스마트 컨트랙트 검증, 테스팅, 자동 수정

소순범, 오학주

고려대학교 정보대학 컴퓨터학과

2022.07.14 @ERC 워크샵, 포항

블록체인

소비자

전자화폐 지불

상품

상점 A

블록체인

소비자

전자화폐 지불

상품

상점 A

상품

중복사용

상점 B

블록체인

소비자

전자화폐 지불

상품

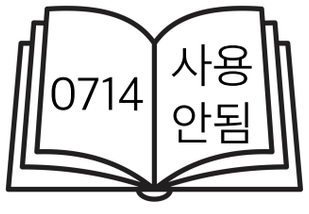
상점 A

상품

중복사용

상점 B

유효성 검증



신뢰가능한 중개인

블록체인

소비자

전자화폐 지불

상품

중복사용

상점 B

유효성 검증

상점 A

신뢰가능한 중개인

스마트 컨트랙트

블록체인 1.0

중개인이 필요 없는
전자화폐 거래 알고리즘

vs.

블록체인 2.0

임의의 거래가 가능

스마트 컨트랙트

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임의의 거래가 가능

Key: 스마트 컨트랙트

스마트 컨트랙트 생김새

```
1   contract Netkoin {
2     mapping (address => uint) public balance;
3     uint public totalSupply;
4
5     constructor (uint initialSupply) {
6       totalSupply = initialSupply;
7       balance[msg.sender] = totalSupply;
8     }
9
10    function transfer (address to, uint value) public
11    returns (bool) {
12      require (balance[msg.sender] >= value);
13      balance[msg.sender] -= value;
14      balance[to] += value;
15      return true;
16    }
17
18    function burn (uint value) public returns (bool) {
19      require (balance[msg.sender] >= value);
20      balance[msg.sender] -= value;
21      totalSupply -= value;
22      return true;
23    }
24  }
```

데이터

생성자

함수

함수

스마트 컨트랙트 생김새

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사용자의 계좌 정보

데이터

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사용자의 계좌 정보

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잔고가 충분하면

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사용자의 계좌 정보

송금

잔고가 충분하면
거래를 실행

데이터

생성자

함수

함수

스마트 컨트랙트 분석 연구

Google 학술검색 | smart contract analysis

학술자료 | 검색결과 약 1,290,000개 중 12페이지 (**0.04**초)

모든 날짜
2022 년부터
2021 년부터
2018 년부터
기간 설정...

관련도별 정렬
날짜별 정렬

모든 언어
한국어 웹

모든 유형
검토 자료

☐ 특허 포함
☑ 서지정보 포함

Smart contract relations in e-commerce: legal implications of exchanges conducted on the blockchain
PA Ryan - Technology Innovation Management Review, 2017 - opus.lib.uts.edu.au
… This article will apply Macaulay's behavioural **analysis** of business exchanges to **smart** …
Once the management of performance of a **smart contract** is explained and understood, it is …
☆ 저장 99 인용 73회 인용 관련 학술자료 전체 11개의 버전 »

Defining **smart contract** defects on ethereum
J Chen, X Xia, D Lo, J Grundy, X Luo… - IEEE Transactions on …, 2020 - ieeexplore.ieee.org
… **contract** defects in 587 real world **smart contract** and publicly released our dataset. Finally, we summarized 5 impacts caused by **contract** … studies on **smart contract analysis** and testing, …
☆ 저장 99 인용 51회 인용 관련 학술자료 전체 14개의 버전

A study of inequality in the ethereum **smart contract** ecosystem
BC Gupta, SK Shukla - 2019 Sixth International Conference on …, 2019 - ieeexplore.ieee.org
… To tackle the problem of finding the **smart contract** addresses, we … find whether address contained a **smart contract** or not. Listing … Next we move our **analysis** to the **contract** creation trans…
☆ 저장 99 인용 5회 인용 관련 학술자료

스마트 컨트랙트 분석 연구

Since 2016, more than 100 tools have been developed

Table 6.1: Identified security analysis tools – continued from previous page

PS Ref.	Tool Name or *Identifier*	Publ. Date	Open Source	Short Description	Mapped SLRs, Surveys and *SmartBugs* [268]
[10]•	Syrup	2020-05	✓	Gas super-optimization of smart contracts, based on symbolic execution and Max-SMT encoding, which finds bytecode blocks with minimal gas cost	1: [141]
[164]	teEther	2019-02	✓	Automated vulnerability detection and exploit generation on smart contract bytecode, based on CFG generation, symbolic execution and SMT solving	11: [141, 160, 296, 304, 49, 74, 81, 145, 157, 229, 331]
[142]	*Transaction-based analysis with LSTM network*	2021-03	✗	Transaction-based classification of Ethereum smart contracts for anomaly detection and malicious contract identification, using a long short-term memory (LSTM) network machine learning approach	0: –
[36]	Vandal	2016-08	✓	Smart contract bytecode security analysis framework for vulnerability detection, based on semantic logic relation conversion, CFG and data flow analysis, user generated security specifications and vulnerability queries	14: [141, 160, 296, 15, 49, 74, 81, 105, 157, 189, 229, 233, 246, 253]
[270]	VeriSmart	2020-04	✓	Arithmetic safety verification for Solidity smart contracts, based on CEGIS-style verification, automatically inferring transaction invariants, providing safety property guarantees, such as freedom from integer overflow	3: [141, 160, 296]
[140]•	Vertigo	2019-08	✓	Mutation testing framework for Solidity smart contracts and Truffle, implementing a range of mutation operators	0: –
[231]	VerX	2020-05	✗	Automatic verification to prove functional properties and temporal safety properties, based on reachability checking, code instrumentation, symbolic execution and delayed predicate abstraction `https://verx.ch/`	2: [141, 304]
[266]	Visualgas	2018-11	✗	Gas cost analysis for Solidity smart contracts, based on AST generation, fuzz testing and transaction trace analysis to support gas-efficient smart contract development	0: –
[236]	VulDeeSmartContract	2020-01	✓	Reentrancy vulnerability detection in Solidity smart contracts, based on an extension of the VulDeePecker framework implementing the bidirectional long-short term memory with attention mechanism (BLSTM-ATT) deep learning approach	0: –
[156]•	Zeus	2018-02	✗	Smart contract security verification framework and vulnerability detection, based on Solidity to LLVM translation, abstract interpretation and symbolic model checking via constrained horn clauses	19: [141, 160, 267, 296, 304, 15, 14, 49, 74, 81, 105, 145, 157, 203, 206, 229, 233, 246, 253]
TOTALS	**140**		**83**		**>0: 101, 0: 39**

•: Additional primary study identified during data extraction. ✓: See table 6.2 for open source information

Images captured from:

Systematic Review of Ethereum Smart Contract Security Vulnerabilities, Analysis Methods and Tools (Heidelinde Rameder's BSc Thesis, 2021)

모든 유형

검토 자료

☐ 특허 포함

☑ 서지정보 포함

A study of inequality in the ethereum **smart contract** ecosystem

BC Gupta, SK Shukla - 2019 Sixth International Conference on …, 2019 - ieeexplore.ieee.org

… To tackle the problem of finding the **smart contract** addresses, we … find whether address contained a **smart contract** or not. Listing … Next we move our **analysis** to the **contract** creation trans…

☆ 저장 99 인용 5회 인용 관련 학술자료

스마트 컨트랙트는 안전성 검증이 필수

- 한번 배포되면 코드 수정 불가능
- 공격에 성공하면 막대한 금전적 피해 발생


KLINT FINLEY 06.18.16 04:30 AM

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

650억원 (2016)

스마트 컨트랙트는 안전성 검증이 필수

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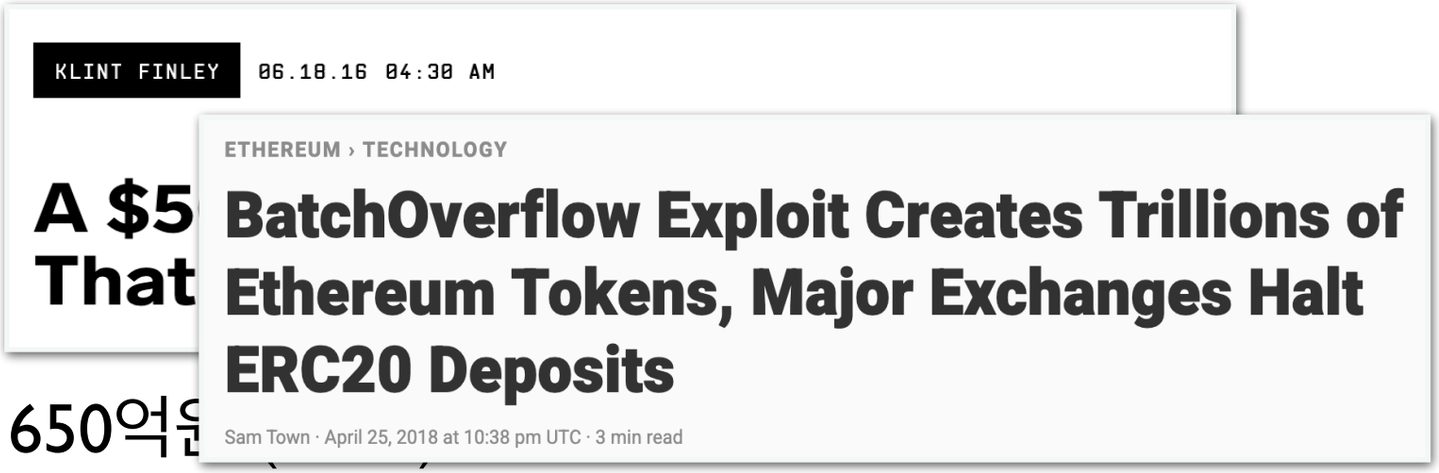
KLINT FINLEY 06.18.16 04:30 AM

A $5
That

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

650억원

천문학적 (2018)

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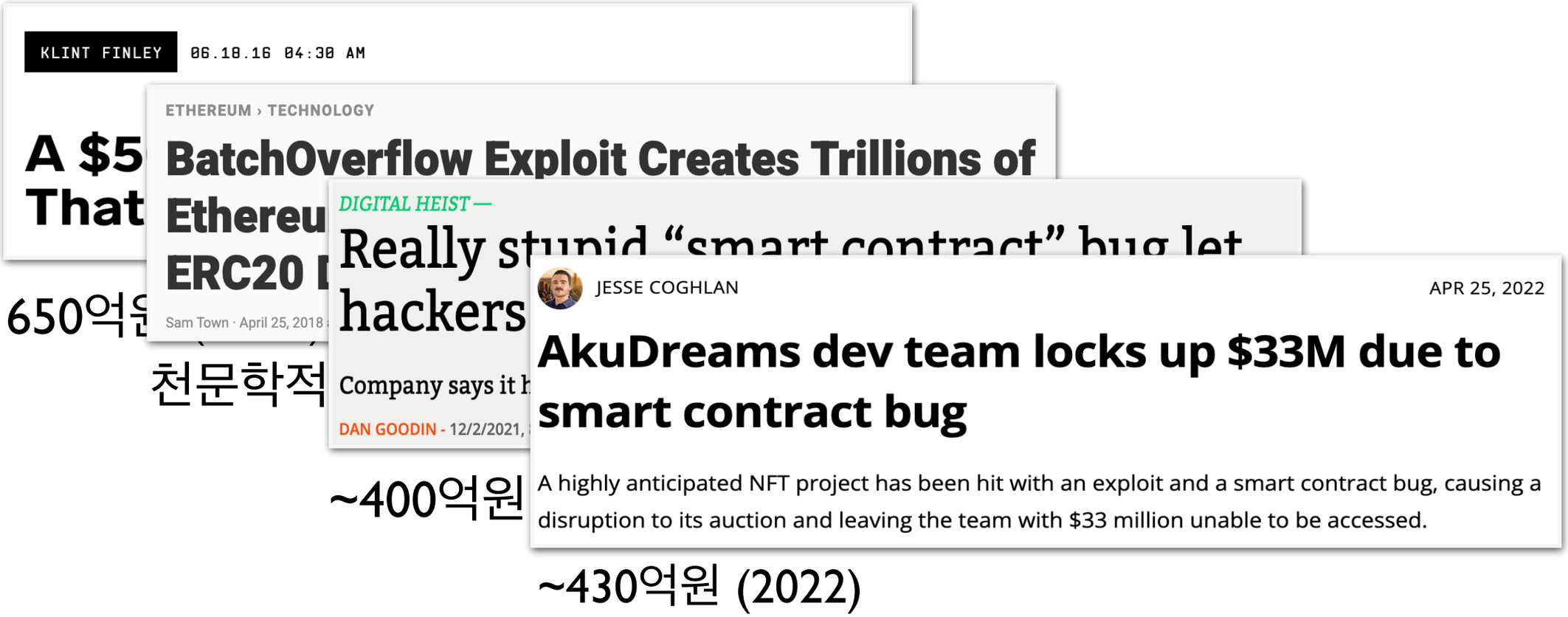

