Dynamic Logic for Practical Program Verification

Set 5

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VTSA Summer School, Luxembourg, 2024

Verification of Solidity

- Ongoing work: Guilherme Alvares, Wolfgang Ahrendt, Richard Bubel
- First results:
  Ahrendt, Bubel
  Functional Verification of Smart Contracts via Strong Data Integrity
  published in ISoLA'20

Part I

Dynamic Logic and Calculus for Solidity

Deductive verification of genuine Solidity

- Specification/verification methodology for Solidity smart contracts

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- Functional verification wrt. payment history
- KeY for Solidity: SolidiKeY (prototype)

Motivating Example: Auction Contract

```
contract Auction {

 address payable private auctionOwner;
 mapping (address => uint) public bid;
 mapping (address => bool) private bidded;

 ...

 function placeOrIncreaseBid() public payable {
  // Call example: auct.placeOrIncreaseBid{value:5}()

  bid[msg.sender] = bid[msg.sender] + msg.value;

  // If the caller didn't bid yet, add her to bidders
  if (!bidded[msg.sender]) {
    bidders[numberOfBidders] = msg.sender;
    ...
  }
 }
 ...
```

Auction Contract (cont'd)

```
...

function withdraw() public {
  // A bidder can withdraw all her money

  require(bidded[msg.sender]);

  msg.sender.transfer(bid[msg.sender]);
  bid[msg.sender] = 0;
}

...
```

Auction Contract (cont'd)

```
  ...

  function closeAuction() public {
    // Determine highestBid and winner
    ...
    // Transfer the money to the auction owner
    auctionOwner.transfer(highestBid);
    bid[winner] = 0;

    // Reimburse everyone else
    for(i = 0; i < numberOfBidders; i = i + 1) {
      bidders[i].transfer(bid[bidders[i]]);
      bid[bidders[i]] = 0;
    }
  }
}
```

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Implementation maintains, at critical points, a contract invariant:

$$\forall a \in \text{address}.$$

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Data integrity $\equiv$ contract invariant holds at critical points

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Revisit Auction:

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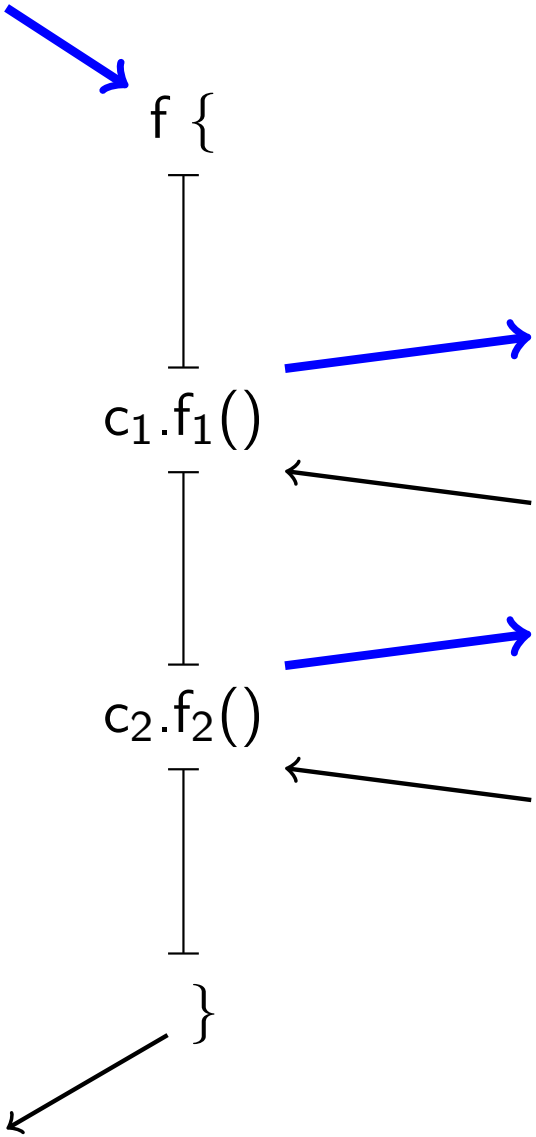
Proof Methodology



