Intro to Scribble

Scribble Bootcamp

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Plan

DILIGENCE Fuzzing

Plan

Scribble Overview

DILIGENCE Fuzzing

Plan

Scrible Overview
Function Annotations

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Plan

Scrible Overview
Function Annotations
Contract Invariants

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The Problem

The Problem

We expect certain properties of our code to be true.

The Problem

```
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
```

We expect certain properties of our code to be true.

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The Problem

```
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
```

We expect certain properties of our code to be true.

“The balance of to increases after the transfer”

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Option 1: Comments

```
/// Balance of to increases
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
```

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Option 1: Comments

```
/// Balance of to increases
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
```

Can’t test/check comments

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Option 2: Add Assertions

```
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
    uint256 oldBalance = balanceOf(to);
    ...
    assert(balanceOf(to) > oldBalance);
}
```

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Option 2: Add Assertions

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function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
    uint256 oldBalance = balanceOf(to);
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Increased runtime cost

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Option 2: Add Assertions

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Increased runtime cost

Pollute code/compilcate dev workflow

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Option 2: Add Assertions

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    uint256 oldBalance = balanceOf(to);
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```

Increased runtime cost

Pollute code/compilcate dev workflow

Can we get the best of both worlds?

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What is Scribble?

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What is Scribble?