SmartMesh 사례 (2018)

- 정수 오버플로우 취약점을 이용하여 천문학적 금액의 토큰을 생성 (CVE-2018-10376)

0xd6a09bdb29e1eafa92a30373c44b09e2e2e0651e

Contract 0x55f93985431fc9304077687a35a1ba103dc1e081 (SmartMesh: Token Sale)

▸ From 0xdf31a499a5a8358... To 0xdf31a499a5a8358...For
65,133,050,195,990,400,000,000,000,000,000,000,000,000,000,000,000,000,000,000.891004451135422463
($223,066,504,429,629,000,000,000,000,000,000,000,000,000,000,000,000,000.00) SmartMesh (SMT)

▸ From 0xdf31a499a5a8358... To 0xd6a09bdb29e1ea... For
50,659,039,041,325,800,000,000,000,000,000,000,000,000,000,000,000,000,000,000.693003461994217473
($173,496,170,111,934,000,000,000,000,000,000,000,000,000,000,000,000,000.00) SmartMesh (SMT)

https://etherscan.io/tx/0x1abab4c8db9a30e703114528e31dee129a3a758f7f8abc3b6494aad3d304e43f

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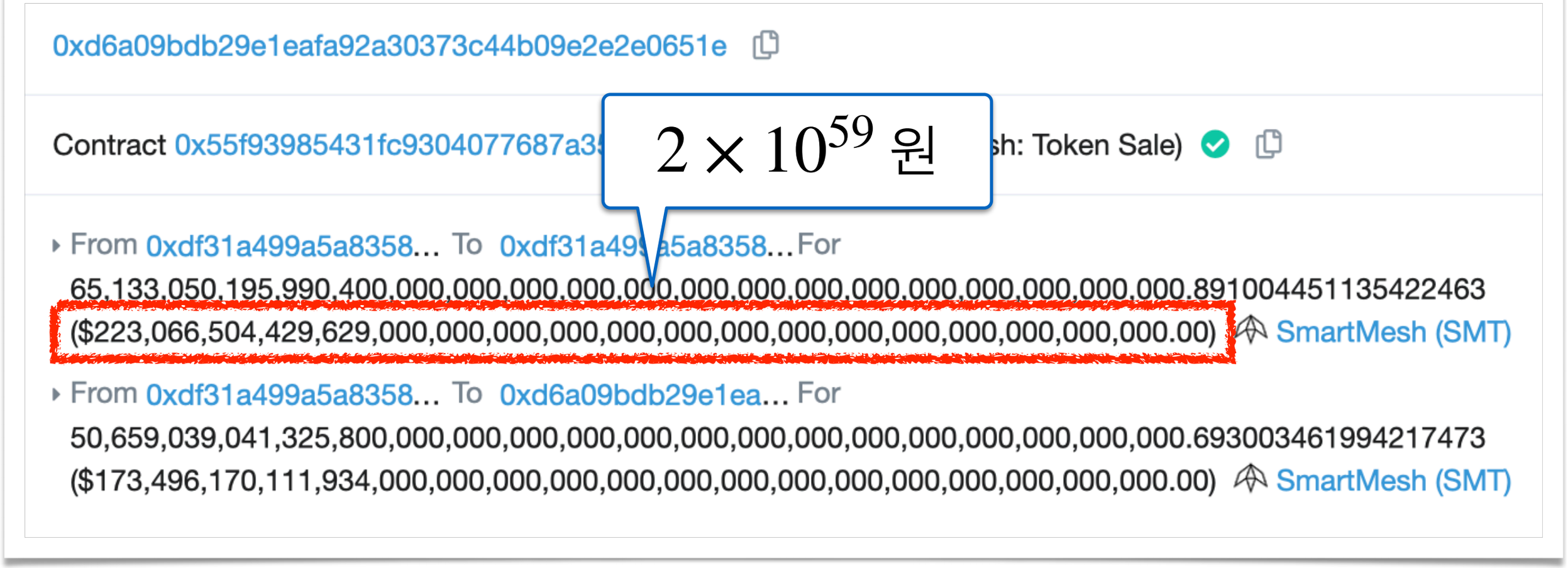

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```
1   function transferProxy (address from, address to, uint
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2     if (balance[from] < fee + value)
3       revert();
4     if (balance[to] + value < balance[to] ||
5         balance[msg.sender] + fee < balance[msg.sender])
6       revert();
7     balance[to] += value;
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보내는 사람의 잔고가 충분한지 체크

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오버플로우 체크

(실질적) 오버플로우/언더플로우 발생하지 않음

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SmartMesh 사례 (2018)

`balance[from] = balance[to] = balance[msg.sender] = 0`

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SmartMesh 사례 (2018)

```
balance[from] = balance[to] = balance[msg.sender] = 0
value: 8fffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
fee  : 7000000000000000000000000000000000000000000000000000000000000001
```

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9     balance[from] -= value + fee;
10    return true;
11  }
```

O!

SmartMesh 사례 (2018)

```
balance[from] = balance[to] = balance[msg.sender] = 0
value: 8fffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
fee  : 7000000000000000000000000000000000000000000000000000000000000001
```

```
1   function transferProxy (address from, address to, uint
          value, uint fee) public returns (bool) {
2     if (balance[from] < fee + value) revert();
3
4     if (balance[to] + value < balance[to] ||
5         balance[msg.sender] + fee < balance[msg.sender])
6       revert();
7     balance[to] += value;
8     balance[msg.sender] += fee;
9     balance[from] -= value + fee;
10    return true;
11  }
```

false

0!

SmartMesh 사례 (2018)

```
balance[from] = balance[to] = balance[msg.sender] = 0
value: 8fffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
fee  : 7000000000000000000000000000000000000000000000000000000000000001
```

```
1   function transferProxy (address from, address to, uint
          value, uint fee) public returns (bool) {
2       if (balance[from] < fee + value) revert();
3
4       if (balance[to] + value < balance[to] ||
5           balance[msg.sender] + fee < balance[msg.sender])
6           revert();
7       balance[to] += value;
8       balance[msg.sender] += fee;
9       balance[from] -= value + fee;
10      return true;
11  }
```

false

false

0!

SmartMesh 사례 (2018)

```
balance[from] = balance[to] = balance[msg.sender] = 0
value: 8fffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
fee  : 7000000000000000000000000000000000000000000000000000000000000001
```

```
1   function transferProxy (address from, address to, uint
          value, uint fee) public returns (bool) {
2       if (balance[from] < fee + value) revert();
3
4       if (balance[to] + value < balance[to] ||
5           balance[msg.sender] + fee < balance[msg.sender])
6           revert();
7       balance[to] += value;
8       balance[msg.sender] += fee;
9       balance[from] -= value + fee;
10      return true;
11  }
```

false

false

0!

8fffff…ff

SmartMesh 사례 (2018)

```
balance[from] = balance[to] = balance[msg.sender] = 0
value: 8fffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
fee  : 7000000000000000000000000000000000000000000000000000000000000001
```

```
1   function transferProxy (address from, address to, uint
          value, uint fee) public returns (bool) {
2       if (balance[from] < fee + value) revert();
3
4       if (balance[to] + value < balance[to] ||
5           balance[msg.sender] + fee < balance[msg.sender])
6           revert();
7       balance[to] += value;
8       balance[msg.sender] += fee;
9       balance[from] -= value + fee;
10      return true;
11  }
```

false

false

0!

8fffff…ff

700…00

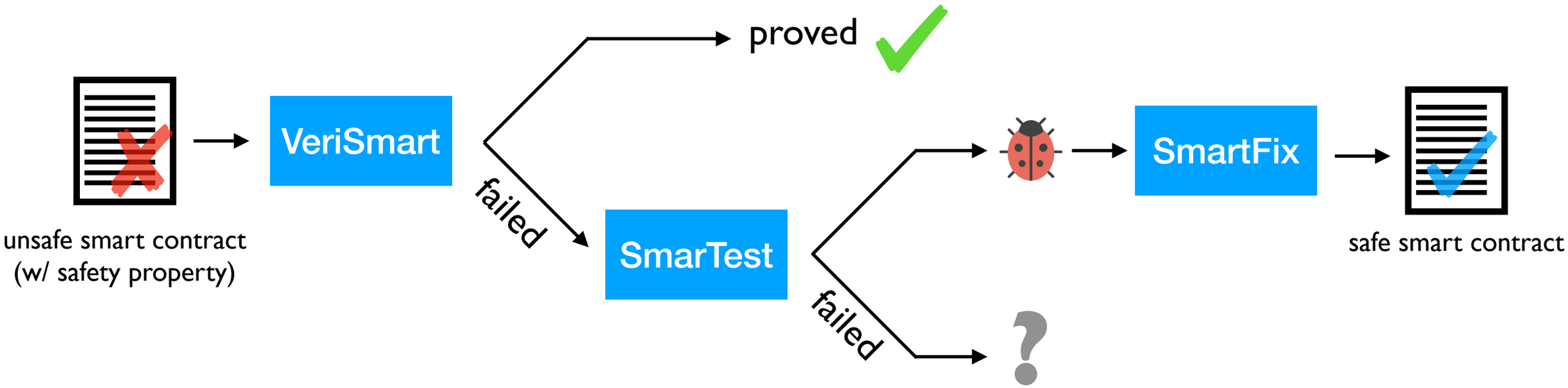
SmartMesh 사례 (2018)

```
balance[from] = balance[to] = balance[msg.sender] = 0
value: 8fffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
fee  : 7000000000000000000000000000000000000000000000000000000000000001
```

```
1   function transferProxy (address from, address to, uint
          value, uint fee) public returns (bool) {
2       if (balance[from] < fee + value) // false, 0!
3           revert();
4       if (balance[to] + value < balance[to] ||
5           balance[msg.sender] + fee < balance[msg.sender]) // false
6           revert();
7       balance[to] += value; // 8fffff…ff
8       balance[msg.sender] += fee; // 700…00
9       balance[from] -= value + fee; // 0!
10      return true;
11  }
```

스마트 컨트랙트 자동 분석 기술

- **VeriSmart** (IEEE S&P 2020): 오류 검증기 (정적 분석)
- **SmarTest** (USENIX Security 2021): 오류 검출기 (동적 분석)
- **SmartFix** (in progress): 오류 수정기



VeriSmart: 오류 검증기

```
1  contract SocialChain {
2    uint totalSupply;
3    mapping(address=>uint) balance;
4    mapping(address=>mapping(address=>uint)) allowance;
5
6    constructor (uint initialSupply) {
7      totalSupply = initialSupply;
8      balance[msg.sender] = initialSupply;
9    }
10
11   function transfer (address to, uint value)
12   public returns(bool) {
13     require (balance[msg.sender] >= value);
14     balance[msg.sender] -= value;
15     balance[to] += value;
16     return true;
17   }
18
19   function approve (address spender, uint value)
20   public returns(bool) {
21     allowance[msg.sender][spender] = value;
22     return true;
23   }
24
25   function transferFrom (address from, address to,
26         uint value) public returns (bool) {
27     require (balance[from] >= value);
28     require (balance[to] + value > balance[to]);
29     require (allowance[from][msg.sender] >= value);
30     balance[from] -= value;
31     balance[to] += value;
32     allowance[from][msg.sender] += value;
33     return true;
34   }
35 }
```

VeriSmart: 오류 검증기

```
1   contract SocialChain {
2     uint totalSupply;
3     mapping(address=>uint) balance;
4     mapping(address=>mapping(address=>uint)) allowance;
5
6     constructor (uint initialSupply) {
7       totalSupply = initialSupply;
8       balance[msg.sender] = initialSupply;
9     }
10
11    function transfer (address to, uint value)
12    public returns(bool) {
13      require (balance[msg.sender] >= value);
14      balance[msg.sender] -= value;
15      balance[to] += value;
16      return true;
17    }
18
19    function approve (address spender, uint value)
20    public returns(bool) {
21      allowance[msg.sender][spender] = value;
22      return true;
23    }
24
25    function transferFrom (address from, address to,
26          uint value) public returns (bool) {
27      require (balance[from] >= value);
28      require (balance[to] + value > balance[to]);
29      require (allowance[from][msg.sender] >= value);
30      balance[from] -= value;
31      balance[to] += value;
32      allowance[from][msg.sender] += value;
33      return true;
34    }
35  }
```

VeriSmart Output

safe

safe

unsafe (may overflow)

기존 정적 분석 도구들

- Bug-finders

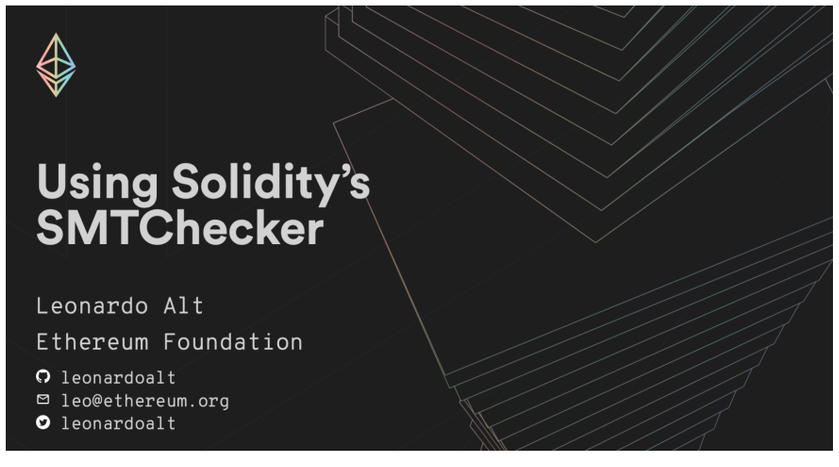
Oyente

Mythril

Manticore

Osiris

- Verifiers



SMT Checker

Zeus

기존 자동 분석 기술의 한계 (I)

- 오류 검출기(e.g., Mythril, Osiris, Oyente): 놓치는 취약점이 존재