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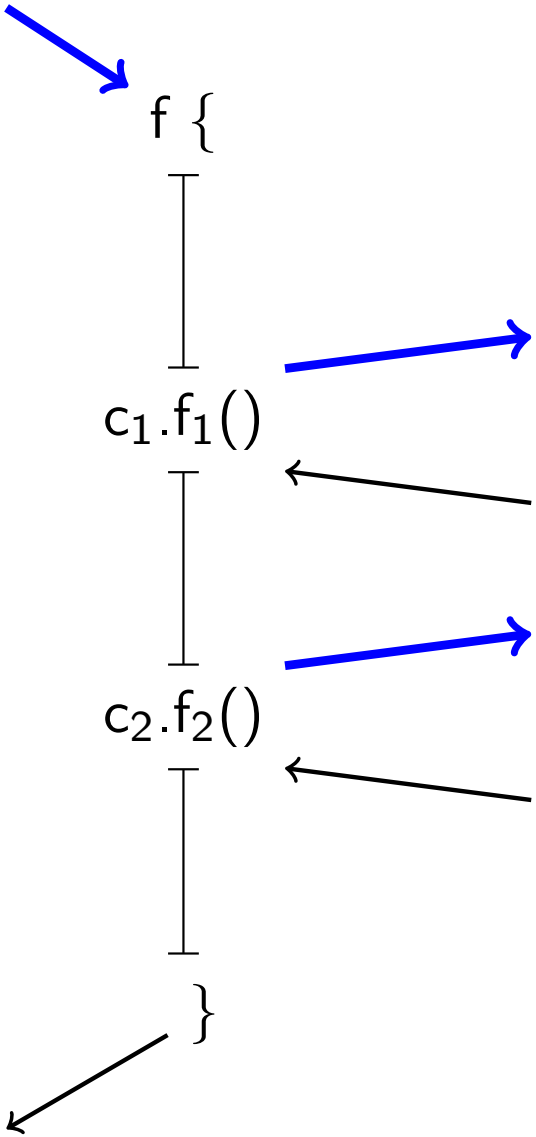

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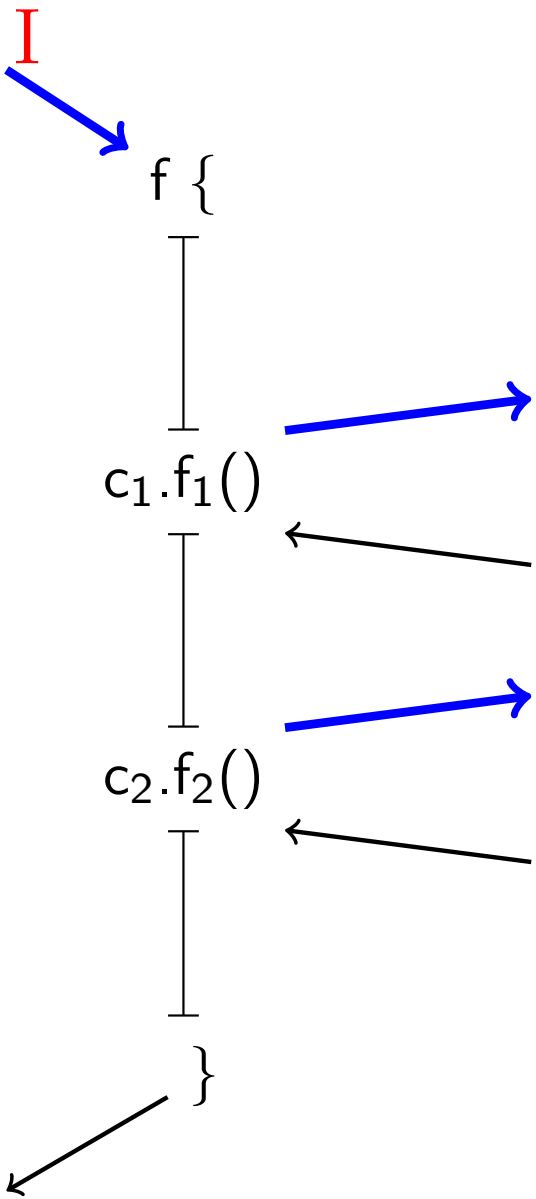

