VETSC: Towards Automated Safety Vetting of Smart Contracts in Decentralized Applications

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Smart Contract

Physical contracts

Trusted 3rd party

Slow speed

High cost

Smart Contract

Spontaneous

Fully automated

High speed

Secure

Decentralized Applications

```
function bidOnAuction(uint _id) public payable {
    uint256 ethAmountSent = msg.value;

    // owner cannot bid on his/her own merchandise
    Auction memory myAuction = auctions[_id];
    if(myAuction.owner == msg.sender) revert();

    // check whether auction has expired
    if(block.timestamp > myAuction.deadline) revert();

    // check whether previous bids exist
    uint bidsLength = accepted[_id].length;
    uint256 tempAmount = myAuction.startPrice;
    Bid memory lastBid;
    if(bidsLength > 0) {
        lastBid = accepted[_id][bidsLength-1];
        tempAmount = lastBid.amount;
    }

    // check if bid price is greater than the current highest
    if(ethAmountSent < tempAmount) revert();

    // refund the last bidder
    if(bidsLength > 0)
        if(!lastBid.from.send(lastBid.amount)) revert();

    // add the new bid to auction state
    Bid memory newBid;
    newBid.from = msg.sender;
    newBid.amount = ethAmountSent;
    accepted[_id].push(newBid);
    emit BidSuccess(msg.sender, _id);
}
```

Owner can cancel at ANYTIME. Safety risk!

```
function cancelAuction(uint _id) public isOwner(_id) {
    Auction memory myAuction = auctions[_id];
    uint bidsLength = accepted[_id].length;

    // refund the last bid, if prior bids exist
    if(bidsLength > 0) {
        Bid memory lastBid = accepted[_id][bidsLength - 1];
        if(!lastBid.from.send(lastBid.amount)) revert();
    }
    auctions[_id].active = false;
    emit AuctionCanceled(msg.sender, _id);
}
```

Smart Contract Safety Vetting

- Challenge:
  Understanding function and variable semantics

terminate a bidding process

```
35 function cancelAuction(uint _id) public isOwner(_id) {
36     Auction memory myAuction = auctions[_id];
37     uint bidsLength = accepted[_id].length;
38
39     // refund the last bid, if prior bids exist
40     if(bidsLength > 0) {
41         Bid memory lastBid = accepted[_id][bidsLength -
        1];
42         if(!lastBid.from.send(lastBid.amount)) throw;
43     }
44     auctions[_id].active = false;
45     emit AuctionCanceled(msg.sender, _id);
46 }
```

prior accepted bids

auction state

Smart Contract Safety Vetting

- Ex

unreliable
terious and error-prone
unavailable

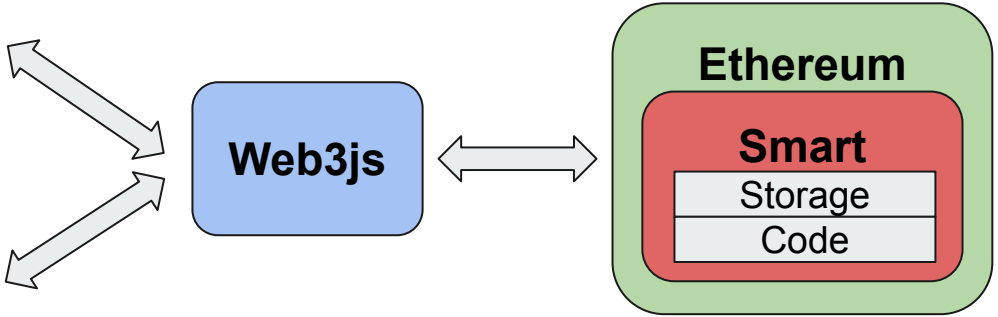
  - M
    exception m and cy, etc.)
  - Semantic i s extracted manually
    - from variable names, function names, etc