```
1   function transferProxy (address from, address to, uint
        value, uint fee) public returns (bool) {
2     if (balance[from] < fee + value)
3       revert();
4     if (balance[to] + value < balance[to] ||
5         balance[msg.sender] + fee < balance[msg.sender])
6       revert();
7     balance[to] += value;
8     balance[msg.sender] += fee;
9     balance[from] -= value + fee;
10    return true;
11  }
```

Osiris만 검출 가능

CVE-2018-10376

기존 자동 분석 기술의 한계 (I)

- 오류 검출기(e.g., Mythril, Osiris, Oyente): 놓치는 취약점이 존재

```
1  function multipleTransfer(address[] to, uint value) {
2    require(value * to.length > 0);
3    require(balances[msg.sender] >= value * to.length);
4    balances[msg.sender] -= value * to.length;
5    for (uint i = 0; i < to.length; ++i) {
6      balances[to[i]] += value;
7    }
8    return true;
9  }
```

앞의 경우와 비슷한 오류이지만 검출 모두 실패

CVE-2018-14006

기존 자동 분석 기술의 한계 (2)

- 오류 검증기(SMTChecker, Zeus): 허위경보 존재

```
1  contract Netkoin {
2    mapping (address => uint) public balance;
3    uint public totalSupply;
4
5    constructor (uint initialSupply) {
6      totalSupply = initialSupply;
7      balance[msg.sender] = totalSupply;
8    }
9
10   function transfer (address to, uint value) public
11   returns (bool) {
12     require (balance[msg.sender] >= value);
13     balance[msg.sender] -= value;
14     balance[to] += value;
15     return true;
16   }
17
18   function burn (uint value) public returns (bool) {
19     require (balance[msg.sender] >= value);
20     balance[msg.sender] -= value;
21     totalSupply -= value;
22     return true;
23   }
24 }
```

허위 경보 (False alarm)

허위 경보 (False alarm)

41st IEEE Symposium on Security and Privacy

VeriSmart

- 안전하면서 정확한 스마트 컨트랙트 정적 분석기

CVE-2018-10376

```
function transferProxy (address from, address to, uint
    value, uint fee) public returns (bool) {
  if (balance[from] < fee + value)
    revert();
  if (balance[to] + value < balance[to] ||
      balance[msg.sender] + fee < balance[msg.sender])
    revert();
  balance[to] += value;
  balance[msg.sender] += fee;
  balance[from] -= value + fee;
  return true;
}
```

CVE-2018-14006

```
function multipleTransfer(address[] to, uint value) {
 require(value * to.length > 0);
 require(balances[msg.sender] >= value * to.length);
 balances[msg.sender] -= value * to.length;
 for (uint i = 0; i < to.length; ++i) {
   balances[to[i]] += value;
 }
 return true;
}
```

오류가 있다면 검출

```
contract Netkoin {
  mapping (address => uint) public balance;
  uint public totalSupply;

  constructor (uint initialSupply) {
    totalSupply = initialSupply;
    balance[msg.sender] = totalSupply;
  }

  function transfer (address to, uint value) public
  returns (bool) {
    require (balance[msg.sender] >= value);
    balance[msg.sender] -= value;
    balance[to] += value;
    return true;
  }

