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# The Best of Both Worlds: Integrating Semantic Features with Expert Features for Smart Contract Vulnerability Detection

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# Smart Contract

- Digital contract written in programming languages.
  - e.g., Decentralized Finance, food supply chain (IBM Food Trust).
- Send transactions by invoking functions in smart contracts.

```
1 function transfer (address to, uint value) public
2 returns (bool) {
3     require (balance[msg.sender] >= value);
4     balance[msg.sender] -= value;
5     balance[to] += value;
6     return true;
7 }
```

## Solidity Function

balance[X] = 20,  
balance[Y] = 0

X sends 5  
tokens to Y.

transfer(Y, 5)  
with X=msg.sender

balance[X] = 15,  
balance[Y] = 5

# Importance of Securing Smart Contracts

- **Immutable** once deployed.
- **Huge financial damage** once exploited.

(2016)

KLINT FINLEY 06.18.16 04:38 AM

**A \$50 Million Hack Just Showed That the DAO Was All Too Human**

(2017)

 WILLIAM SUBERG

NOV 08, 2017

**'Accidentally Killed It': Parity Grapples With \$280 Mln Locked ETH**

Parity is dealing with another code vulnerability which allowed a user to block access to almost \$300 mln ETH.

ETHEREUM > TECHNOLOGY

**BatchOverflow Exploit Creates Trillions of Ethereum Tokens, Major Exchanges Halt ERC20 Deposits**

Sam Town · April 25, 2018 at 10:38 pm UTC · 3 min read

(2018)

**DeFi Protocol bZx Hacked Again: \$8 Million Worth of ETH, LINK, Stablecoins Drained (Updated)**

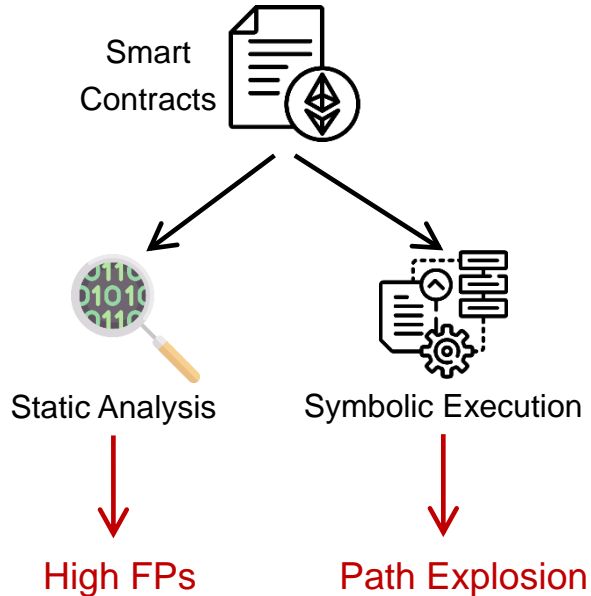
 Author: Himadri Saha · Last Updated Sep 14, 2020 @ 17:20

*In yet another full-blown attack, hackers made away with crypto funds worth more than \$8 million from DeFi lending protocol bZx.*

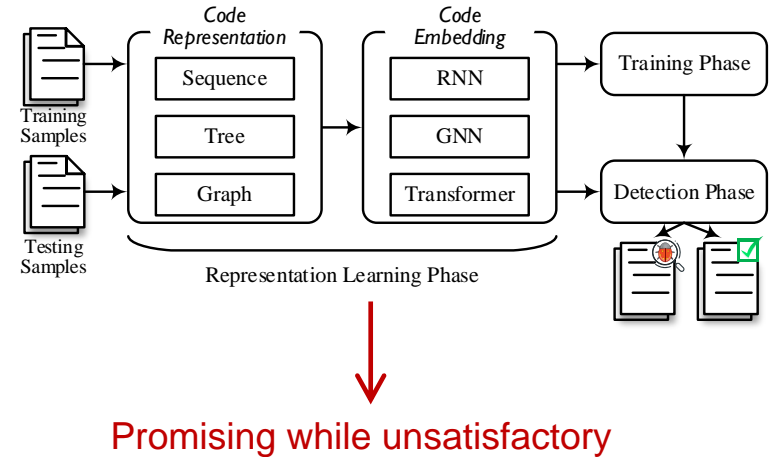
(2020)

