Towards Formal Verification of Solidity Smart Contracts Using PAT

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A **smart contract** is a compute protocol intended to facilitate, verify, or enforce the negotiation or performance of a contract.

Popular platform: **Ethereum**.

Popular language: **Solidity**.

Based on the **blockchain** technology.

Used with the cryptocurrency token **ether**.
Features of Smart Contracts

• Self-executing and self-enforcing
• Decentralised control
• Reduced costs associated with contracting
• Blockchain technology solves the “double-spending” problem
• Open networks
  • Everyone can join
  • Easy to attract criminals
• Immutable
  • Once a smart contract is in places, it cannot be tampered
  • If a smart contract has vulnerabilities, it’s hard to fix
  • 50 million USD gone in the DAO attack
  • Ethereum sometimes has to perform a “hard fork” to reappropriate the stolen funds
• Possible to mix trusted code with untrusted code
Improving Security: The PAT Approach
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01 Find core features in Solidity
02 Model Solidity contracts in PAT
03 Survey security problems
04 Build attack models
05 Verify Solidity contracts against attack models
Improving Security: The PAT Approach

Many smart contracts don’t reveal source code

The PAT approach involves the following steps:

1. **Solidity Source Code** → **Modelling** → **Solidity Model in CSP#** → **Verification** → **Attack Model** → **Refinement** → **Proof** → **EVM Model in CSP#** → **Decompilation & Modelling** → **EVM Bytecode**
Solidity Vulnerabilities

• Timestamp can be modified at runtime
• Transaction values can be changed last minute
• Re-entrance
• Stack overflow
• Integer overflow
• Exception handling
• Delegate calls can be used to execute new unknown code
• Sending money from contracts automatically is prone to vulnerabilities
Exceptions in Solidity

- Out of stack (> 1024)
- Out of Gas
- Out of (array) index
- Code not found (call to undefined external function)
- Called function throws exceptions
- New contract not finished properly during creation
- /0 (Div by zero), %0 (Modulo by zero)
- Ether paid to a function without ‘payable’
- Received ether via a public accessor function
- ‘Throw’ for any custom reason
- Shift by a negative amount
- Convert negative or too large values into enum types
- External function call to a contract with no code
- .transfer() fail
Solidity Properties in Verification

• Different versions
• Stack based – 1024 levels (top 16 accessible) – stack overflow exception
• Logical evaluations apply short circuits
• ContractAddress.send() causes the contracts fall back functions to
• Call, callcode and calldelagate break type-safety and should be avoided
• Literal division used to be truncated to integers but now isn’t
• Function calls to other contracts cannot return anything but whether they finished or crashed
• ‘var’ variable declaration will use the simplest type possible for the given expression
• Accessing the hash of a block more than 256 blocks before will return 0
• Exceptions don’t bubble through call(), send(), callcode() and calldelagate() but instead return false
• Allows inline assembly code which has different behaviours altogether
function confirmPurchase()
  inState(State.Created)
  require(msg.value == 2 * value)
  payable
  {
    purchaseConfirmed();
    buyer = msg.sender;
    state = State.Locked;
  }

ConfirmPurchase(msgsender, msgvalue) =
if(state == Created && msgvalue == 2 * value){
  confirmPurchase{
    purchaseConfirmed();
    buyer = msgsender;
    state = Locked;
  } -> StandBy()
}
Verification by Model Checking

We can then verify various properties of the Solidity code in PAT

- Deadlock free
- Functional correctness
  - Program reaches desired states
  - Program doesn’t reach “bad” states
- Stack/integer overflow?
- Object-oriented features?

Next steps:
- Automate the translation
- Cover more properties/vulnerabilities