  function burn (uint value) public returns (bool) {
    require (balance[msg.sender] >= value);
    balance[msg.sender] -= value;
    totalSupply -= value;
    return true;
  }
}
```

Verified!

오류가 없다면 없다고 검증

기존 취약점 검출기와 성능 비교

No.	CVE ID	Name	LOC	#Q	VeriSmart			Osiris [7]			Oyente [9], [26]			Mythril [8]			MantiCore [10]		
					#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE
#1	2018-10299	BEC	299	6	2	0	✓	0	0	✗	1	0	△	2	0	✓	0	0	✗
#2	2018-10376	SMT	294	22	13	0	✓	1	0	✓	2	0	✗	1	0	✗	timeout (> 3 days)		
#3	2018-10468	UET	146	27	14	0	✓	9	0	✗	8	0	✓	5	0	✓	0	0	✗
#4	2018-10706	SCA	404	48	33	0	✓	9	0	✗	4	0	△	2	0	✗	internal error		
#5	2018-11239	HXG	102	11	7	0	✓	6	0	✓	2	0	✗	3	0	✓	2	0	✓
#6	2018-11411	DimonCoin	126	15	7	0	✓	5	0	✗	5	0	✓	5	0	✓	3	0	✓
#7	2018-11429	ATL	165	9	4	0	✓	3	0	✓	2	0	△	0	0	✗	0	0	✗
#8	2018-11446	GRX	434	39	24	2	✓	8	2	✗	12	4	✗	4	2	✗	internal error		
#9	2018-11561	EETHER	146	10	5	0	✓	4	0	✓	2	0	△	2	0	✓	0	0	✗
#10	2018-11687	BTCR	99	20	4	0	✓	2	0	✓	2	0	△	3	2	✗	0	0	✗
#11	2018-12070	SEC	269	40	8	0	✓	6	0	✓	4	0	✗	3	1	✗	0	0	✗
#12	2018-12230	RMC	161	9	5	0	✓	3	0	✓	5	0	✓	0	0	✗	0	0	✗
#13	2018-13113	ETT	142	9	2	0	N/A	4	2	N/A	2	2	N/A	0	0	N/A	0	0	N/A
#14	2018-13126	MoxyOnePresale	301	5	3	0	✓	0	0	✗	0	0	✗	0	0	✗	0	0	✗
#15	2018-13127	DSPX	238	6	4	0	✓	3	0	✓	3	0	△	1	0	✗	0	0	✗
#16	2018-13128	ETY	193	10	4	0	✓	3	0	✓	3	0	△	0	0	✗	0	0	✗
#17	2018-13129	SPX	276	9	6	0	✓	5	0	✓	3	0	△	1	0	✗	internal error		
#18	2018-13131	SpadePreSale	312	4	3	0	✓	0	0	✗	0	0	✗	0	0	✗	internal error		
#19	2018-13132	SpadeIco	403	9	6	0	✓	0	0	✗	0	0	✗	0	0	✗	internal error		
#20	2018-13144	PDX	103	5	2	0	✓	2	1	✓	2	1	✓	internal error			0	0	✗
#21	2018-13189	UNLB	335	4	3	0	✓	2	0	✓	3	0	✓	1	0	✗	0	0	✗
#22	2018-13202	MyBO	183	17	11	0	✓	5	0	✓	3	0	✗	1	0	✗	internal error		
#23	2018-13208	MoneyTree	171	17	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#24	2018-13220	MAVCash	171	15	10	0	✓	4	0	✓	2	0	✗	1	0	✗	0	0	✗
#25	2018-13221	XT	186	15	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#26	2018-13225	MyYLCToken	181	17	11	0	✓	5	0	✓	6	0	✗	0	0	✗	0	0	✗
#27	2018-13227	MCN	172	17	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#28	2018-13228	CNX	171	17	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#29	2018-13230	DSN	171	17	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#30	2018-13325	GROW	176	12	2	0	✓	4	2	✓	1	1	✗	0	0	✗	0	0	✗
#31	2018-13326	BTX	135	9	2	0	N/A	4	2	N/A	2	2	N/A	0	0	N/A	0	0	N/A
#32	2018-13327	CCLAG	92	5	2	0	✓	2	1	✓	2	1	✓	0	0	✗	0	0	✗
#33	2018-13493	DaddyToken	344	40	22	0	✓	8	0	✗	2	0	✗	3	0	✗	internal error		
#34	2018-13533	ALUXToken	191	23	13	0	✓	8	0	✓	2	0	✓	1	0	✗	1	0	✗
#35	2018-13625	Krown	271	22	9	0	✓	1	0	✗	3	0	✓	0	0	✗	internal error		
#36	2018-13670	GFCB	103	14	11	0	✓	6	1	✓	3	1	✓	1	0	✗	0	0	✗
#37	2018-13695	CTest7	301	17	8	0	✓	0	0	✗	0	0	✗	0	0	✗	0	0	✗
#38	2018-13698	Play2LivePromo	131	8	7	0	✓	7	0	✓	7	0	✓	5	0	✗	5	0	✗
#39	2018-13703	CERB_Coin	262	17	8	0	✓	5	0	✓	2	0	✗	2	1	✗	0	0	✗
#40	2018-13722	HYIPToken	410	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	internal error		
#41	2018-13777	RRToken	166	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	0	0	✗
#42	2018-13778	CGCToken	224	13	6	0	✓	4	0	✓	4	0	✓	1	0	✗	1	0	✗
#43	2018-13779	YLCToken	180	17	11	0	✓	5	0	✓	6	0	✓	0	0	✗	0	0	✗
#44	2018-13782	ENTR	171	17	10	0	✓	4	0	✓	2	0	✓	2	0	✗	0	0	✗
#45	2018-13783	JiucaiToken	271	19	11	0	✓	6	0	✓	4	0	✓	0	0	✗	internal error		
#46	2018-13836	XRC	119	22	7	0	✓	5	0	✗	3	0	△	3	1	✓	timeout (> 3 days)		
#47	2018-14001	SKT	152	19	10	0	✓	4	0	✗	3	0	△	3	0	✓	0	0	✗
#48	2018-14002	MP3	83	12	4	0	✓	2	0	✗	2	0	△	2	1	✗	timeout (> 3 days)		
#49	2018-14003	WMC	200	15	6	0	✓	3	0	✗	2	0	△	3	0	✓	1	0	✗
#50	2018-14004	GLB	299	40	8	0	✓	5	0	✓	1	0	△	0	0	✗	0	0	✗
#51	2018-14005	Xmc	255	29	11	0	✓	8	0	✓	1	0	△	3	0	△	0	0	✗
#52	2018-14006	NGT	249	27	13	0	✓	1	0	✗	5	0	△	0	0	✗	timeout (> 3 days)		
#53	2018-14063	TRCT	178	9	1	0	✓	1	0	✓	1	0	✓	4	2	✓	0	0	✗
#54	2018-14084	MKCB	273	17	10	0	✓	5	0	✓	4	0	✗	2	0	✗	1	0	✗
#55	2018-14086	SCO	107	16	14	0	✓	7	2	✓	5	2	✗	0	0	✗	0	0	✗
#56	2018-14087	EUC	174	15	7	0	✓	4	0	✗	4	0	✗	0	0	✗	0	0	✗
#57	2018-14089	Virgo_ZodiacToken	208	30	20	0	✓	12	0	✓	5	0	✓	14	0	✓	0	0	✗
#58	2018-14576	SunContract	194	12	4	0	✓	1	0	✓	0	0	✗	0	0	✗	0	0	✗
#59	2018-17050	AI	141	8	3	0	✓	1	0	✓	1	0	✓	0	0	✗	0	0	✗
#60	2018-18665	NXX	79	7	5	0	✓	4	0	✓	4	0	✓	0	0	✗	0	0	✗
Total			12493	976	492	2	✓:58 △: 0 ✗ : 0	240	13	✓:41 △: 0 ✗ :17	171	14	✓:20 △:15 ✗ :23	94	10	✓:10 △: 1 ✗ :46	14	0	✓: 2 △: 0 ✗ :42

기존 취약점 검출기와 성능 비교

No.	CVE ID	Name	LOC	#Q	VeriSmart #Alarm	VeriSmart #FP	VeriSmart CVE	Osiris [7] #Alarm	Osiris [7] #FP	Osiris [7] CVE	Oyente [9], [26] #Alarm	Oyente [9], [26] #FP	Oyente [9], [26] CVE	Mythril [8] #Alarm	Mythril [8] #FP	Mythril [8] CVE	MantiCore [10] #Alarm	MantiCore [10] #FP	MantiCore [10] CVE
#1	2018-10299	BEC	299	6	2	0	✓	0	0	✗	1	0	△	2	0	✓	0	0	✗
#2	2018-10376	SMT	294	22	13	0	✓	1	0	✓	2	0	✗	1	0	✗	timeout (> 3 days)		
#3	2018-10468	UET	146	27	14	0	✓	9	0	✗	8	0	✓	5	0	✓	0	0	✗
#4	2018-10706	SCA	404	48	33	0	✓	9	0	✗	4	0	△	2	0	✗	internal error		
#5	2018-11239	HXG	102	11	7	0	✓	6	0	✓	2	0	✗	3	0	✓	2	0	✓
#6	2018-11411	DimonCoin	126	15	7	0	✓	5	0	✗	5	0	✓	5	0	✓	3	0	✓
#7	2018-11429	ATL	165	9	4	0	✓	3	0	✓	2	0	△	0	0	✗	0	0	✗
#8	2018-11446	GRX	434	39	24	2	✓	8	2	✗	12	4	✗	4	2	✗	internal error		
#9	2018-11561	EETHER	146	10	5	0	✓	4	0	✓	2	0	△	2	0	✓	0	0	✗
#10	2018-11687	BTCR	99	20	4	0	✓	2	0	✓	2	0	△	3	2	✗	0	0	✗
#11	2018-12070	SEC	269	40	8	0	✓	6	0	✓	4	0	✗	3	1	✗	0	0	✗
#12	2018-12230	RMC	161	9	5	0	✓	3	0	✓	5	0	✓	0	0	✗	0	0	✗
#13	2018-13113	ETT	142	9	2	0	N/A	4	2	N/A	2	2	N/A	0	0	N/A	0	0	N/A
#14	2018-13126	MoxyOnePresale	301	5	3	0	✓	0	0	✗	0	0	✗	0	0	✗	0	0	✗
#15	2018-13127	DSPX	238	6	4	0	✓	3	0	✓	3	0	△	1	0	✗	0	0	✗
#16	2018-13128	ETY	193	10	4	0	✓	3	0	✓	3	0	△	0	0	✗	0	0	✗
#17	2018-13129	SPX	276	9	6	0	✓	5	0	✓	3	0	△	1	0	✗	internal error		
#18	2018-13131	SpadePreSale	312	4	3	0	✓	0	0	✗	0	0	✗	0	0	✗	internal error		
#29	2018-13230	DSN	171	17	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#30	2018-13325	GROW	176	12	2	0	✓	4	2	✓	1	1	✗	0	0	✗	0	0	✗
#31	2018-13326	BTX	135	9	2	0	N/A	4	2	N/A	2	2	N/A	0	0	N/A	0	0	N/A
#32	2018-13327	CCLAG	92	5	2	0	✓	2	1	✓	2	1	✓	0	0	✗	0	0	✗
#33	2018-13493	DaddyToken	344	40	22	0	✓	8	0	✗	2	0	✗	3	0	✗	internal error		
#34	2018-13533	ALUXToken	191	23	13	0	✓	8	0	✓	2	0	✓	1	0	✗	1	0	✗
#35	2018-13625	Krown	271	22	9	0	✓	1	0	✗	3	0	✓	0	0	✗	internal error		
#36	2018-13670	GFCB	103	14	11	0	✓	6	1	✓	3	1	✓	1	0	✗	0	0	✗
#37	2018-13695	CTest7	301	17	8	0	✓	0	0	✗	0	0	✗	0	0	✗	0	0	✗
#38	2018-13698	Play2LivePromo	131	8	7	0	✓	7	0	✓	7	0	✓	5	0	✗	5	0	✗
#39	2018-13703	CERB_Coin	262	17	8	0	✓	5	0	✓	2	0	✗	2	1	✗	0	0	✗
#40	2018-13722	HYIPToken	410	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	internal error		
#41	2018-13777	RRToken	166	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	0	0	✗
#42	2018-13778	CGCToken	224	13	6	0	✓	4	0	✓	4	0	✓	1	0	✗	1	0	✗
#43	2018-13779	YLCToken	180	17	11	0	✓	5	0	✓	6	0	✓	0	0	✗	0	0	✗
#44	2018-13782	ENTR	171	17	10	0	✓	4	0	✓	2	0	✓	2	0	✗	0	0	✗
#45	2018-13783	JiucaiToken	271	19	11	0	✓	6	0	✓	4	0	✓	0	0	✗	internal error		
#46	2018-13836	XRC	119	22	7	0	✓	5	0	✗	3	0	△	3	1	✓	timeout (> 3 days)		
#47	2018-14001	SKT	152	19	10	0	✓	4	0	✗	3	0	△	3	0	✓	0	0	✗
#48	2018-14002	MP3	83	12	4	0	✓	2	0	✗	2	0	△	2	1	✗	timeout (> 3 days)		
#49	2018-14003	WMC	200	15	6	0	✓	3	0	✗	2	0	△	3	0	✓	1	0	✗
#50	2018-14004	GLB	299	40	8	0	✓	5	0	✓	1	0	△	0	0	✗	0	0	✗
#51	2018-14005	Xmc	255	29	11	0	✓	8	0	✓	1	0	△	3	0	△	0	0	✗
#52	2018-14006	NGT	249	27	13	0	✓	1	0	✗	5	0	△	0	0	✗	timeout (> 3 days)		
#53	2018-14063	TRCT	178	9	1	0	✓	1	0	✓	1	0	✓	4	2	✓	0	0	✗
#54	2018-14084	MKCB	273	17	10	0	✓	5	0	✓	4	0	✗	2	0	✗	1	0	✗
#55	2018-14086	SCO	107	16	14	0	✓	7	2	✓	5	2	✗	0	0	✗	0	0	✗
#56	2018-14087	EUC	174	15	7	0	✓	4	0	✗	4	0	✗	0	0	✗	0	0	✗
#57	2018-14089	Virgo_ZodiacToken	208	30	20	0	✓	12	0	✓	5	0	✓	14	0	✓	0	0	✗
#58	2018-14576	SunContract	194	12	4	0	✓	1	0	✓	0	0	✗	0	0	✗	0	0	✗
#59	2018-17050	AI	141	8	3	0	✓	1	0	✓	1	0	✓	0	0	✗	0	0	✗
#60	2018-18665	NXX	79	7	5	0	✓	4	0	✓	4	0	✓	0	0	✗	0	0	✗
Total			12493	976	492	2	✓:58 △: 0 ✗ : 0	240	13	✓:41 △: 0 ✗ :17	171	14	✓:20 △:15 ✗ :23	94	10	✓:10 △: 1 ✗ :46	14	0	✓: 2 △: 0 ✗ :42

			VeriSmart #Alarm	VeriSmart #FP	VeriSmart CVE	Osiris [43] #Alarm	Osiris [43] #FP	Osiris [43] CVE	Oyente [9, 34] #Alarm	Oyente [9, 34] #FP	Oyente [9, 34] CVE	Mythril [7] #Alarm	Mythril [7] #FP	Mythril [7] CVE	MantiCore [2] #Alarm	MantiCore [2] #FP	MantiCore [2] CVE
Total	12493	976	492	2	✓: 58 △: 0 ✗: 0	240	13	✓:41 △: 0 ✗ :17	171	14	✓:20 △:15 ✗ :23	94	10	✓:10 △: 1 ✗ :46	14	0	✓: 2 △: 0 ✗ :42

기존 취약점 검출기와 성능 비교