Specification Language For Developers

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What is Scribble?

```
/// #if_succeeds balanceOf(to) >= amount;
function transferFrom(
    address from,
    address to,
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Specification Language For Developers

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What is Scribble?

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Specification Language For Developers

Annotations embedded in docstrings

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What is Scribble?

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- Specification Language For Developers
- Annotations embedded in docstrings
- Solidity-like expressions

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What is Scribble?

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/// #if_succeeds balanceOf(to) >= amount;
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    address from,
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```

Specification Language For Developers

Annotations embedded in docstrings

Solidity-like expressions

Can think of them as checkable comments!

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How do we use Scribble?

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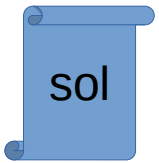
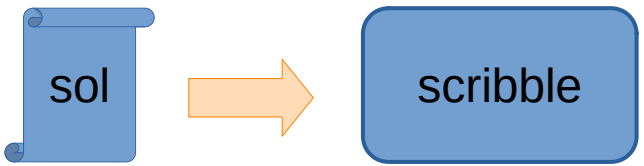


(annotated)

How do we use Scribble?



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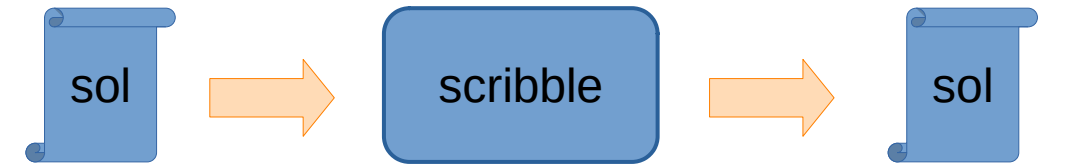
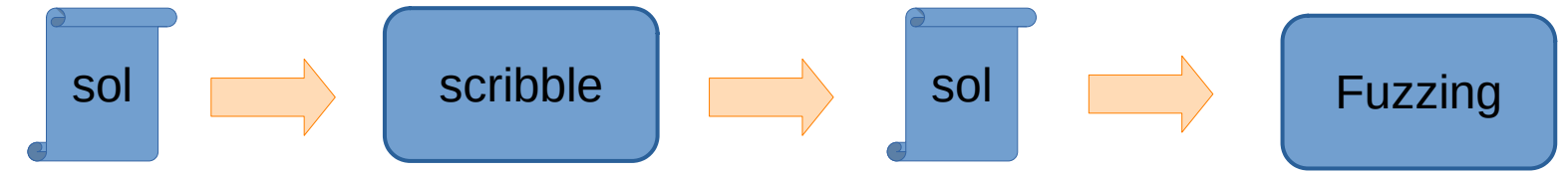
How do we use Scribble?



(annotated) (instrumented)

How do we use Scribble?



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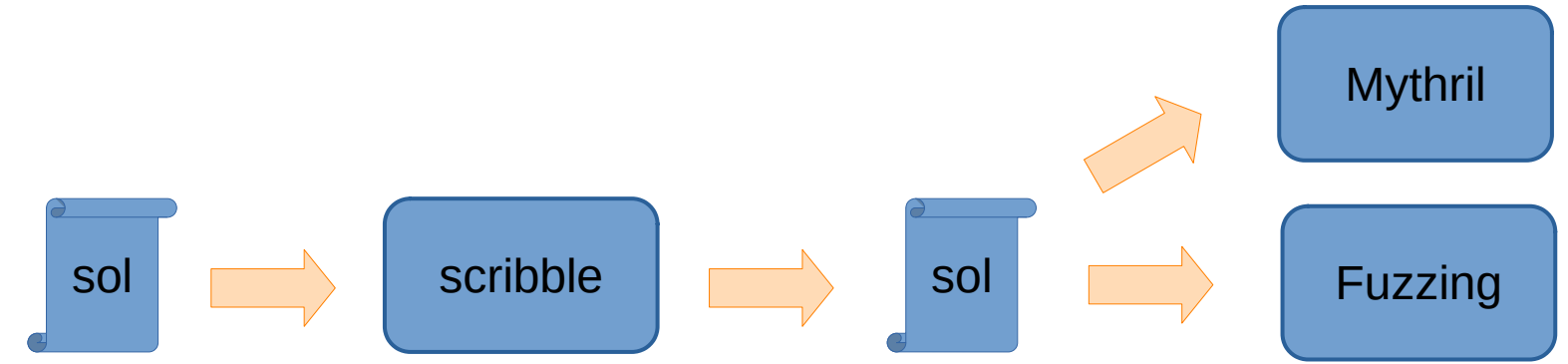

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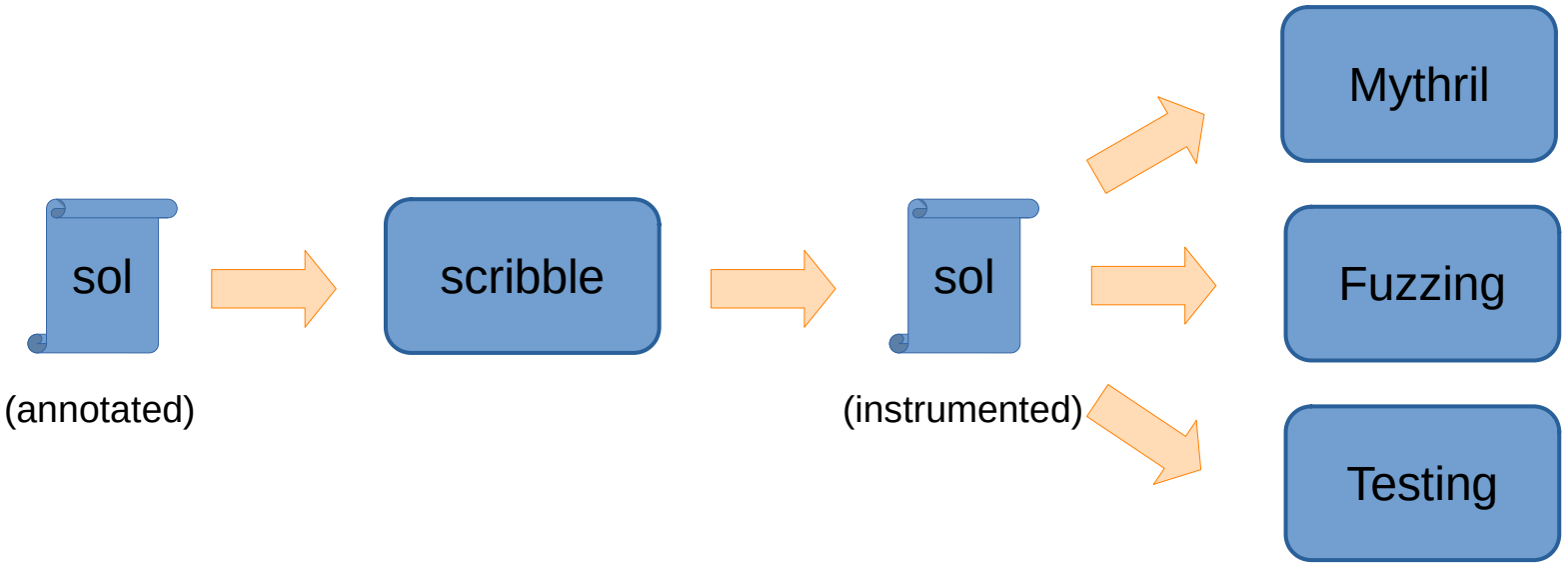

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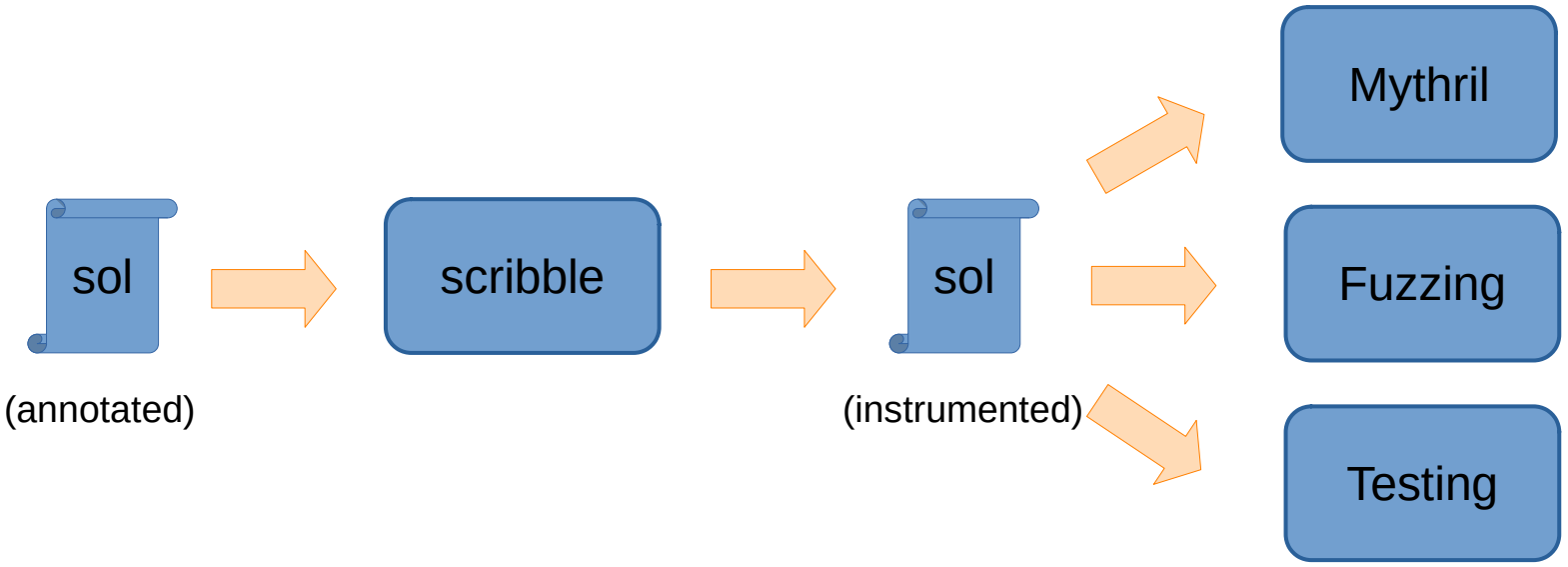

Scribble integrates with many workflows

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Function Annotations

Function Annotations