Decentralized Applications

GUI Front-end

middleware

backend

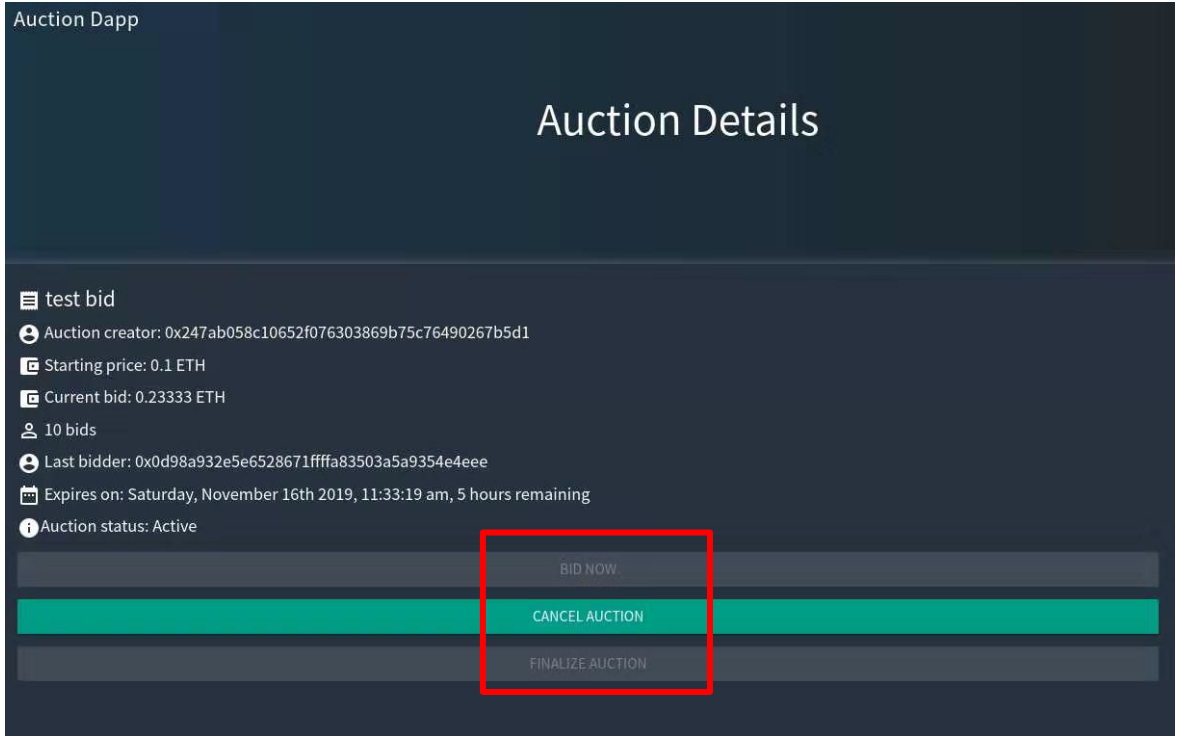


Our Insights

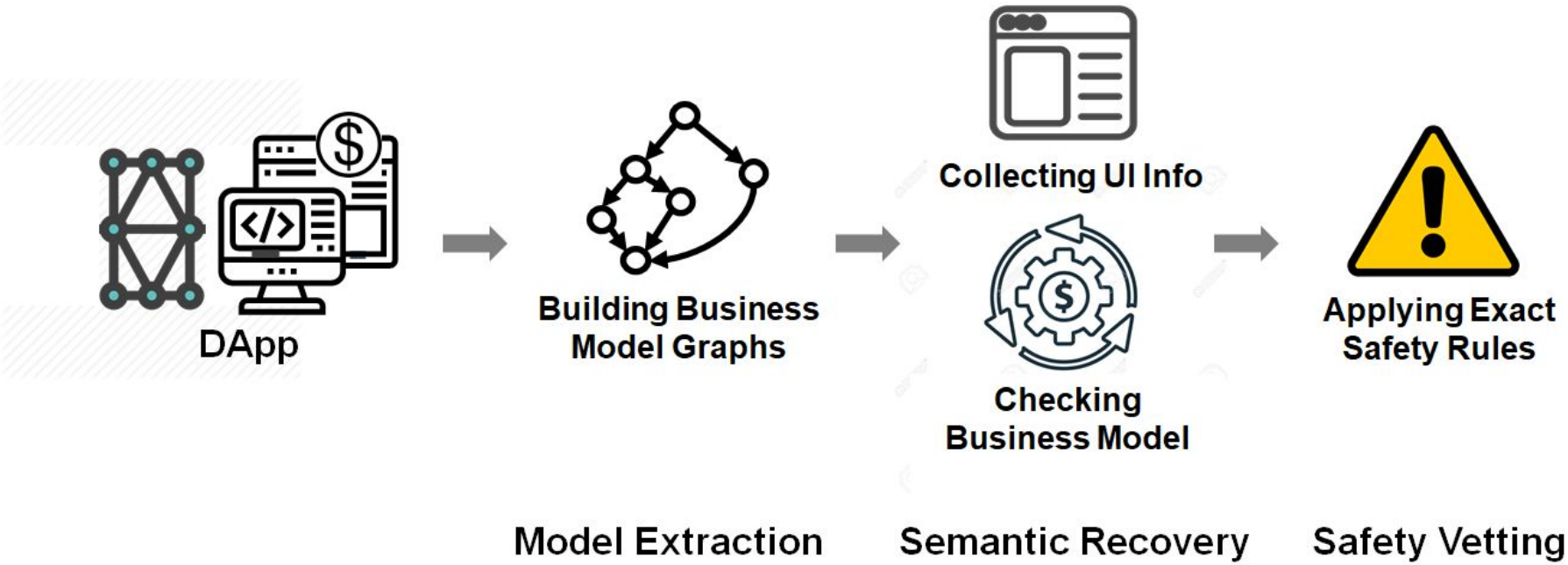
- Limited types of business logics
  - auction
  - voting
  - trading
  - gambling
  - wallet
  - crowdsale

- UI contains semantics info

Semantic Inference



VetSC Overview



Business Model Graph

- To represent high-level business logic
  - key factors
    - transaction properties
      - msg.sender
      - msg.value
      - block.timestamp
      - etc

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    emit BidSuccess(msg.sender, _id);
}
```

Business Model Graph

- To represent high-level business logic
  - key factors
    - transaction properties
    - global variables
    - dataflow
    - condition check
    - cryptocurrency transfer