No.	CVE ID	Name	LOC	#Q	VeriSmart #Alarm	VeriSmart #FP	VeriSmart CVE	Osiris [7] #Alarm	Osiris [7] #FP	Osiris [7] CVE	Oyente [9], [26] #Alarm	Oyente [9], [26] #FP	Oyente [9], [26] CVE	Mythril [8] #Alarm	Mythril [8] #FP	Mythril [8] CVE	MantiCore [10] #Alarm	MantiCore [10] #FP	MantiCore [10] CVE
#1	2018-10299	BEC	299	6	2	0	✓	0	0	✗	1	0	△	2	0	✓	0	0	✗
#2	2018-10376	SMT	294	22	13	0	✓	1	0	✓	2	0	✗	1	0	✗	timeout (> 3 days)		
#3	2018-10468	UET	146	27	14	0	✓	9	0	✗	8	0	✓	5	0	✓	0	0	✗
#4	2018-10706	SCA	404	48	33	0	✓	9	0	✗	4	0	△	2	0	✗	internal error		
#5	2018-11239	HXG	102	11	7	0	✓	6	0	✓	2	0	✗	3	0	✓	2	0	✓
#6	2018-11411	DimonCoin	126	15	7	0	✓	5	0	✗	5	0	✓	5	0	✓	3	0	✓
#7	2018-11429	ATL						3	0	✓	2	0	△	0	0	✗	0	0	✗
#8	2018-11446	GRX						8	2	✗	12	4	✗	4	2	✗	internal error		
#9	2018-11561	EET						4	0	✓	2	0	△	2	0	✓	0	0	✗
#10	2018-11687	BTC						2	0	✓	2	0	△	3	2	✗	0	0	✗
#11	2018-12070	SEC						6	0	✓	4	0	✗	3	1	✗	0	0	✗
#12	2018-12230	RMC						3	0	✓	5	0	✓	0	0	✗	0	0	✗
#13	2018-13113	ETT						4	2	N/A	2	2	N/A	0	0	N/A	0	0	N/A
#14	2018-13126	Mox						0	0	✗	0	0	✗	0	0	✗	0	0	✗
#15	2018-13127	DSP						3	0	✓	3	0	△	1	0	✗	0	0	✗
#16	2018-13128	ETY						3	0	✓	3	0	△	0	0	✗	0	0	✗
#17	2018-13129	SPX						5	0	✓	3	0	△	1	0	✗	internal error		
#18	2018-13131	SpadePreSale	312	4	3	0	✓	0	0	✗	0	0	✗	0	0	✗	internal error		
#29	2018-13230	DSN	171	17	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#30	2018-13325	GROW	176	12	2	0	✓	4	2	✓	1	1	✗	0	0	✗	0	0	✗
#31	2018-13326	BTX	135	9	2	0	N/A	4	2	N/A	2	2	N/A	0	0	N/A	0	0	N/A
#32	2018-13327	CCLAG	92	5	2	0	✓	2	1	✓	2	1	✓	0	0	✗	0	0	✗
#33	2018-13493	DaddyToken	344	40	22	0	✓	8	0	✗	2	0	✗	3	0	✗	internal error		
#34	2018-13533	ALUXToken	191	23	13	0	✓	8	0	✓	2	0	✓	1	0	✗	1	0	✗
#35	2018-13625	Krown	271	22	9	0	✓	1	0	✗	3	0	✓	0	0	✗	internal error		
#36	2018-13670	GFCB	103	14	11	0	✓	6	1	✓	3	1	✓	1	0	✗	0	0	✗
#37	2018-13695	CTest7	301	17	8	0	✓	0	0	✗	0	0	✗	0	0	✗	0	0	✗
#38	2018-13698	Play2LivePromo	131	8	7	0	✓	7	0	✓	7	0	✓	5	0	✗	5	0	✗
#39	2018-13703	CERB_Coin	262	17	8	0	✓	5	0	✓	2	0	✗	2	1	✗	0	0	✗
#40	2018-13722	HYIPToken	410	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	internal error		
#41	2018-13777	RRToken	166	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	0	0	✗
#42	2018-13778	CGCToken	224	13	6	0	✓	4	0	✓	4	0	✓	1	0	✗	1	0	✗
#43	2018-13779	YLCToken	180	17	11	0	✓	5	0	✓	6	0	✓	0	0	✗	0	0	✗
#44	2018-13782	ENTR	171	17	10	0	✓	4	0	✓	2	0	✓	2	0	✗	0	0	✗
#45	2018-13783	JiucaiToken	271	19	11	0	✓	6	0	✓	4	0	✓	0	0	✗	internal error		
#46	2018-13836	XRC	119	22	7	0	✓	5	0	✗	3	0	△	3	1	✓	timeout (> 3 days)		
#47	2018-14001	SKT	152	19	10	0	✓	4	0	✗	3	0	△	3	0	✓	0	0	✗
#48	2018-14002	MP3	83	12	4	0	✓	2	0	✗	2	0	△	2	1	✗	timeout (> 3 days)		
#49	2018-14003	WMC	200	15	6	0	✓	3	0	✗	2	0	△	3	0	✓	1	0	✗
#50	2018-14004	GLB	299	40	8	0	✓	5	0	✓	1	0	△	0	0	✗	0	0	✗
#51	2018-14005	Xmc	255	29	11	0	✓	8	0	✓	1	0	△	3	0	△	0	0	✗
#52	2018-14006	NGT	249	27	13	0	✓	1	0	✗	5	0	△	0	0	✗	timeout (> 3 days)		
#53	2018-14063	TRCT	178	9	1	0	✓	1	0	✓	1	0	✓	4	2	✓	0	0	✗
#54	2018-14084	MKCB	273	17	10	0	✓	5	0	✓	4	0	✗	2	0	✗	1	0	✗
#55	2018-14086	SCO	107	16	14	0	✓	7	2	✓	5	2	✗	0	0	✗	0	0	✗
#56	2018-14087	EUC	174	15	7	0	✓	4	0	✗	4	0	✗	0	0	✗	0	0	✗
#57	2018-14089	Virgo_ZodiacToken	208	30	20	0	✓	12	0	✓	5	0	✓	14	0	✓	0	0	✗
#58	2018-14576	SunContract	194	12	4	0	✓	1	0	✓	0	0	✗	0	0	✗	0	0	✗
#59	2018-17050	AI	141	8	3	0	✓	1	0	✓	1	0	✓	0	0	✗	0	0	✗
#60	2018-18665	NXX	79	7	5	0	✓	4	0	✓	4	0	✓	0	0	✗	0	0	✗
Total			12493	976	492	2	✓:58 △: 0 ✗: 0	240	13	✓:41 △: 0 ✗ :17	171	14	✓:20 △:15 ✗ :23	94	10	✓:10 △: 1 ✗ :46	14	0	✓: 2 △: 0 ✗ :42

정확도: 99.5%
검출률: 100%

			VeriSmart #Alarm	VeriSmart #FP	VeriSmart CVE	Osiris [43] #Alarm	Osiris [43] #FP	Osiris [43] CVE	Oyente [9, 34] #Alarm	Oyente [9, 34] #FP	Oyente [9, 34] CVE	Mythril [7] #Alarm	Mythril [7] #FP	Mythril [7] CVE	MantiCore [2] #Alarm	MantiCore [2] #FP	MantiCore [2] CVE
Total	12493	976	492	2	✓: 58 △: 0 ✗: 0	240	13	✓:41 △: 0 ✗ :17	171	14	✓:20 △:15 ✗ :23	94	10	✓:10 △: 1 ✗ :46	14	0	✓: 2 △: 0 ✗ :42

기존 취약점 검출기와 성능 비교

No.	CVE ID	Name	LOC	#Q	VeriSmart			Osiris [7]			Oyente [9], [26]			Mythril [8]			ManticCore [10]		
					#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE
#1	2018-10299	BEC	299	6	2	0	✓	0	0	✗	1	0	△	2	0	✓	0	0	✗
#2	2018-10376	SMT	294	22	13	0	✓	1	0	✓	2	0	✗	1	0	✗	timeout (> 3 days)		
#3	2018-10468	UET	146	27	14	0	✓	9	0	✗	8	0	✓	5	0	✓	0	0	✗
#4	2018-10706	SCA	404	48	33	0	✓	9	0	✗	4	0	△	2	0	✗	internal error		
#5	2018-11239	HXG	102	11	7	0	✓	6	0	✓	2	0	✗	3	0	✓	2	0	✓
#6	2018-11411	DimonCoin	126	15	7	0	✓	5	0	✗	5	0	✓	5	0	✓	3	0	✓
#7	2018-11429	ATL						3	0	✓	2	0	∠						
#8	2018-11446	GRX						8	2	✗	12	4	✗						
#9	2018-11561	EET						4	0	✓	2	0	∠						
#10	2018-11687	BTC						2	0	✓	2	0	∠						
#11	2018-12070	SEC						6	0	✓	4	0	✗						
#12	2018-12230	RMC						3	0	✓	5	0	✓						
#13	2018-13113	ETT						4	2	N/A	2	2	N/						
#14	2018-13126	Mox						0	0	✗	0	0	✗						
#15	2018-13127	DSP						3	0	✓	3	0	∠						
#16	2018-13128	ETY						3	0	✓	3	0	∠						
#17	2018-13129	SPX						5	0	✓	3	0	∠						
#18	2018-13131	SpadePreSale	312	4	3	0	✓	0	0	✗	0	0	✗	0	0	✗	internal error		
#29	2018-13230	DSN	171	17	10	0	✓	4	0	✓	2	0	✗	2	0	✗	0	0	✗
#30	2018-13325	GROW	176	12	2	0	✓	4	2	✓	1	1	✗	0	0	✗	0	0	✗
#31	2018-13326	BTX	135	9	2	0	N/A	4	2	N/A	2	2	N/A	0	0	N/A	0	0	N/A
#32	2018-13327	CCLAG	92	5	2	0	✓	2	1	✓	2	1	✓	0	0	✗	0	0	✗
#33	2018-13493	DaddyToken	344	40	22	0	✓	8	0	✗	2	0	✗	3	0	✗	internal error		
#34	2018-13533	ALUXToken	191	23	13	0	✓	8	0	✓	2	0	✓	1	0	✗	1	0	✗
#35	2018-13625	Krown	271	22	9	0	✓	1	0	✗	3	0	✓	0	0	✗	internal error		
#36	2018-13670	GFCB	103	14	11	0	✓	6	1	✓	3	1	✓	1	0	✗	0	0	✗
#37	2018-13695	CTest7	301	17	8	0	✓	0	0	✗	0	0	✗	0	0	✗	0	0	✗
#38	2018-13698	Play2LivePromo	131	8	7	0	✓	7	0	✓	7	0	✓	5	0	✗	5	0	✗
#39	2018-13703	CERB_Coin	262	17	8	0	✓	5	0	✓	2	0	✗	2	1	✗	0	0	✗
#40	2018-13722	HYIPToken	410	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	internal error		
#41	2018-13777	RRToken	166	8	3	0	✓	2	0	✓	2	0	✓	0	0	✗	0	0	✗
#42	2018-13778	CGCToken	224	13	6	0	✓	4	0	✓	4	0	✓	1	0	✗	1	0	✗
#43	2018-13779	YLCToken	180	17	11	0	✓	5	0	✓	6	0	✓	0	0	✗	0	0	✗
#44	2018-13782	ENTR	171	17	10	0	✓	4	0	✓	2	0	✓	2	0	✗	0	0	✗
#45	2018-13783	JiucaiToken	271	19	11	0	✓	6	0	✓	4	0	✓	0	0	✗	internal error		
#46	2018-13836	XRC	119	22	7	0	✓	5	0	✗	3	0	△	3	1	✓	timeout (> 3 days)		
#47	2018-14001	SKT	152	19	10	0	✓	4	0	✗	3	0	△	3	0	✓	0	0	✗
#48	2018-14002	MP3	83	12	4	0	✓	2	0	✗	2	0	△	2	1	✗	timeout (> 3 days)		
#49	2018-14003	WMC	200	15	6	0	✓	3	0	✗	2	0	△	3	0	✓	1	0	✗
#50	2018-14004	GLB	299	40	8	0	✓	5	0	✓	1	0	△	0	0	✗	0	0	✗
#51	2018-14005	Xmc	255	29	11	0	✓	8	0	✓	1	0	△	3	0	△	0	0	✗
#52	2018-14006	NGT	249	27	13	0	✓	1	0	✗	5	0	△	0	0	✗	timeout (> 3 days)		
#53	2018-14063	TRCT	178	9	1	0	✓	1	0	✓	1	0	✓	4	2	✓	0	0	✗
#54	2018-14084	MKCB	273	17	10	0	✓	5	0	✓	4	0	✗	2	0	✗	1	0	✗
#55	2018-14086	SCO	107	16	14	0	✓	7	2	✓	5	2	✗	0	0	✗	0	0	✗
#56	2018-14087	EUC	174	15	7	0	✓	4	0	✗	4	0	✗	0	0	✗	0	0	✗
#57	2018-14089	Virgo_ZodiacToken	208	30	20	0	✓	12	0	✓	5	0	✓	14	0	✓	0	0	✗
#58	2018-14576	SunContract	194	12	4	0	✓	1	0	✓	0	0	✗	0	0	✗	0	0	✗
#59	2018-17050	AI	141	8	3	0	✓	1	0	✓	1	0	✓	0	0	✗	0	0	✗
#60	2018-18665	NXX	79	7	5	0	✓	4	0	✓	4	0	✓	0	0	✗	0	0	✗
	Total		12493	976	492	2	✓:58 △: 0 ✗ : 0	240	13	✓:41 △: 0 ✗ :17	171	14	✓:20 △:15 ✗ :23	94	10	✓:10 △: 1 ✗ :46	14	0	✓: 2 △: 0 ✗ :42

정확도: 99.5%
검출률: 100%

정확도: < 94.6%
검출률: < 70.7%

			VeriSmart			Osiris [43]			Oyente [9, 34]			Mythril [7]			ManticCore [2]		
			#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE	#Alarm	#FP	CVE
Total	12493	976	492	2	✓: 58 △: 0 ✗: 0	240	13	✓:41 △: 0 ✗ :17	171	14	✓:20 △:15 ✗ :23	94	10	✓:10 △: 1 ✗ :46	14	0	✓: 2 △: 0 ✗ :42

기존 취약점 검증기와 성능 비교

No.	LOC	#Q	VeriSmart			SMTChecker [12]			Zeus [11]
			#Alarm	#FP	Verified	#Alarm	#FP	Verified	Verified
#1	42	3	0	0	✓	3	3	✗	✗
#2	78	2	1	0	✓	2	1	✗	✗
#3	75	7	2	0	✓	7	5	✗	✗
#4	70	7	0	0	✓	7	7	✗	✗
#5	103	8	0	0	✓	6	6	✗	✗
#6	141	5	2	0	✓	internal error			✗
#7	74	6	1	0	✓	6	5	✗	✗
#8	84	6	0	0	✓	4	4	✗	✗
#9	82	6	0	0	✓	6	6	✗	✗
#10	99	2	1	0	✓	internal error			✗
#11	171	15	9	0	✓	internal error			✗
#12	139	7	0	0	✓	internal error			✗
#13	139	7	0	0	✓	internal error			✗
#14	139	7	0	0	✓	internal error			✗
#15	139	7	0	0	✓	internal error			✗
#16	141	16	10	0	✓	internal error			✗
#17	153	5	0	0	✓	internal error			✗
#18	139	7	0	0	✓	internal error			✗
#19	113	4	0	0	✓	4	4	✗	✗
#20	40	3	0	0	✓	3	3	✗	✗
#21	59	3	0	0	✓	internal error			✗
#22	28	3	1	0	✓	1	0	✓	✗
#23	19	3	0	0	✓	3	3	✗	✗
#24	457	30	13	6	✗	internal error			✗
#25	17	3	0	0	✓	3	3	✗	✗
Total	2741	172	40	6	✓:24 ✗ : 1	55	50	✓: 1 ✗: 12	✓: 0 ✗:25

VeriSmart 핵심 차별점

- 트랜잭션 불변 성질 (Transaction invariant) 자동 추론