# Existing Solutions

## Traditional Approaches

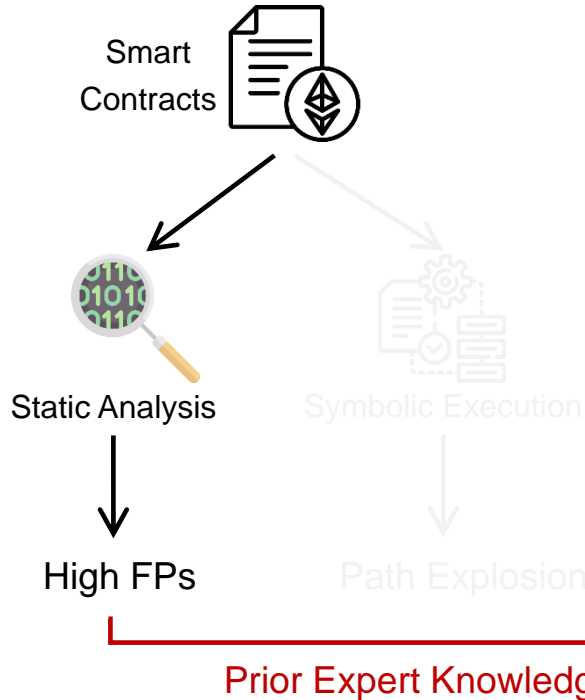


## Learning-based Approaches

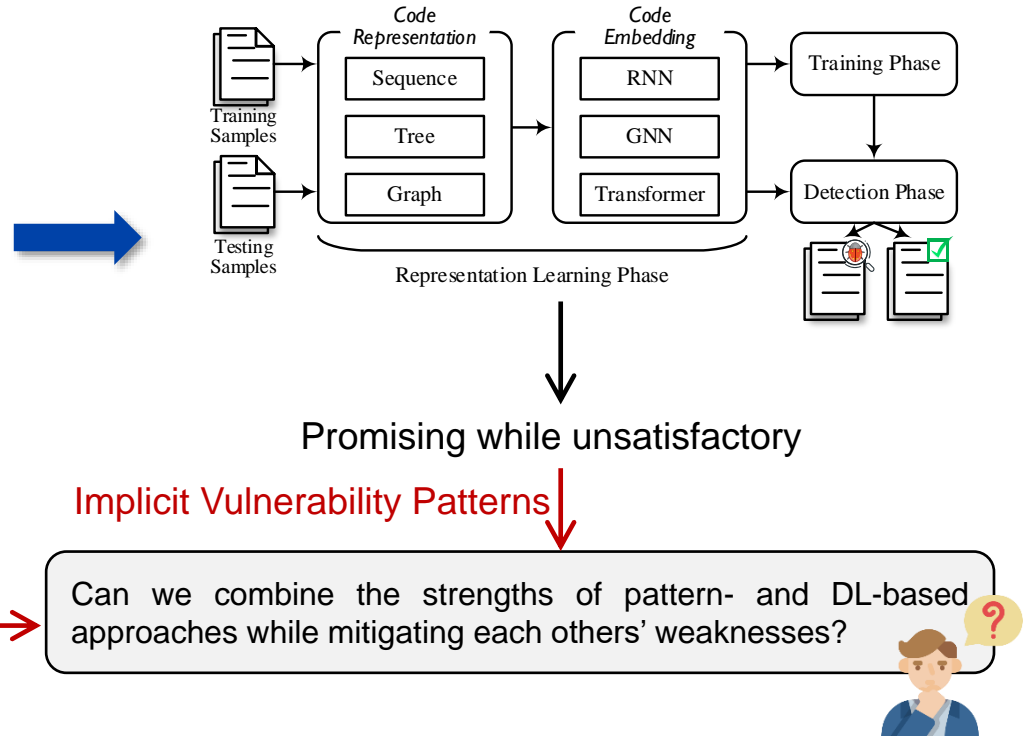


# Existing Solutions

## Traditional Approaches



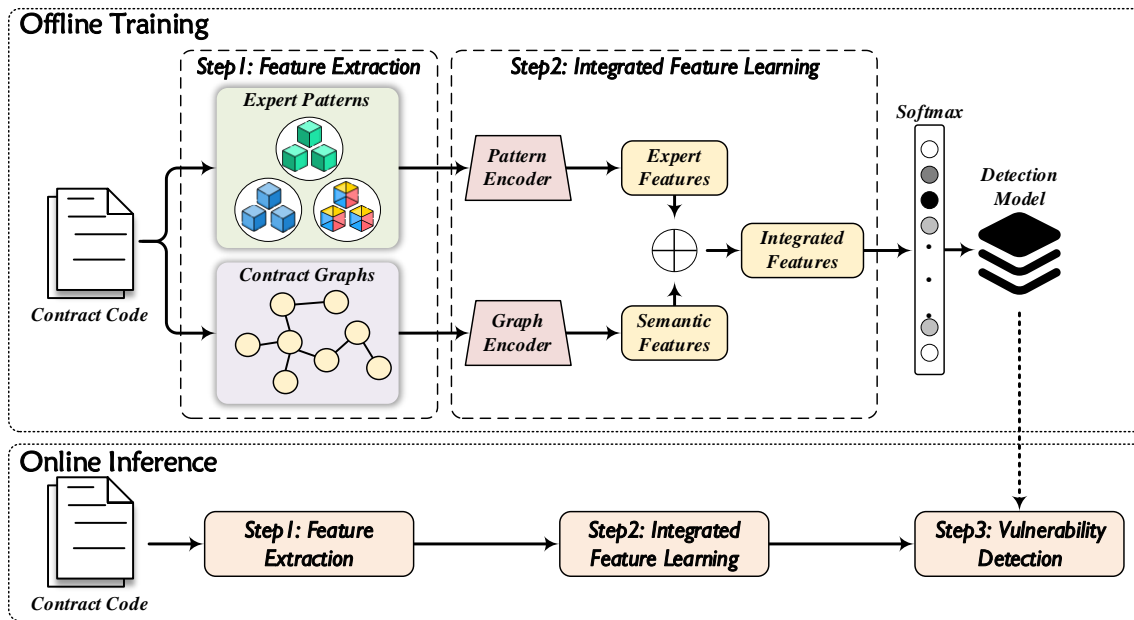
## Learning-based Approaches



# Our approach: SMARTFuSE

## Static Analysis + Graph-based Representation Learning

- ❑ Extracting expert features and semantic features from statistical data and source code.
- ❑ Fusing expert features and semantic features for vulnerability detection



# Detail: Feature Extraction

## Common expert features

Vulnerability Type	Expert pattern	Security-Critical Operations
Reentrancy	enoughBalance callValueInvocation balanceDeduction	call.value invocation a function that contains call.value the variable: correspond to user balance