```
1  function bidOnAuction(uint _id) public payable {
2      uint256 ethAmountSent = msg.value;
3
4      // owner cannot bid on his/her own merchandise
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11     // check whether previous bids exist
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14     Bid memory lastBid;
15     if(bidsLength > 0) {
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17         tempAmount = lastBid.amount;
18     }
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20     // check if bid price is greater than the current
       highest
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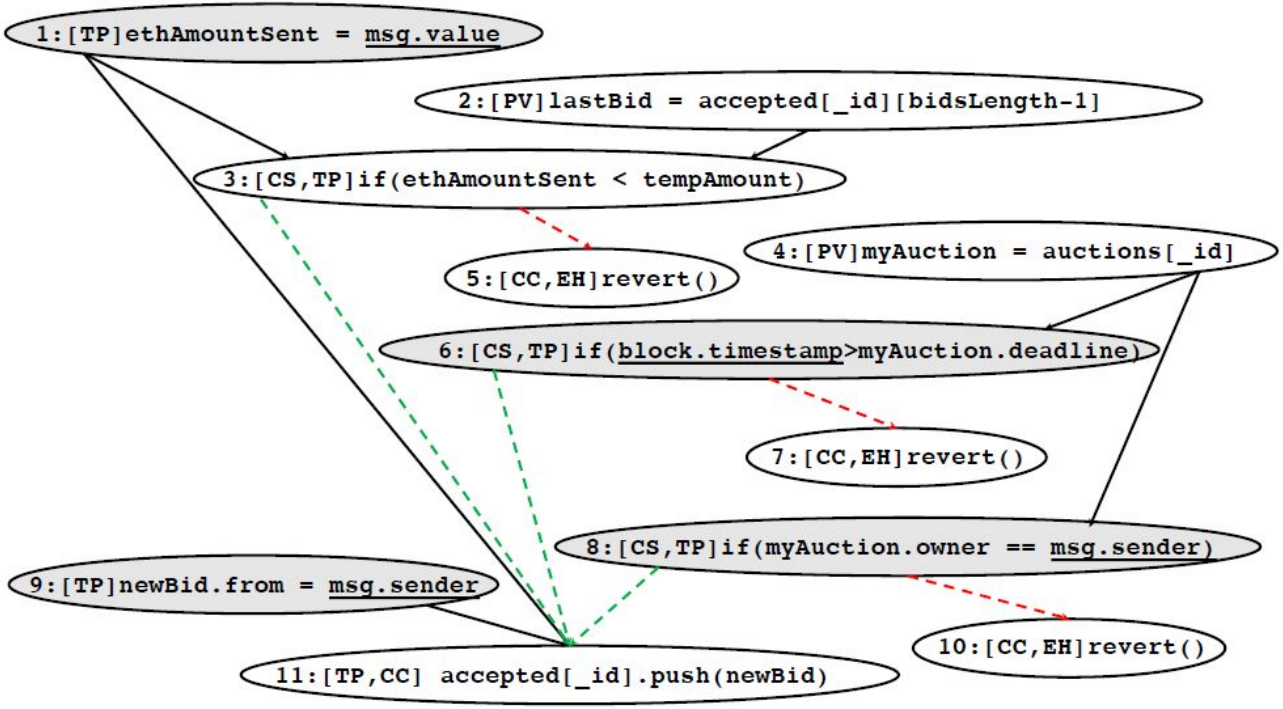
29     newBid.from = msg.sender;
30     newBid.amount = ethAmountSent;
31     accepted[_id].push(newBid);
32     emit BidSuccess(msg.sender, _id);
33 }
```

Business Model Graph

- A Business Model Graph is:
  - directed graph G = (V, E, $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$) over statements $\boldsymbol{\Sigma}$ and relations R
  - V: statements in $\boldsymbol{\Sigma}$
  - E: causal dependencies between statements
  - $\boldsymbol{\alpha}$: V -> $\boldsymbol{\Sigma}$