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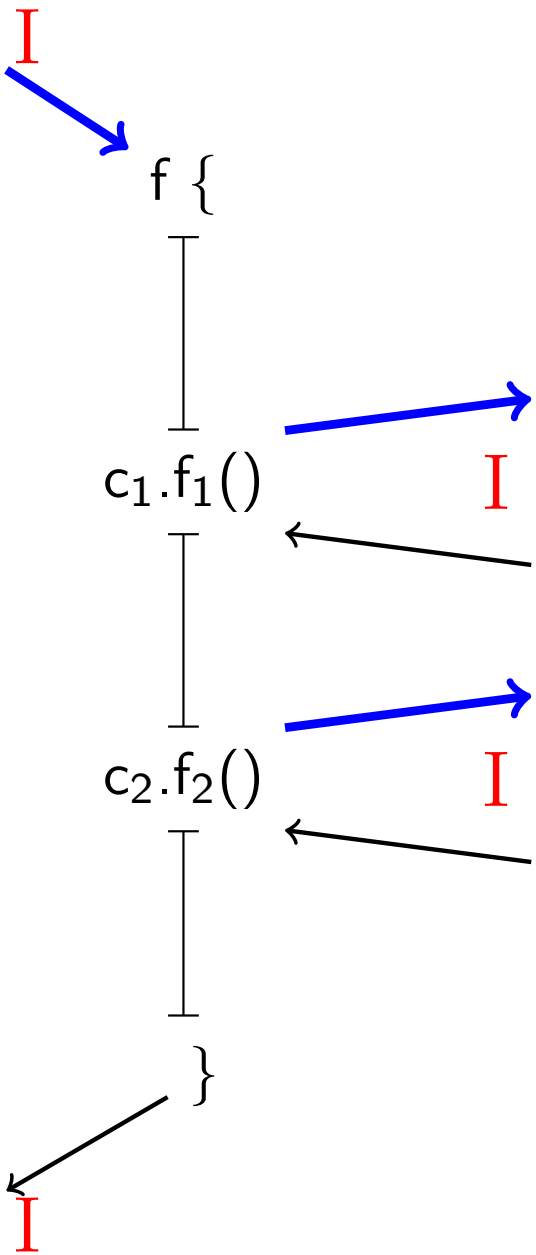

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Capturing the History of Money-Flow

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Instead:
Reasoning about a mapping

$$\text{net} : \text{address} \to \mathbb{Z}$$

$$\text{net}(a) = \begin{cases} \text{money received by } \textit{this} \text{ contract from } a \\ - \\ \text{money sent by } \textit{this} \text{ contract to } a \end{cases}$$

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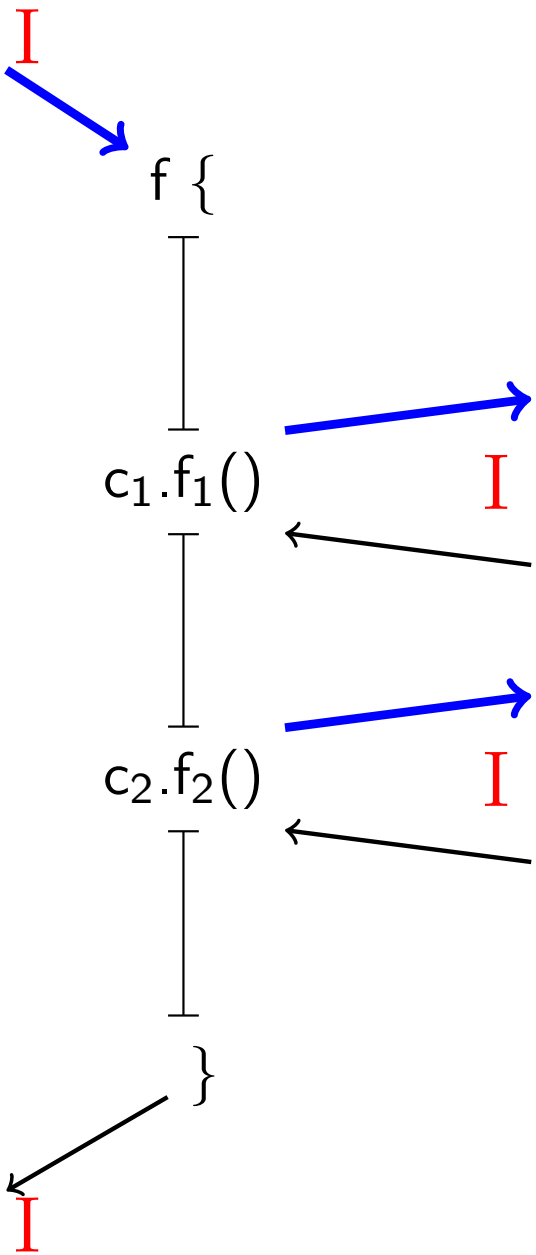

