Accurate Smart Contract Verification through Direct Modelling

Matteo Marescotti[1], **Rodrigo Otoni**[1], Leonardo Alt[2],
Patrick Eugster[1], Antti E. J. Hyvärinen[1], and Natasha Sharygina[1]

[1] Università della Svizzera italiana, Lugano, Switzerland
[2] Ethereum Foundation, Zug, Switzerland

2nd June 2021

Foreword

Industrial application of our work

- Component of the SMTChecker module of the Solidity compiler
  SMTChecker's constrained Horn clauses model checking engine

Availability of our tool

- `github.com/ethereum/solidity`
- Add `pragma experimental SMTChecker;` to the source file

Formal Verification of Smart Contracts

Essential for safety

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- Symbolic execution, e.g.:
  - Oyente [Luu et al., CCS'16]
  - Maian [Nikolić et al., ACSAC'18]
  - Manticore [Mossberg et al., ASE'19]
  - VerX [Permenev et al., S&P'20]
- Model checking, e.g.:
  - Zeus [Kalra et al., NDSS'18]
  - SAFEVM [Albert et al., ISSTA'19]
  - VeriSol [Wang et al., VSTTE'20]
- Others, e.g.:
  - F* [Bhargavan et al., PLAS'16]
  - KEVM [Hildenbrandt et al., CSF'18]
  - Securify [Tsankov et al., CCS'18]
  - Why3 [Nehaï and Bobot, FM'19]
  - Solc-Verify [Hajdu and Jovanovic, VSTTE'19, ESOP'20]

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Limitations to be addressed

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Common Feature: Domain Translation

Translation for reuse

- Established off-the-shelf frameworks, e.g.:
  - Boogie
  - LLVM
- Programming languages ecosystems, e.g.:
  - C/C++
  - WhyML

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- Requires correctness proofs
- Adverse effect on precision and efficiency

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Our approach

- Direct modelling into the target formalism
  - Focus on Solidity contracts
  - Modelling in constrained Horn clauses (CHCs)

Smart Contracts Verification through Direct Modelling

- Rule-based encoding for assertion checking

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- Rule-based encoding for assertion checking, starting with the contracts' control-flow graphs

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CHC rule format

$$\forall V : \underbrace{H(x)}_{\text{head}} \leftarrow \underbrace{\exists y : P_1(y) \wedge \ldots \wedge P_n(y) \wedge (x; y)}_{\text{body}}$$

with V a set of variables over a background theory T, $x \; [\; y \quad V, n \quad 0$

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Smart Contracts Veri cation through Direct Modelling

Rule-based encoding for assertion checking, starting with the contracts' control- ow grap

CHC rule format

$$\forall V : (H(x) \land \{z\}) \rightarrow \exists y : P_1(y) \land \cdots \land P_n(y) \land \{z\} \land (x; y))$$

head body

with V a set of variables over a background theory x [y V , n 0

Rule Jump$_{f,e}$

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6      function o er () public payable f
7          uint new_bid = msg.value = 10^15 wei;
8          require(bid < new_bid);
9          if (winner 6= address(0)) f
10             //assert(bid cash);
11             winner.transfer(bid);
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14         bid = new _bid;
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$$P_o^3 \quad P \quad {}_o^2 \wedge l_{nb} = l_v \quad 10^{15} \wedge l_b < l_{nb} \wedge l_w 6= 0$$

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$$P_o^n(b;c;w;s;v;l_b;l_c;l_w;l_s;l_v;l_{nb};l_r), \ n \ 2 \ f \ 1::6g$$

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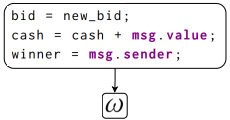

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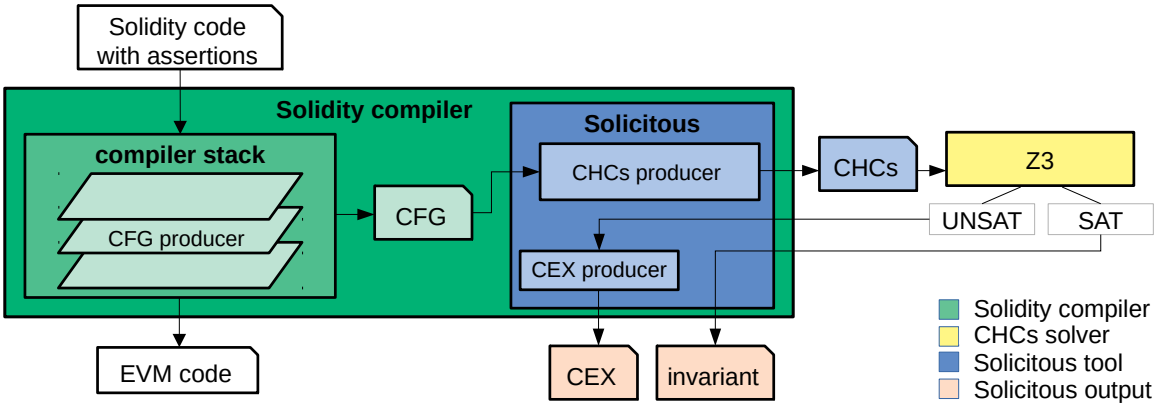
Modelling Framework



Solicitous (Solidity Contract verification using constrained Horn clauses)

- Assertion failures lead to reverts, which are modelled as error predicates
- Queries are made to the solver for the reachability of error predicates

Evaluation

- Evaluation with 22446 real-world contracts
  Solidity versions 0.5 to 0.8

	Solicitous	Solc-Verify	VeriSol	Mythril
Instances	**22446**	13310	12402	**22446**
Safe	**6651**	103	201	0
Unsafe	8	0	9	**21**
Unknown	2970	5601	230	728
Timeout	9058	3163	4032	19511
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`verify.inf.usi.ch/research/fvsc`