    - labeling function that associates nodes with labels
  - $\boldsymbol{\beta}$: V -> R
    - labeling function that associates edges with labels

Business Model Graph

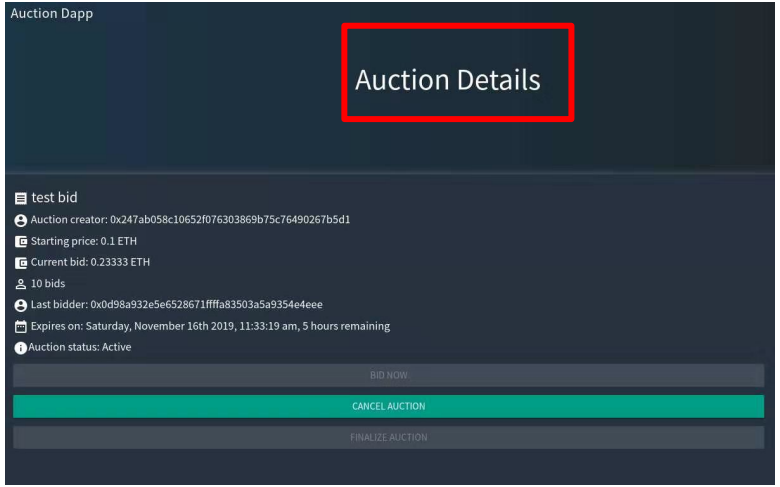


Business Model Graph

- Memory Aliasing
  - two global memory regions
    - storage
    - memory

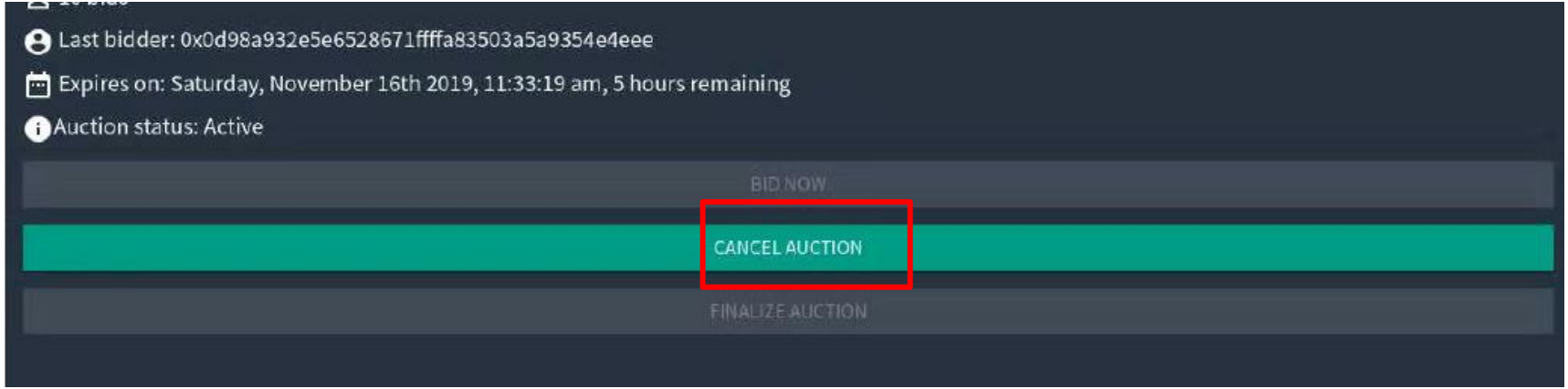
Semantics Recovery

- Three levels of semantics recovery
  - smart contract level
    - HTML parsing ⇒ NLP technique ⇒ semantics



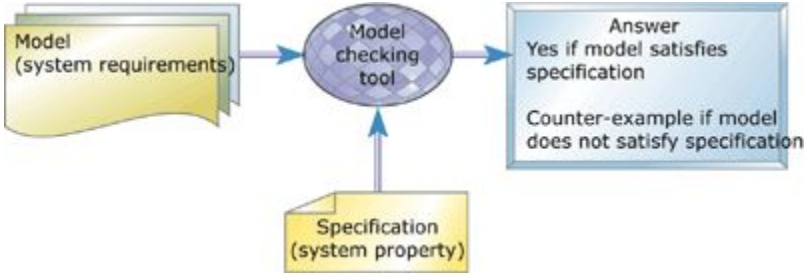
Semantics Recovery

- Three levels of semantics recovery
  - function level
    - GUI text ⇒ NLP technique ⇒ semantics

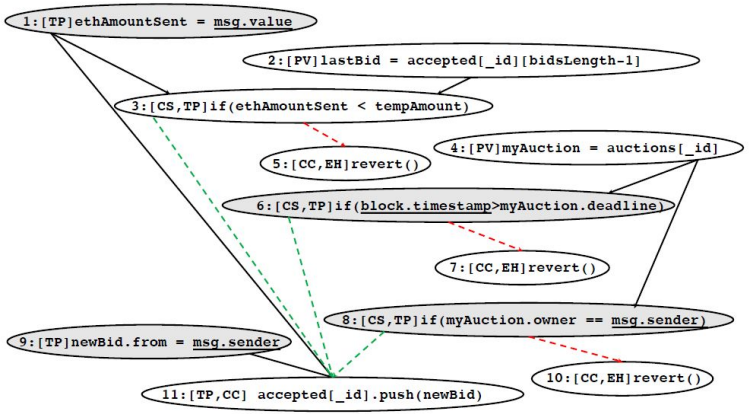


Semantics Recovery

- Three levels of semantics recovery
  - variable level
    - model checking
      - pre-defined specs
      - extracted models



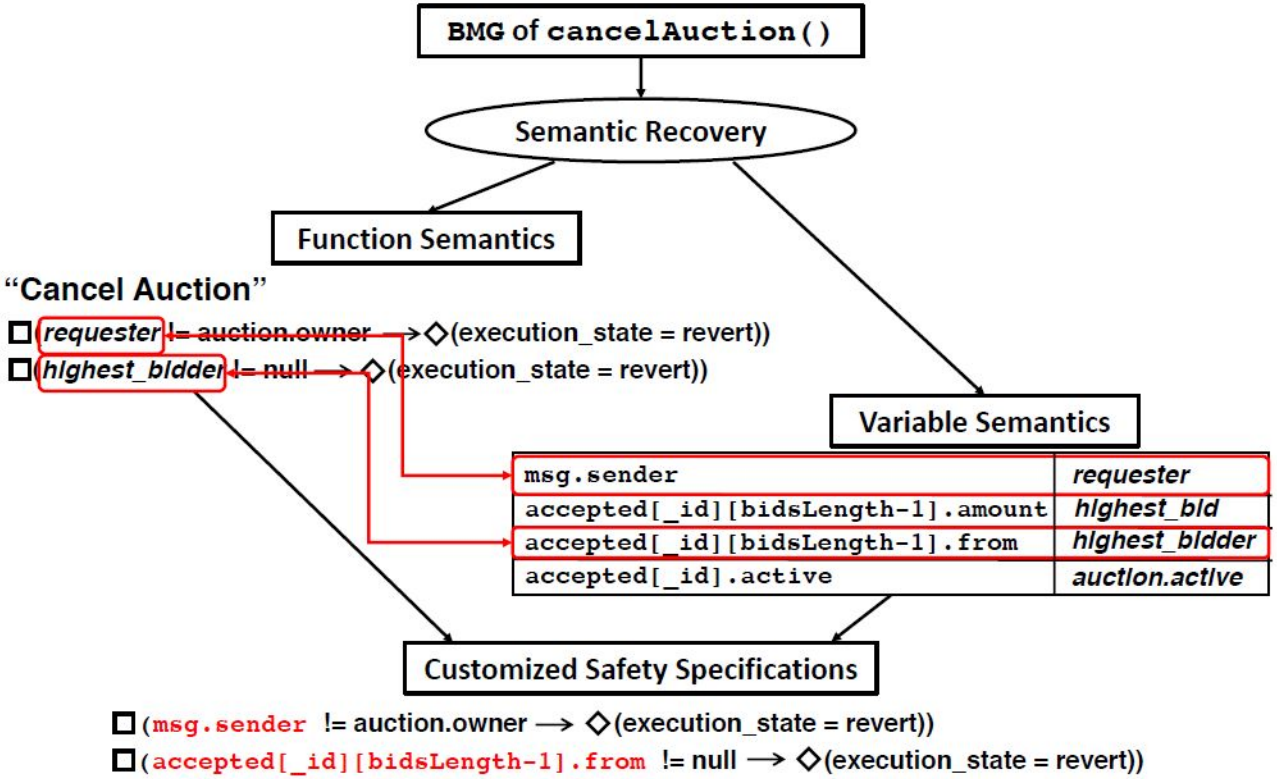
Semantics Recovery



NuSMV Model

Function	Spec Type	Formal Spec
Bidding	Essential#1	$\Box(current\_bid > highest\_bid \rightarrow \Diamond(highest\_bid := current\_bid \wedge highest\_bidder := current\_bidder))$