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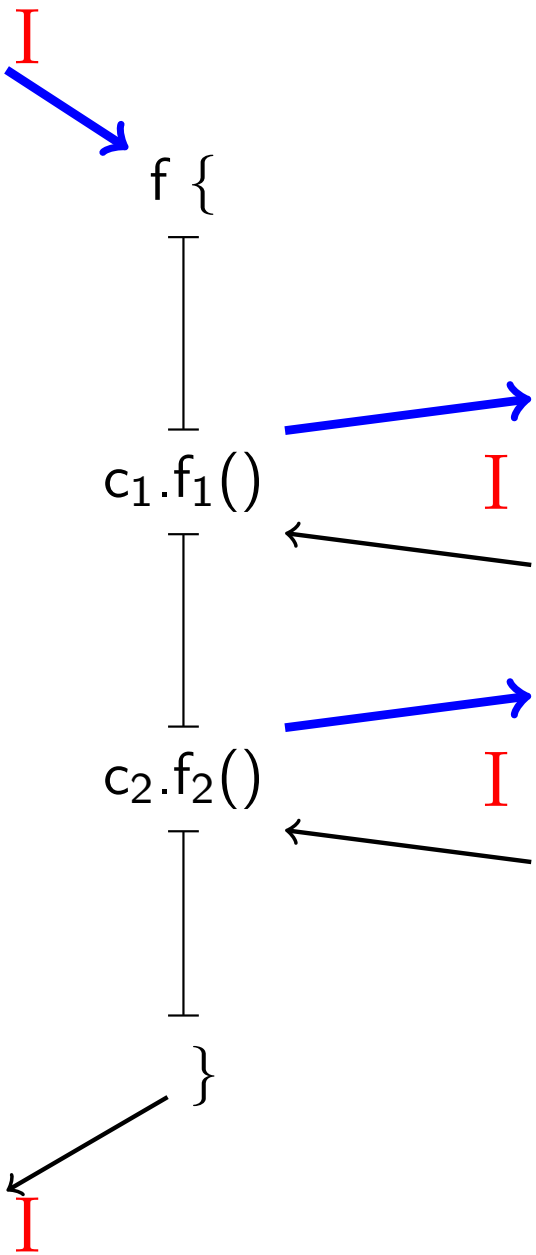

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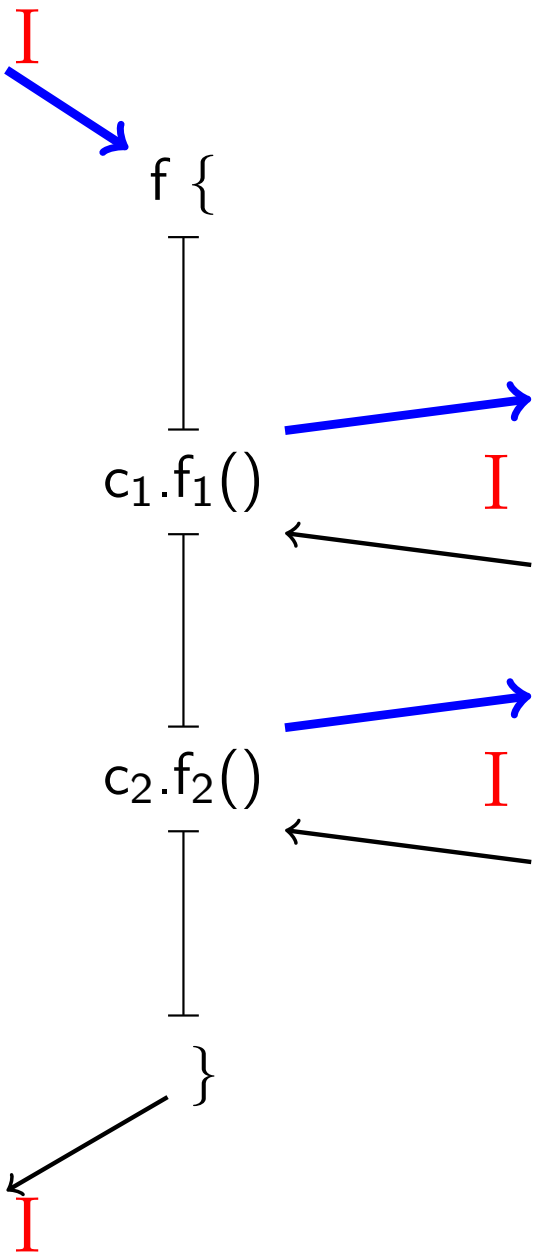

