Well-bracketed control flow

Defining well-bracketed control flow and local state encapsulation

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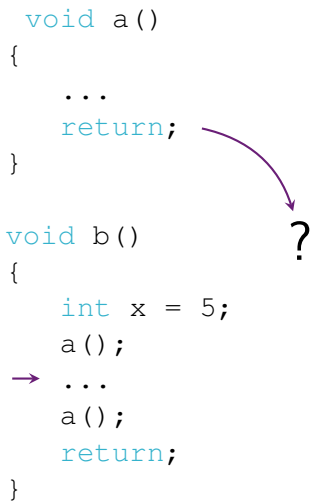

Well-bracketed control flow

Desired properties of the WBCF and LSE definition

1. *Intuitive*
2. *Useful for reasoning*
3. *Reusable in secure compiler chains*
4. *Arguably "complete"*

Overlay Semantics

```
move  rtmp1 42
store rstk rtmp1
cca   rstk -1
geta  rtmp1 rstk
cca   rretc 5
move  rtmp1 pc
cca   rtmp1 -20
```

```
load  rtmp1 rtmp1
cca   rtmp1 -21
cseal rretd rtmp1
move  rretc pc
xjmp  r1 r2
cseal rretc rtmp1
move  rtmp1 0
```

Linear Capability Machine (LCM)

Overlay Semantics

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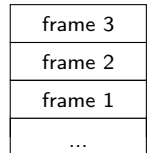
Builtin call stack



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Linear Capability Machine (LCM)

Overlay Semantics

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cca   rstk
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move  rtmp1 pc
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```

call

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cseal rretd rtmp1
move  rretc pc
xjmp  r1 r2
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```
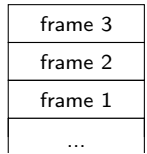

return

Builtin call stack



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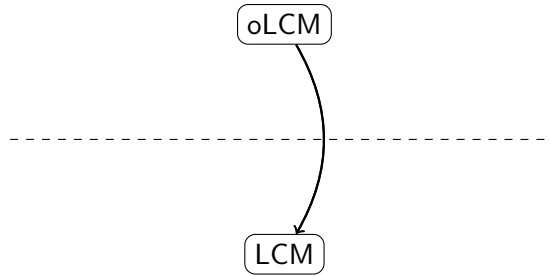
Linear Capability Machine (LCM)

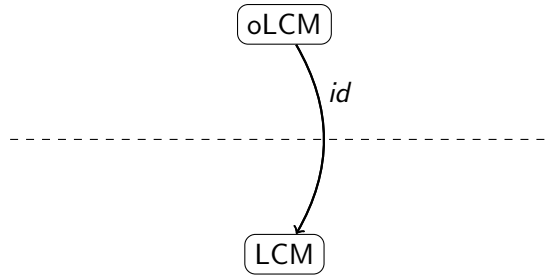
Fully-abstract overlay semantics

- Compile from oLCM to LCM



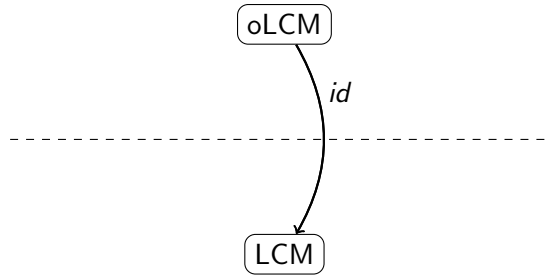
Fully-abstract overlay semantics

- Compile from oLCM to LCM
- Compilation is the identity



Fully-abstract overlay semantics

- Compile from oLCM to LCM
- Compilation is the identity
- Builtin call stack abstraction in oLCM preserved after compilation



Evaluating the definition

1. *Intuitive*
2. *Useful for reasoning*
3. *Reusable in secure compiler chains*
4. *Arguably "complete"*

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1. *Intuitive*
   Yes, call stack corresponds exactly to our intuition.
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Evaluating the definition

1. *Intuitive*
   Yes, call stack corresponds exactly to our intuition.
2. *Useful for reasoning*
   Yes, ...
3. *Reusable in secure compiler chains*

4. *Arguably "complete"*

Evaluating the definition

1. *Intuitive*
   Yes, call stack corresponds exactly to our intuition.
2. *Useful for reasoning*
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3. *Reusable in secure compiler chains*
   Yes, fully-abstract compilations compose vertically, so oLCM can be used as a target for other compilation phases.
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The StkTokens calling convention

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... is explained in the paper.

Thank you!

Full-abstraction proof sketch