Timestamp dependence	timestampInvocation timestampAssign timestampContaminate	block.timestamp invocation block.number invocation a variable: affect critical operation
Infinite loop	loopStatement loopCondition selfInvocation	for while self-call function

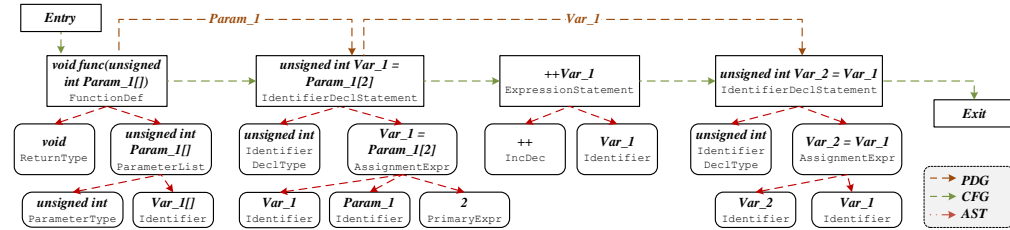
```

1 function withdraw(uint amount) public {
2   if (credit[msg.sender] > amount) {
3     require(msg.sender.call.value(amount));
4     credit[msg.sender]-=amount;*str1;
5   }
6 }
    
```

```

1 function() payable {
2   if (msg.sender >= 10 finney) {
3     bytes20 bh = ripemd160(block.timestamp);
4     if (bh[0] ==0) {
5       uint8 bM = ((bh[1] & 0x01 !=0)? 1:0);
6       uint256 bTI = (msg.sender * 100) * bM;
7     }
8   }
9 }
    
```