	Safety#1	$\Box(current\_time > deadline \rightarrow \Diamond(execution\_state := revert))$
	Safety#2	$\Box(auction.active == false \rightarrow \Diamond(execution\_state := revert))$
	Safety#3	$\Box current\_bidder == auction.owner \rightarrow \Diamond(execution\_state := revert))$
Cancel	Essential#1	$auction.active := false$
	Safety#1	$\Box(requester != auction.owner \rightarrow \Diamond(execution\_state := revert))$
	Safety#2	$\Box(highest\_bidder != null \rightarrow \Diamond(execution\_state := revert))$

Customized Spec Generation



Semantics Recovery

- Recovered semantics

Function/Domain	Smart Contract Variable	Spec Concept
`bidOnAction`	`msg.value`	*current_bid*
`bidOnAction`	`msg.sender`	*current_bidder*
`bidOnAction`	`newBid.amount`	*highest_bid*
`bidOnAction`	`newBid.from`	*highest_bidder*
`cancelAction`	`msg.sender`	*requester*
contract-wide	`accepted[_id][bidsLength-1].amount`	*highest_bid*
contract-wide	`accepted[_id][bidsLength-1].from`	*highest_bidder*
contract-wide	`accepted[_id].active`	*auction.active*

Evaluation

- Dataset
  - 24 real-world DApps
  - 465 solidity functions
- Comparison with state-of-the-art
  - VerX

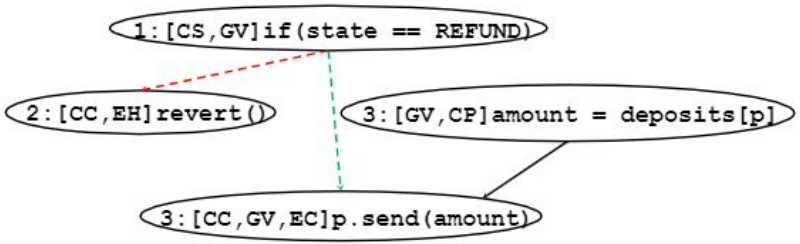