```
1  contract Netkoin {
2    mapping (address => uint) public balance;
3    uint public totalSupply;
4
5    constructor (uint initialSupply) {
6      totalSupply = initialSupply;
7      balance[msg.sender] = totalSupply;
8    }
9
10   function transfer (address to, uint value) public
11   returns (bool) {
12     require (balance[msg.sender] >= value);
13     balance[msg.sender] -= value;
14     balance[to] += value;
15     return true;
16   }
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18   function burn (uint value) public returns (bool) {
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21     totalSupply -= value;
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```

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totalSupply = ∑balance

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24 }
```

totalSupply = ∑balance

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VeriSmart 핵심 차별점

- 트랜잭션의 불변 성질을 이용한 안전성 증명

```
require (balance[msg.sender] >= value);
balance[msg.sender] -= value;
totalSupply -= value;
```

assert (totalSupply >= value)

totalSupply = ∑balance … transaction invariant

≥ balance[msg.sender] … def. of ∑balance

≥ value … assumption (require)

VeriSmart 핵심 차별점

- 트랜잭션의 불변 성질을 이용한 안전성 증명

```
require (balance[msg.sender] >= value);
balance[msg.sender] -= value;
totalSupply -= value;
```

assert (totalSupply >= value)

totalSupply = ∑balance … transaction invariant

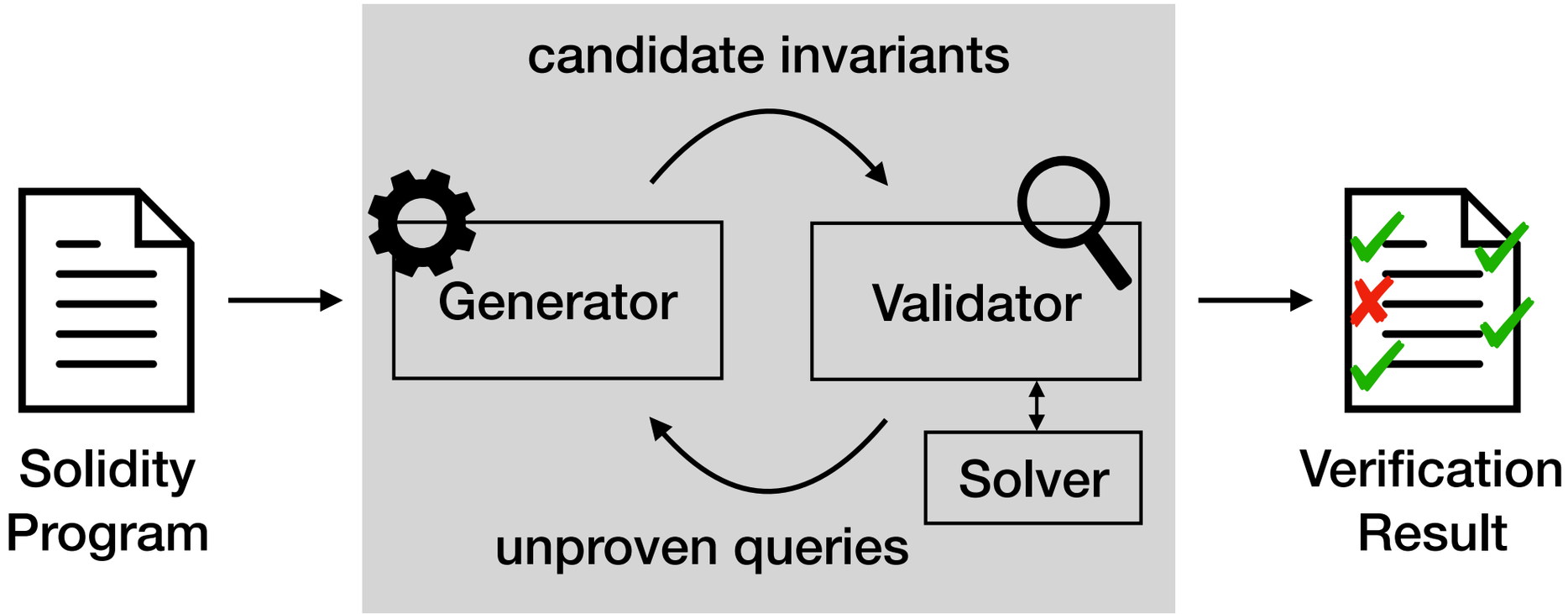
≥ balance[msg.sender] … def. of ∑balance

≥ value … assumption (require)

기존 취약점 검출기 / 검증기들은 불변 성질 추론을 못하여 FN / FP 발생

VeriSmart 검증 알고리즘

- Invariant Generator: 트랜잭션 불변 성질을 추론 시도
- Validator: 추론된 불변 성질을 이용하여 안전성 검증 시도



SmarTest: 오류 검출기

```
1   contract SocialChain {
2     uint totalSupply;
3     mapping(address=>uint) balance;
4     mapping(address=>mapping(address=>uint)) allowance;
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6     constructor (uint initialSupply) {
7       totalSupply = initialSupply;
8       balance[msg.sender] = initialSupply;
9     }
10
11    function transfer (address to, uint value)
12    public returns(bool) {
13      require (balance[msg.sender] >= value);
14      balance[msg.sender] -= value;
15      balance[to] += value;
16      return true;
17    }
18
19    function approve (address spender, uint value)
20    public returns(bool) {
21      allowance[msg.sender][spender] = value;
22      return true;
23    }
24
25    function transferFrom (address from, address to,
26          uint value) public returns (bool) {
27      require (balance[from] >= value);
28      require (balance[to] + value > balance[to]);
29      require (allowance[from][msg.sender] >= value);
30      balance[from] -= value;
31      balance[to] += value;
32      allowance[from][msg.sender] += value;
33      return true;
34    }
35  }
```

safe

safe

unsafe (may overflow)

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오류 시나리오

with msg.sender = A

constructor(0x8800…00)

with msg.sender = A

approve(B, 0x8100..00)

with msg.sender = B

transferFrom(A,C,0x7f00..00)

기호 실행 (Symbolic Execution)

1 x: α, y: β
pc: $true$