```
/// #if_succeeds balanceOf(to) >= amount;
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
```

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Function Annotations

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if_succeeds P; checks that P holds upon successful termination of function

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if_succeeds P; checks that P holds upon successful termination of function

P can be any valid pure solidity expression

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Function Annotations

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    address from,
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if_succeeds P; checks that P holds upon successful termination of function

P can be any valid pure solidity expression

P can include some scribble extensions

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Function Annotations

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/// #if_succeeds balanceOf(to) >= amount;
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    address from,
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) public virtual override returns (bool) {
```

if_succeeds P; checks that P holds upon successful termination of function

P can be any valid pure solidity expression

P can include some scribble extensions

What if we want to say exactly how much to's balance increases?

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Function Annotations

Function Annotations

```
/// #if_succeeds
///     old(balanceOf(to)) + amount == balanceOf(to);
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
```

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Function Annotations

```
/// #if_succeeds
///     old(balanceOf(to)) + amount == balanceOf(to);
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Use old() to refer to state before call

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Function Annotations

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/// #if_succeeds
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    address from,
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Use old() to refer to state before call

In old(E), E must have a value type

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Function Instrumentation

Function Instrumentation

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/// #if_succeeds
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    address from,
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Function Instrumentation

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/// #if_succeeds
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    address from,
    address to,
    uint256 amount
) public virtual override returns (bool) {
```

```
function transferFrom(
    address from,
    address to,
    uint256 amount
) virtual override public returns (bool RET_0) {
    vars0 memory _v;
    _v.old_0 = balanceOf(to);

    RET_0 = _original_Foo_transferFrom(from, to, amount);

    if (!((_v.old_0 + amount) == balanceOf(to))) {
        assert(false);
    }
}

function _original_Foo_transferFrom(
    address from,
    address to,
    uint256 amount
) private returns (bool) {
```

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Function Instrumentation

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/// #if_succeeds
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function transferFrom(
    address from,
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Inserted a wrapper function with all the instrumentation

```
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Original function renamed and private

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function transferFrom(
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DILIGENCE Fuzzing

Function Instrumentation

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/// #if_succeeds
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Original function renamed and private

Invoked in wrapper

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DILIGENCE Fuzzing

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Old state computed before call

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Function Instrumentation

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/// #if_succeeds
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Old state computed before call

Property checked after call

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function transferFrom(
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```

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Demo

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Function Instrumentation

Function Instrumentation

if_succeeds also allowed on contracts

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Function Instrumentation

```
/// #if_succeeds counter > old(counter);
contract Foo {
    uint counter;

    function a() public {
        ...
    }

    function b() public {
        ...
    }
}
```

if_succeeds also allowed on contracts

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Function Instrumentation

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if_succeeds also allowed on contracts

Same as adding the same if_succeeds to every public/external function

Function Instrumentation

```
contract Foo {
    uint counter;
    /// #if_succeeds counter > old(counter);
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    }
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```

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Function Instrumentation

```
contract Foo {
    uint counter;
    /// #if_succeeds counter > old(counter);
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    function b() public {
        ...
    }
}
```

if_succeeds also allowed on contracts

Same as adding the same if_succeeds to every public/external function

if_succeeds added to subcontract functions too

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Contract Invariants

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Contract Invariants

```
/// #invariant unchecked_sum(balances) == totalSupply;
contract ERC20 {
    mapping(address => uint) balances;
    uint totalSupply;
```

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Contract Invariants

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Specified with #invariant keyword

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Contract Invariants

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/// #invariant unchecked_sum(balances) == totalSupply;
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```

Specified with #invariant keyword

unchecked_sum is a scribble builtin

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Contract Invariants

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/// #invariant unchecked_sum(balances) == totalSupply;
contract ERC20 {
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Invariants over the lifetime of a contract

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Contract Invariants

```
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Invariants over the lifetime of a contract

Can talk about contract state variables

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Contract Invariants

```
/// #invariant unchecked_sum(balances) == totalSupply;
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    mapping(address => uint) balances;
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```

- Invariants over the lifetime of a contract
- Can talk about contract state variables
- Cannot use ‘old’

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Contract Invariants

```
/// #invariant unchecked_sum(balances) == totalSupply;
contract ERC20 {
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```

Is this invariant true at **every** point?

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Contract Invariants

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/// #invariant unchecked_sum(balances) == totalSupply;
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Is this invariant true at **every** point?