Evaluation

#	Name	Unsafe Func Name	Code Logic	Major Widget Text/Context	UI == Logic?	Safety Issue in Smart Contracts	Violated Policy	Source Analyzability
1	cryptoatoms.org	-	-	-	Yes	-	-	Yes
2	proofoflove.digital	-	-	-	Yes	-	-	Yes
3	snailking	-	-	-	Yes	-	-	Yes
4	cryptominingwar	-	-	-	Yes	-	-	Yes
5	market.start.solar	-	-	-	Yes	-	-	No (Missing Source)
6	etheroll	-	-	-	Yes	-	-	No (Inlined Bytecode)
7	cryptokitties	`bid()`	Auction-Bid	*"buy"*	Ambiguity	N/A	N/A	Yes
8	hyperdragons	-	-	-	Yes	-	-	No (Missing Source)
9	dice2.win	-	-	-	Yes	-	-	No (Inlined Bytecode)
10	all-for-one.club	`drawNow()`	Lottery-Draw	*"Draw"*	Yes	Drawing for an expired lottery	Lottery-Draw-S2	No (Inlined Bytecode)
		`play()`	Lottery-Buy	*"pay 1 ETH"*	Yes	Buying an expired ticket	Lottery-Buy-S1	No (Inlined Bytecode)
11	openberry-ac	`placeBid()`	Auction-Bid	*"place BID"*	Yes	Bidding for an expired auction	Auction-Bid-S1	Yes
		`finalizeAuction()`	Auction-Close	*"handle Finalize"*	Yes	Closing a non-expired auction	Auction-Close-S1	Yes
						Closing an active auction	Auction-Close-S2	
12	create-react-dapp	`voteForCandidate()`	Voting-Vote	*"vote Rama/Nick/Jose"*	Yes	Voting for an expired election	Voting-Vote-S1	Yes