```
int double (int v) {
  return 2*v;
}

void testme(int x, int y) {
1
   z := double (y);
2
   if (z==x) {
    3
     if (x>y+10) {
      4 Error;
     } else { 5 …}
   }
6 }
```

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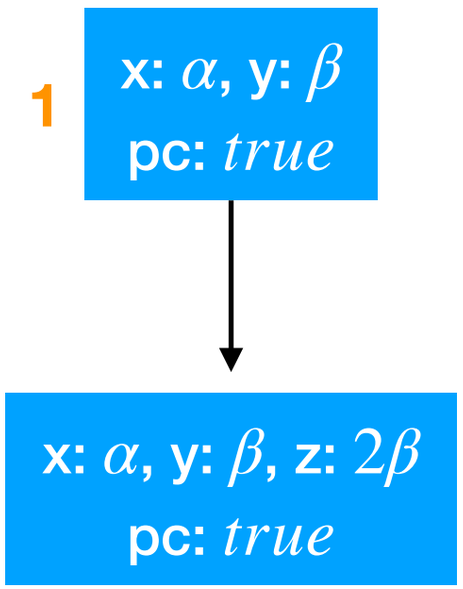

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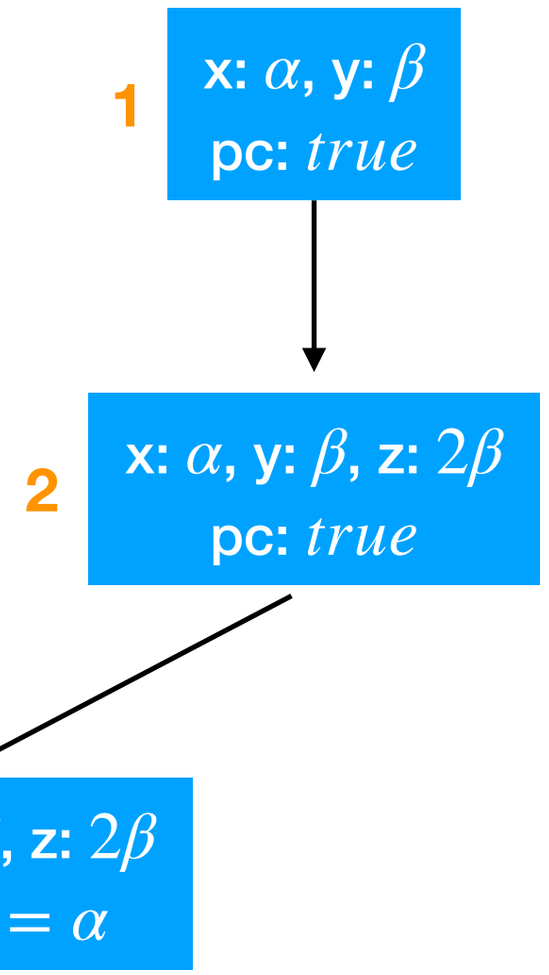

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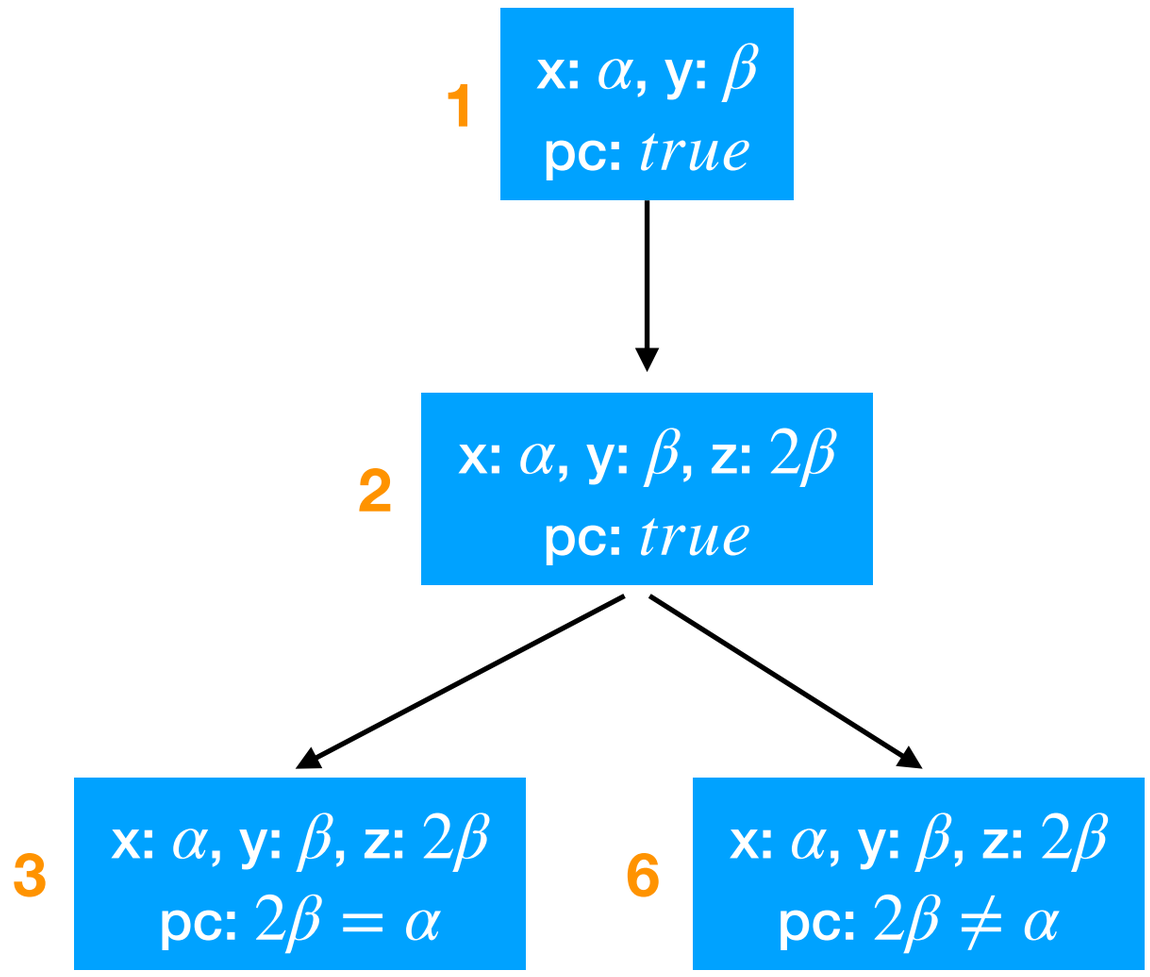

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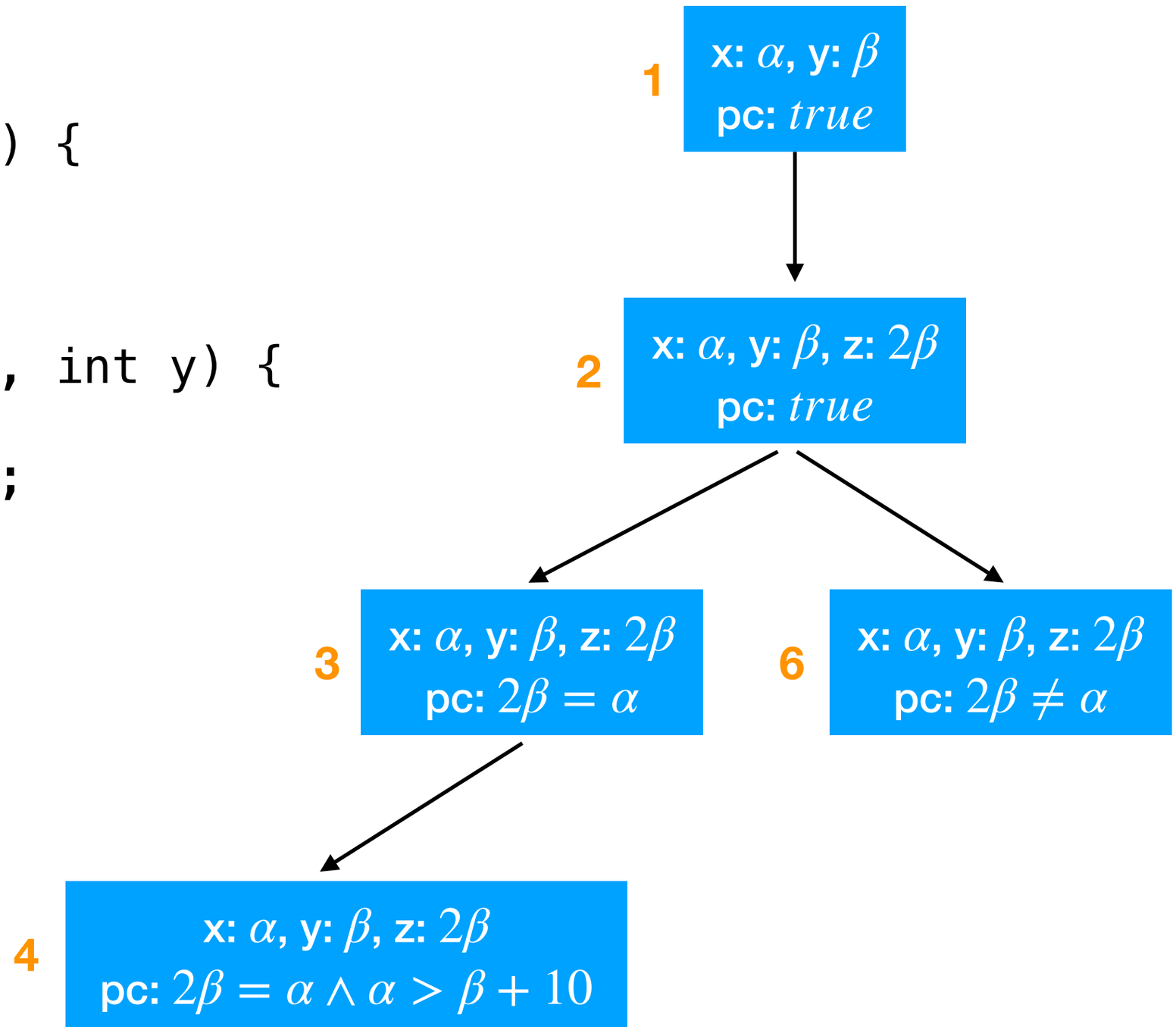

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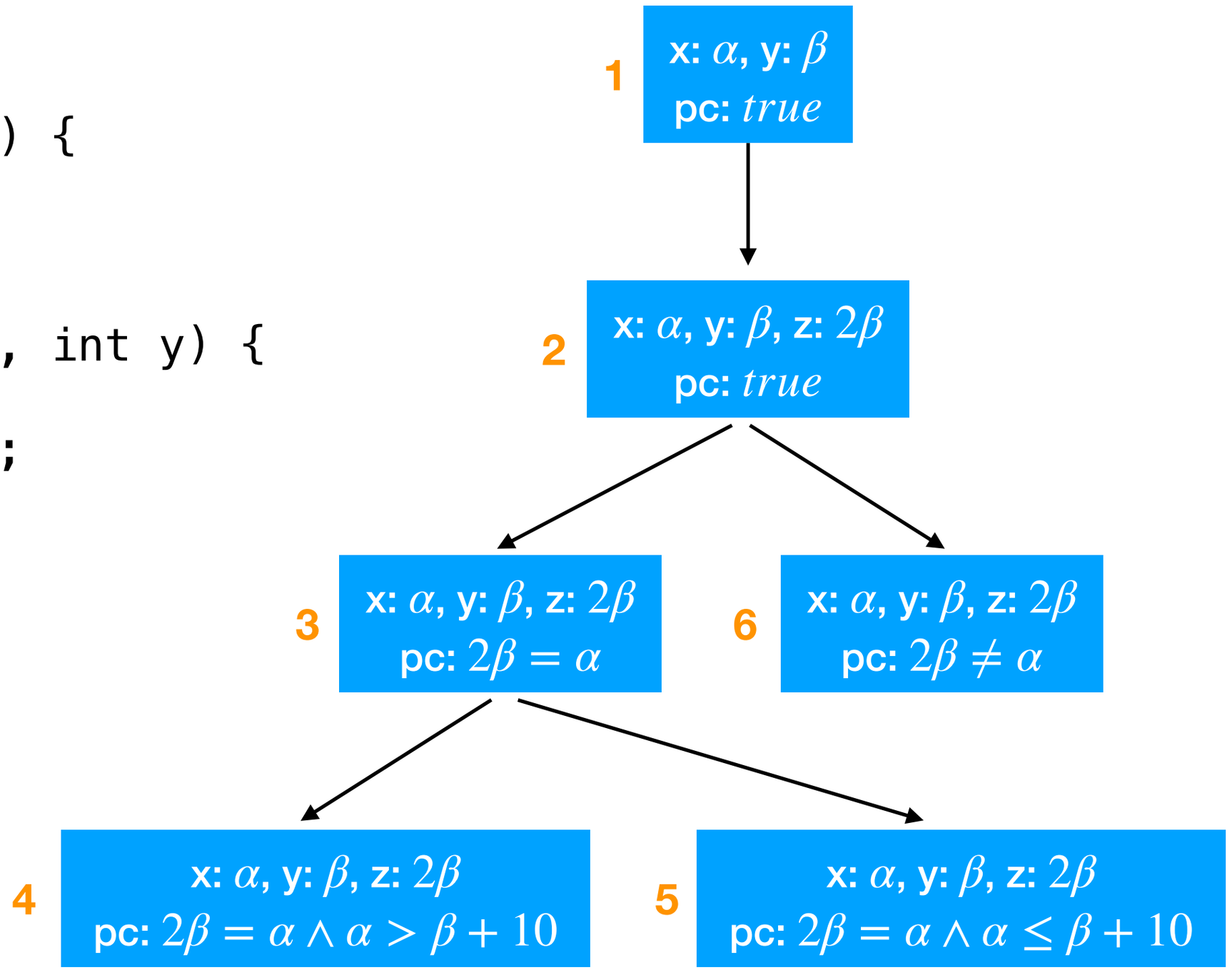

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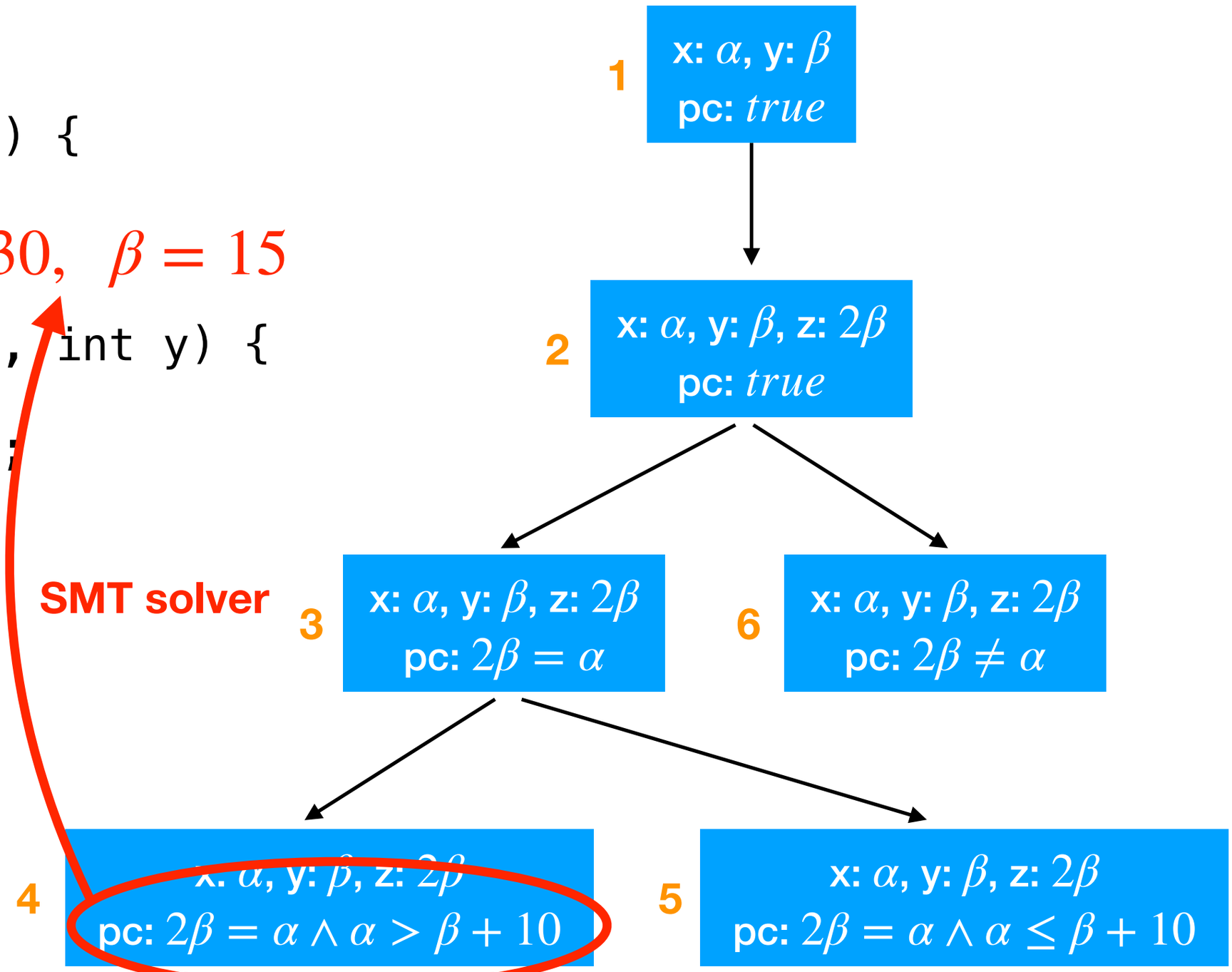
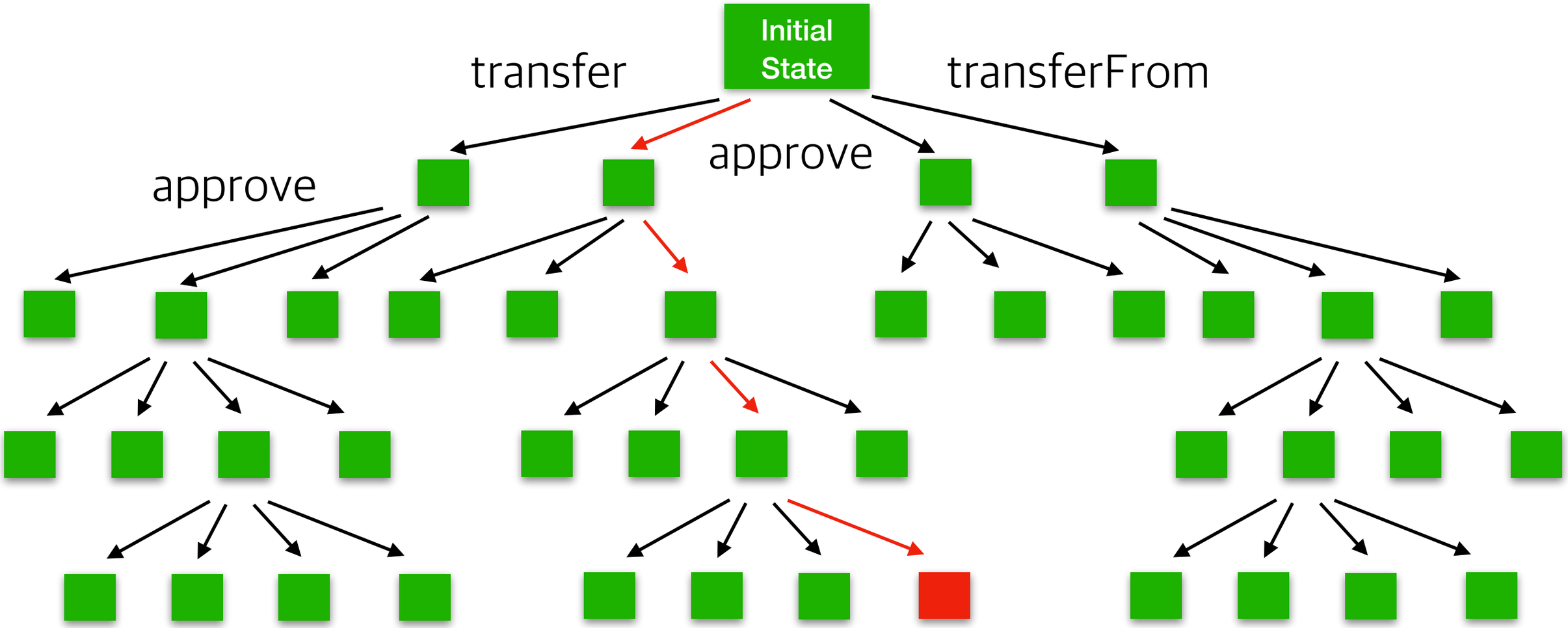
```