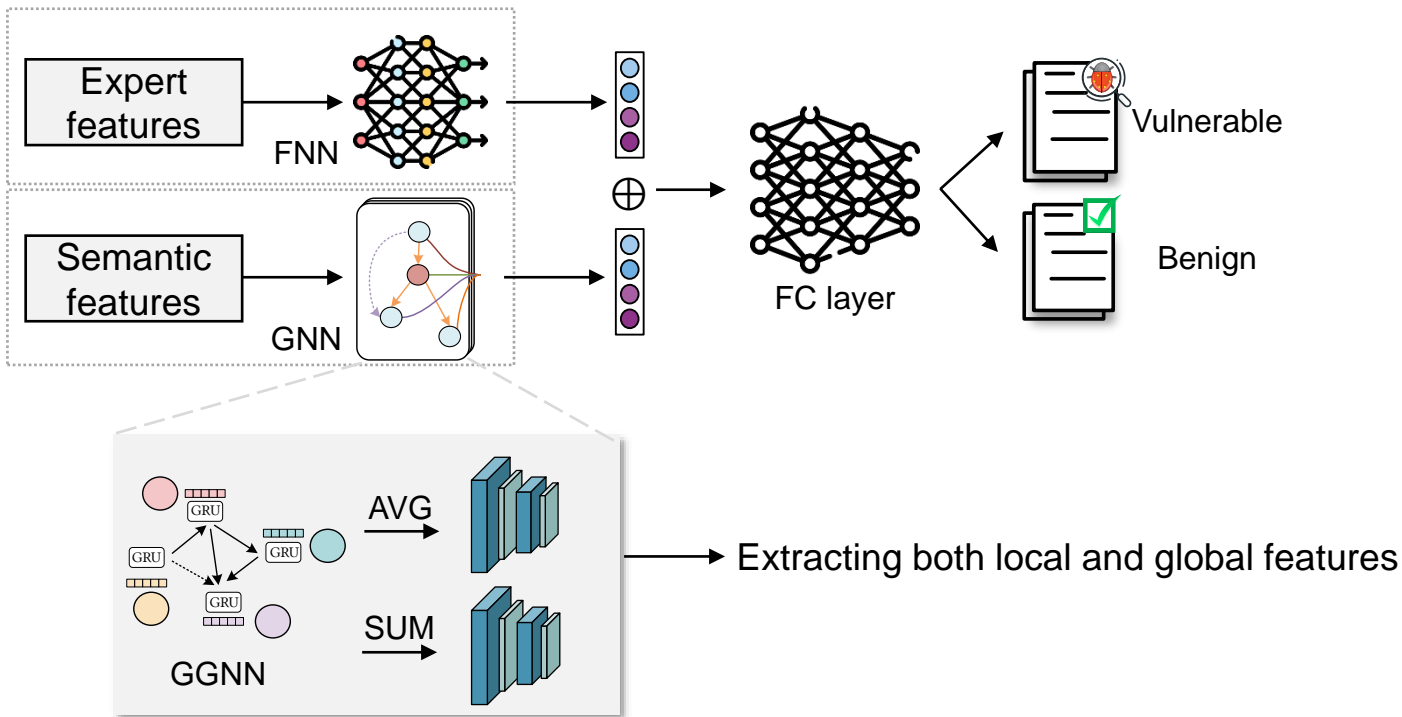
## Code-centric semantic features



Slice Criteria	Example
block info	<i>block.number, block.gaslimit</i>
delegatecall	<i>address.delegatecall</i>
arithmetic operations	<i>*, +, -</i>
external function call	<i>address.call</i>
selfdestruct operation	<i>selfdestruct</i>
input address parameters	<i>address input_address</i>
block timestamp	<i>block.timestamp</i>
low level call operation	<i>address.call</i>

Program slicing

# Detail: Integrated Feature Learning





# Evaluation Setup

- **Benchmark:** Ethereum Smart Contracts (ESC) + (VNT chain Smart Contracts)
  - <https://github.com/Messi-Q/Smart-Contract-Dataset>
- Compared with 5 analysis-based approaches and 2 DL-based approaches
  - **Analysis-based:** Oyente, Mythril, Smartcheck, Securify, Slither
  - **DL-based:** Peculiar, TMP
- Used 4 common evaluation metrics: Accuracy, Precision, Recall, and F1-score
- 10-fold cross validation

# Evaluation Results

## RQ1: Effectiveness

Method	Accuracy	Precision	Recall	F1-score
Oyente	57.3	41.1	42.8	41.9
Mythril	53.9	64.7	36.4	46.6
Securify	50.5	53.2	55.2	54.2
Smartcheck	37.8	59.4	43.5	50.2
Slither	61.9	63.1	58.4	50.7
Peculiar	82.7	55.2	41.6	47.4
TMP	85.0	83.9	66.5	74.2
SMARTFUSE	<b>91.4</b>	<b>88.6</b>	<b>94.3</b>	<b>91.4</b>



**Result:** Overall, SMARTFUSE outperforms all of the five referred analysis-based detectors and two DL-based approaches.

## RQ2&3: Ablation Study

Setting	Accuracy	Precision	Recall	F1-score
Expert Features	86.9	84.3	90.2	87.1
Semantic Features	83.2	81.5	88.6	84.9
SMARTFUSE	<b>91.4</b>	<b>88.6</b>	<b>94.3</b>	<b>91.4</b>

Setting	Accuracy	Precision	Recall	F1-score
Sum Pooling	75.7	74.7	83.6	87.1
Avg Pooling	80.1	78.4	87.4	84.9
Global Attention Pooling	83.8	81.6	89.5	87.1
Self Attention Pooling	87.6	84.2	92.6	84.9
SMARTFUSE	<b>91.4</b>	<b>88.6</b>	<b>94.3</b>	<b>91.4</b>



**Result:** The combination of expert features and semantic features, as well as our graph representation learning with hybrid pooling layer, contribute significantly to the performance of SMARTFUSE.

# Thanks for listening!