						Double voting	Voting-Vote-S2	
13	ethereum-voting	`vote()`	Voting-Vote	*"Vote"*	Yes	Voting for an expired election	Voting-Vote-S1	Yes
14	ethereum-wallet	-	-	-	Yes	-	-	Yes
15	heiswap.exchange	-	-	-	Yes	-	-	No (Inlined Bytecode)
16	Lottery-DApp	`makeGuess()`	Lottery-Buy	*"Buy", "Lottery"*	Yes	Buying an expired ticket	Lottery-Buy-S1	Yes
		`closeGame()`	Lottery-Draw	*"Close Game", "Lottery"*	Yes	Drawing for an expired lottery	Lottery-Draw-S2	Yes
17	mastering-e-a-d	`cancelAuction()`	Auction-Cancel	*"CANCEL AUCTION"*	Yes	Seller cancel after bidding starts	Auction-Cancel-S2	Yes
18	multisender.app	-	-	-	Yes	-	-	Yes
19	note_dapp	-	-	-	Yes	-	-	Yes
20	metacoin	-	-	-	Yes	-	-	Yes
21	simple-vote	`vote()`	N/A	*"Start a vote"*	No Impl.	N/A	N/A	Yes
22	truffle-voting	`vote()`	Voting-Vote	*"Approve/Against/Abstain"*	Yes	Voting for an expired election	Voting-Vote-S1	Yes
23	Overview	`invest()`	CS-Invest	*"Buy tokens", "Crowdsale"*	Yes	Invest an expired crowdsale	CS-Invest-S2	Yes
24	Crowdsale	-	-	-	Yes	-	-	Yes

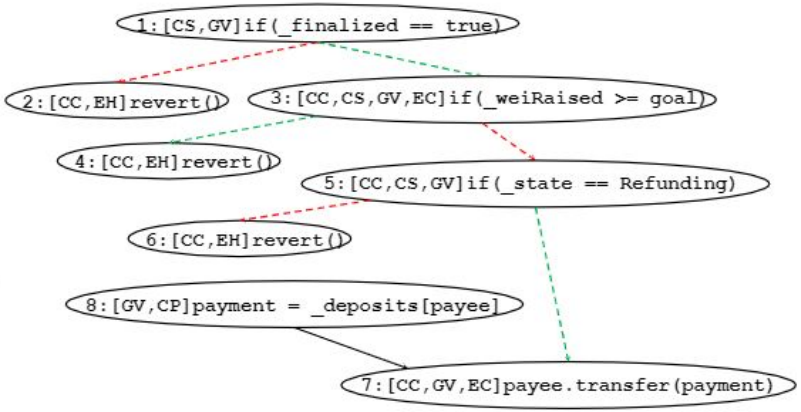
Evaluation - Source Analyzability