```
function transferFrom(
    address from,
    address to,
    uint256 amount
) public virtual returns (bool) {
    ...
    balances[from] -= amount;
    balances[to] += amount;
```

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/// #invariant unchecked_sum(balances) == totalSupply;
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Invariant temporarily broken here

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Contract Invariants

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/// #invariant unchecked_sum(balances) == totalSupply;
contract ERC20 {
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Is this invariant true at **every** point?

So when are these invariants true?

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function transferFrom(
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Contract Invariants

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/// #invariant unchecked_sum(balances) == totalSupply;
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Invariants true at “observable points” in contract lifetime

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Contract Invariants

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/// #invariant unchecked_sum(balances) == totalSupply;
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Invariants true at “observable points” in contract lifetime

An “observable point” is any point before we enter/after we exit the contract

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Contract Invariants

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So how do we check invariant holds at all observable points?

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So how do we check invariant holds at all observable points?

1. Check invariant holds after constructor

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Contract Invariants

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/// #invariant unchecked_sum(balances) == totalSupply;
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    mapping(address => uint) balances;
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    constructor() {
        check_invs();
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So how do we check invariant holds at all observable points?

1. Check invariant holds after constructor

2. Check invariant holds before exiting external call

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        ...
        check_invs();
        return true;
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So how do we check invariant holds at all observable points?

1. Check invariant holds after constructor
2. Check invariant holds before exiting external call
3. Check invariant holds before making an external call

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Contract Invariants

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    function transferFrom(
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    ) public virtual returns (bool) {
        ...
        check_invs();
        someListenerContract.transferCallback();
        ...
        check_invs();
        return true;
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So how do we check invariant holds at all observable points?

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Demo

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Let bindings

```
/// #if_succeeds
///     old(balanceOf(from)) > amount &&
///     old(balanceOf(from)) - amount == balanceOf(from);
function transferFrom(
    address from,
    address to,
    uint256 amount
) public returns (bool) {

}
```

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Let bindings

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/// #if_succeeds
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    address from,
    address to,
    uint256 amount
) public returns (bool) {

}
```

Same expression computed twice

DILIGENCE Fuzzing

Let bindings

```
/// #if_succeeds
///     old(balanceOf(from)) > amount &&
///     old(balanceOf(from)) - amount == balanceOf(from);
function transferFrom(
    address from,
    address to,
    uint256 amount
) public returns (bool) {

}
```

Same expression computed twice

Can reduce computation using a let-binding

DILIGENCE Fuzzing

Let bindings

```
/// #if_succeeds
///     let oldBalance := old(balanceOf(from)) in
///         oldBalance > amount &&
///         oldBalance - amount == balanceOf(from);
function transferFrom(
    address from,
    address to,
    uint256 amount
) public returns (bool) {
```

DILIGENCE Fuzzing

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DILIGENCE Fuzzing

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    address to,
    uint256 amount
) public returns (bool) {
```

Let bindings are immutable
(not variables)

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Implication

Implication

You can express implication using ==>

Implication

```
/// #if_succeeds
///     amount > 0 ==> balanceOf(to) > old(balanceOf(to))
function transferFrom(
    address from,
    address to,
    uint256 amount
) public returns (bool) {
```

You can express implication using ==>

DILIGENCE Fuzzing

Summary

Summary

- Scribble overview

DILIGENCE Fuzzing

Summary

- Scribble overview
- Function annotations (#if_succeeds)

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- Contract invariants (#invariant)

Summary

- Scribble overview
- Function annotations (#if_succeeds)
- Contract invariants (#invariant)
- Other language features (sum, let, old, ==>)

Homework

Questions

Course Material:
https://github.com/ConsenSys/secureum-diligence-bootcamp/

Other:
Scribble: https://github.com/consensys/scribble
Scribble Docs: https://docs.scribble.codes/
Discord Channel: #carex-diligence-scribble-nov22
Instructors: dimo#1001, wuestholz#3558

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