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Part II

Solidity Dynamic Logic

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- $[\mathsf{p}]\phi$
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What about non-termination?

Calculus Rules: require

Rules for `require`

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assume b = *true* when verifying remaining code

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expression e symbolically executed first

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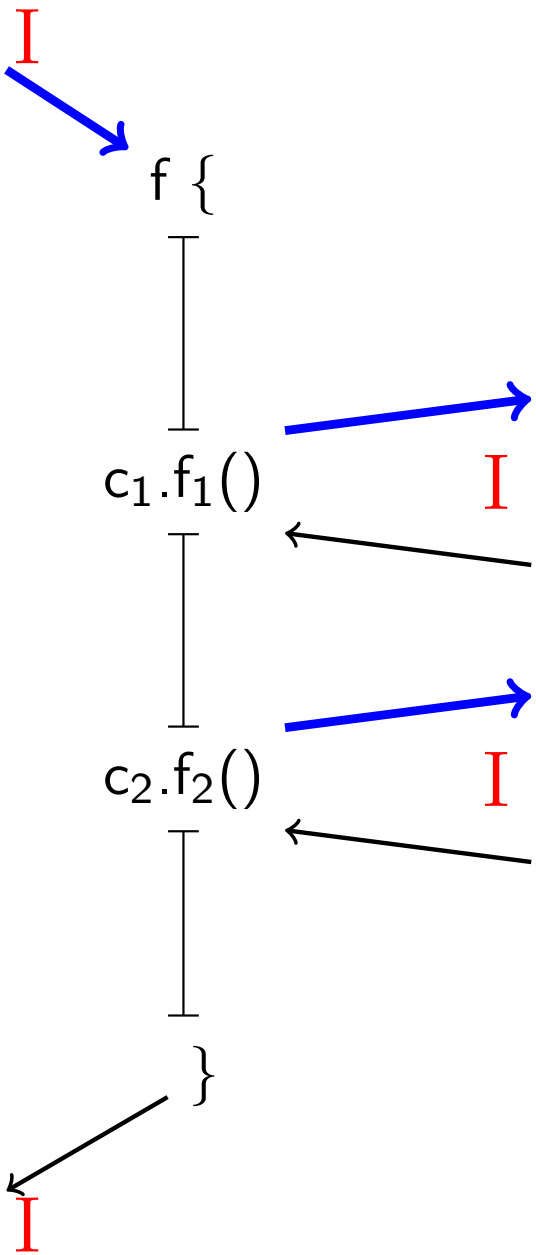
Recall: Proof Methodology



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Verification Attempt of Auction Contract shows:

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Invariant broken here.
Re-entrance attack possible.

Fixed Auction Contract

```
contract Auction {

  ...

  function withdraw() public {
    // A bidder can withdraw all her money

    require(bidded[msg.sender]);

    uint tmp = bid[msg.sender];
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    msg.sender.transfer(tmp);
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Send the money, and verify $[\omega]\phi$ afterwards.

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Send the money, and verify $[\omega]\phi$ afterwards.
No need to show I. (Why?)

This rule applies to *current* Ethereum.
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SolidiKeY supports both options (as taclet options)

Part III

Concluding Remarks

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Thanks!