$\alpha = 30, \quad \beta = 15$



Path Explosion

- 트랜잭션들이 만들어내는 경우의 수가 폭발



Language Model-guided Symbolic Execution

transfer ⟶ approve ⟶ transferFrom ⟶ ⋯ 80%

approve ⟶ transferFrom ⟶ transfer ⟶ ⋯ 20%

Language Model-guided Symbolic Execution

transfer ⟶ approve ⟶ transferFrom ⟶ ⋯ 80%

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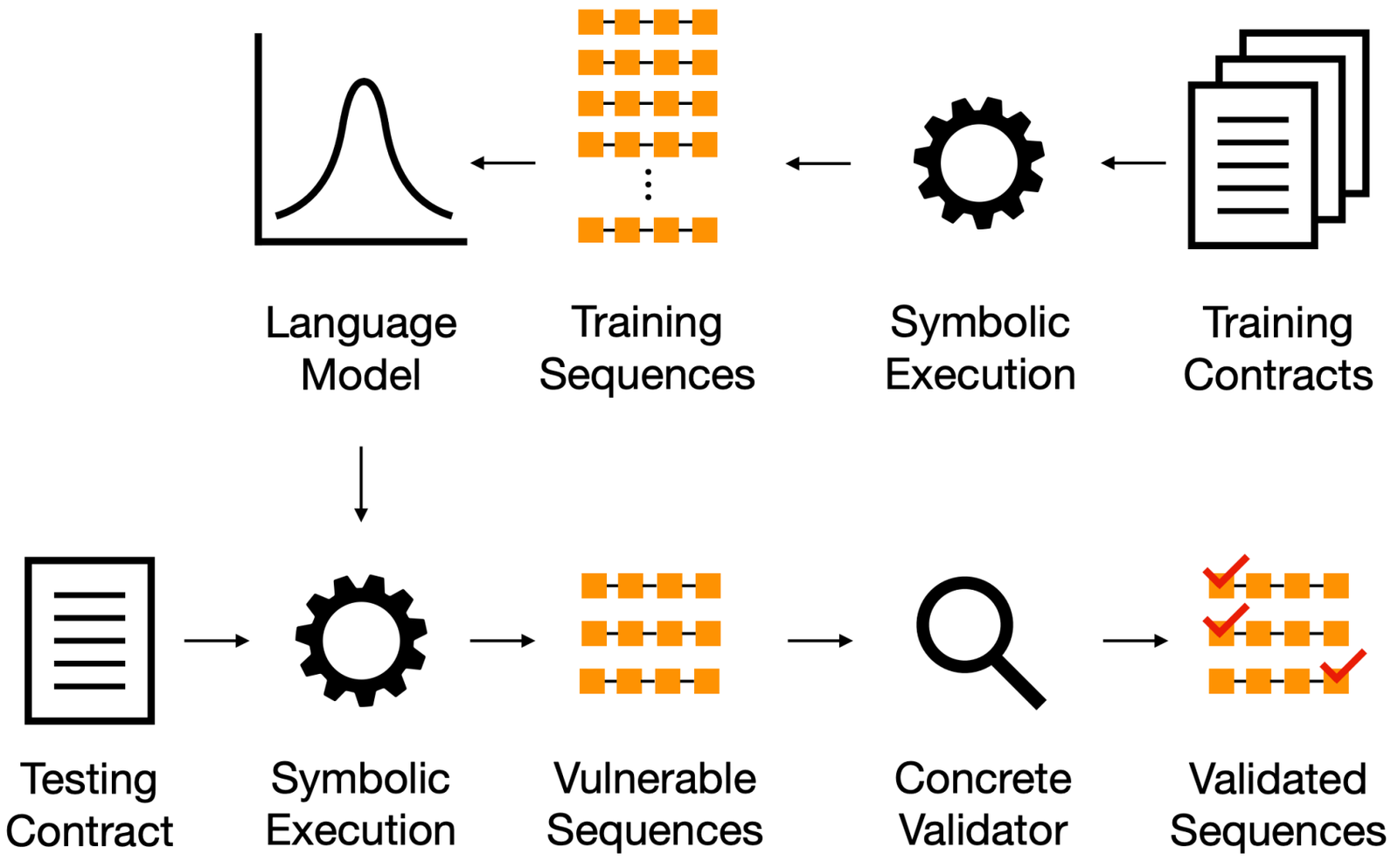

Performance

Tool	Integer Overflow	Division by Zero	Assertion Violation	ERC20 Violation	CVE Vulnerabilities
SmarTest	1982	203	77	654	219
Mythril (ConsenSys)	460	73	25	n/a	85
Manticore (Trail of Bits)	2	1	3	n/a	0

SmartFix: 오류 자동 수정기

```
1   contract SocialChain {
2     uint totalSupply;
3     mapping(address=>uint) balance;
4     mapping(address=>mapping(address=>uint)) allowance;
5
6     constructor (uint initialSupply) {
7       totalSupply = initialSupply;
8       balance[msg.sender] = initialSupply;
9     }
10
11    function transfer (address to, uint value)
12    public returns(bool) {
13      require (balance[msg.sender] >= value);
14      balance[msg.sender] -= value;
15      balance[to] += value;
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```

safe

safe

unsafe (may overflow)

오류 시나리오

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constructor(0x8800…00)

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```

safe

safe

unsafe (may overflow)

+= should be −=

패치

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SmartFix 목표: 취약점을 자동으로 안전하게 수정

CVE-2018-11411

```
1   function transferFrom (address from, address to, uint value) returns (bool success) {
2     if (value == 0) return false;
3     uint fromBalance = balance[from];
4     uint allowance = allowed[from][msg.sender];
5
6     bool sufficientFunds = fromBalance <= value;
7     bool sufficientAllowance = allowance <= value;
8     bool overflowed = balance[to] + value > balance[to];
9
10     if(sufficientFunds && sufficientAllowance && !overflowed) {
11      balance[to] += value;                    // overflow
12      balance[from] -= value;                  // underflow
13      allowed[from][msg.sender] -= value; // underflow
14      return true;
15    }
16    else {return false;}
17  }
```

SmartFix

Line 6 : Replace <= by >=
Line 7 : Replace <= by >=
Line 8 : Replace > by <

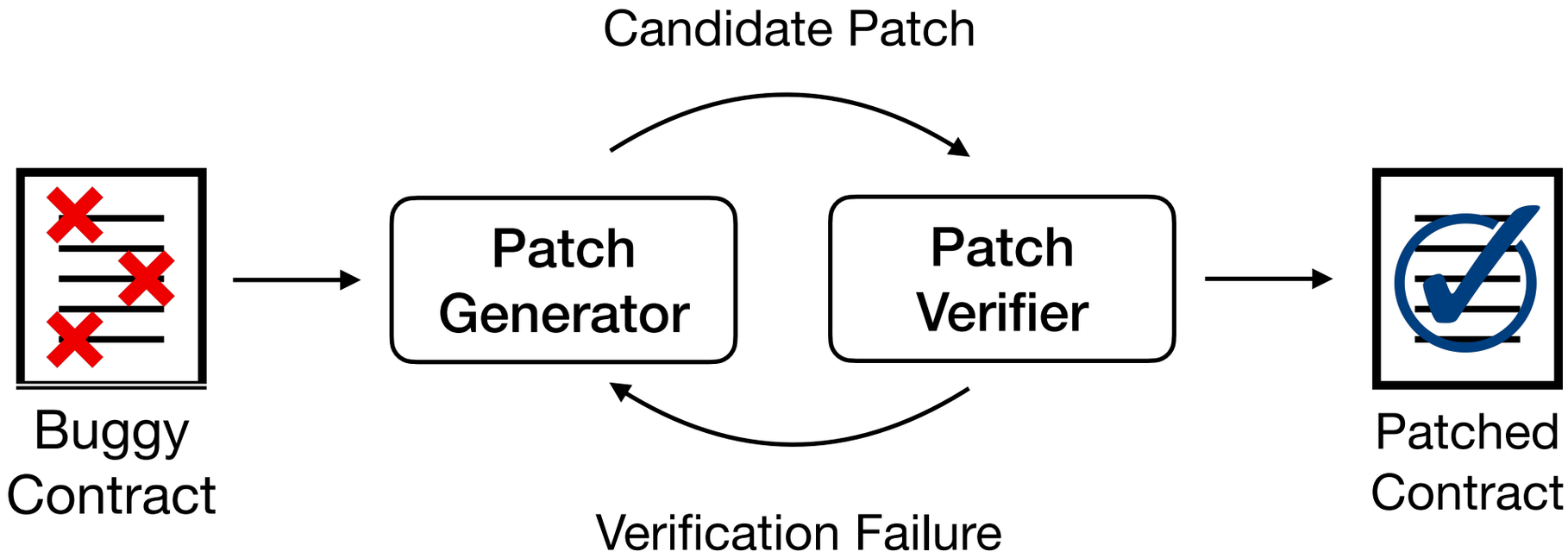
기존 기술: 단순한 패치만 가능

```
1   function transferFrom (address from, address to, uint value) returns (bool success) {
2     if (value == 0) return false;
3     uint fromBalance = balance[from];
4     uint allowance = allowed[from][msg.sender];
5
6     bool sufficientFunds = fromBalance <= value;
7     bool sufficientAllowance = allowance <= value;
8     bool overflowed = safeAdd(balance[to],value) > balance[to];
9
10     if(sufficientFunds && sufficientAllowance && !overflowed) {
12       balance[to] = safeAdd(balance[to],value);
11       balance[from] = safeSub(balance[from],value);
13       allowed[from][msg.sender] = safeSub(allowed[from][msg.sender],value);
14       return true;
15     }
16     else {return false;}
17  }
```

sGuard [IEEE S&P '21], SmartShield, Elysium:
Runtime check 삽입에만 의존

Approach

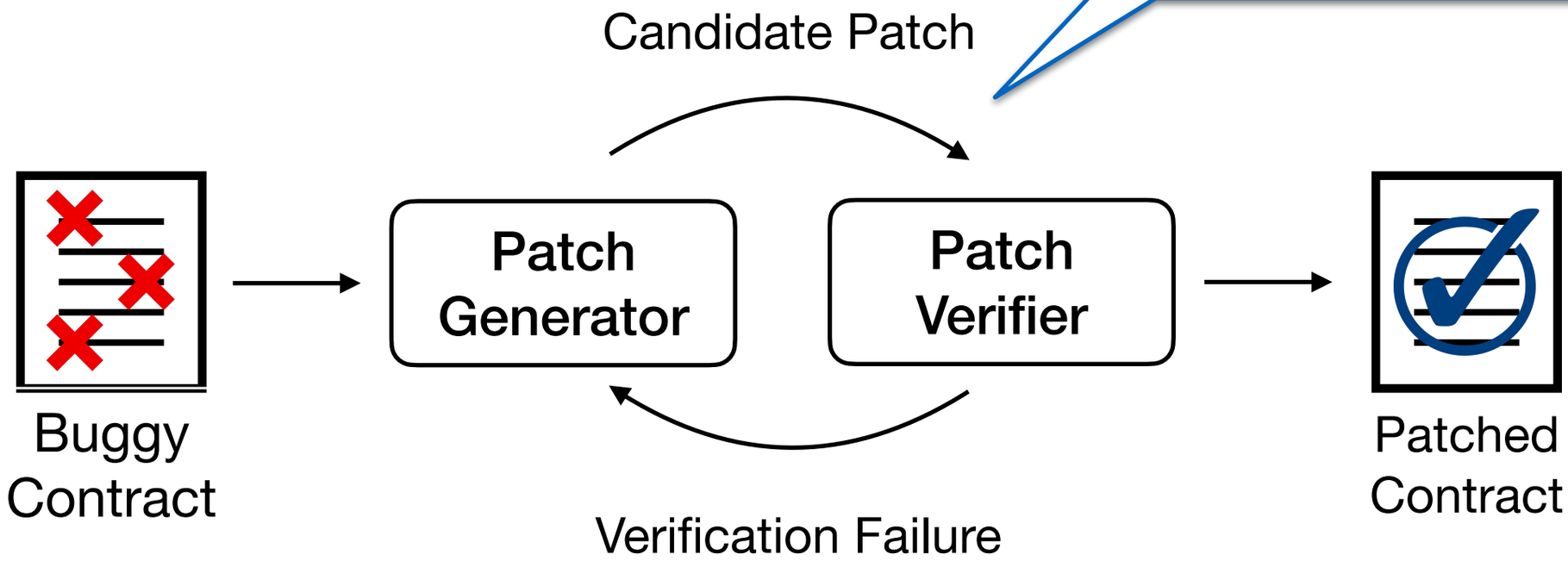
- (패치 후보 나열; 패치 후보 검증)*



Approach

- (패치 후보 나열; 패치 후보 검증)*

온/오프라인 학습을 통해 가속



Performance

Bug Type	#Bug	SmartFix		sGuard [IEEE S&P '21]	
		Succ. Rate	Accuracy	Succ. Rate	Accuracy
IO	229	93.9%	98.6%	60.8%	100%
RE	52	90.2%	100.0%	87.9%	87.9%
TX	12	100.0%	100.0%	100.0%	100.0%
EL	138	57.8%	94.0%	n/a	n/a
SU	53	70.6%	90.0%	n/a	n/a
IO+RE+TX	293	**93.5%**	**98.9%**	**65.5%**	**97.1%**

마무리

- 스마트 컨트랙트는 배포 전 안전성 검증이 필수
- **목표**: 안전한 스마트 컨트랙트 개발을 돕기 위한 **검증, 테스팅, 수정 기술**
  - **VeriSmart**: 스마트 컨트랙트 검증기
  - **SmarTest**: 스마트 컨트랙트 테스팅 도구
  - **SmartFix**: 스마트 컨트랙트 수정 도구

소스코드: https://github.com/kupl/VeriSmart-public
벤치마크: https://github.com/kupl/VeriSmart-benchmarks

감사합니다!