```
function appendInt(buffer memory buf, uint data, uint len)
    internal constant returns(buffer memory) {
    ...
    assembly {
        let bufptr := mload(buf)
        let buflen := mload(bufptr)
        let dest := add(add(bufptr, buflen), len)
        mstore(dest, or(and(mload(dest), not(mask)), data)
    )
        mstore(bufptr, add(buflen, len))
    }
    return buf;
}
```

Evaluation- Comparison with VerX



(c) BMG of `refund()` in *Overview* app



(d) BMG of `refund()` in *Crowdsale* app

Analysis Step	VETSC	Verx
(a) High-level Specs	One-Time Manual Effort	None
(b) Semantic Recovery	Automated (UI-Guided)	Manual Effort for Each Func
(c) Specs Customization	Automated	Manual Effort for Each Func
(d) Safety Verification	Automated	Automated

Evaluation

- Comparison with VerX

Analysis Step	VETSC	Verx
(a) High-level Specs	One-Time Manual Effort	None
(b) Semantic Recovery	Automated (UI-Guided)	Manual Effort for Each Func
(c) Specs Customization	Automated	Manual Effort for Each Func
(d) Safety Verification	Automated	Automated

Conclusion

- Automated Safety Vetting of Smart Contracts in DApps
- Semantic inference
  - smart contract level
  - function level
  - variable level
- Evaluation on real-world DApps