भारतीय प्रौद्योगिकी संस्थान पटना
Indian Institute of Technology Patna

Course Code
CS577

Department of
Computer Science
and Engineering

Ethereum and Smart Contract Development in Solidity

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Ethereum

- **world computer**
- **state transition system**

$$\sigma_{t+1} \equiv \Upsilon(\sigma_t, T)$$

Ethereum

- **world** computer

$$\sigma_{t+1} \equiv \Pi(\sigma_t, B)$$

$$B \equiv (\ldots, (T_0, T_1, \ldots))$$

$$\Pi(\sigma, B) \equiv \Omega(B, \Upsilon(\Upsilon(\sigma, T_0), T_1)\ldots)$$

Credit: Gavin Wood

Gas and Payment

To Avoid issue of network abuse

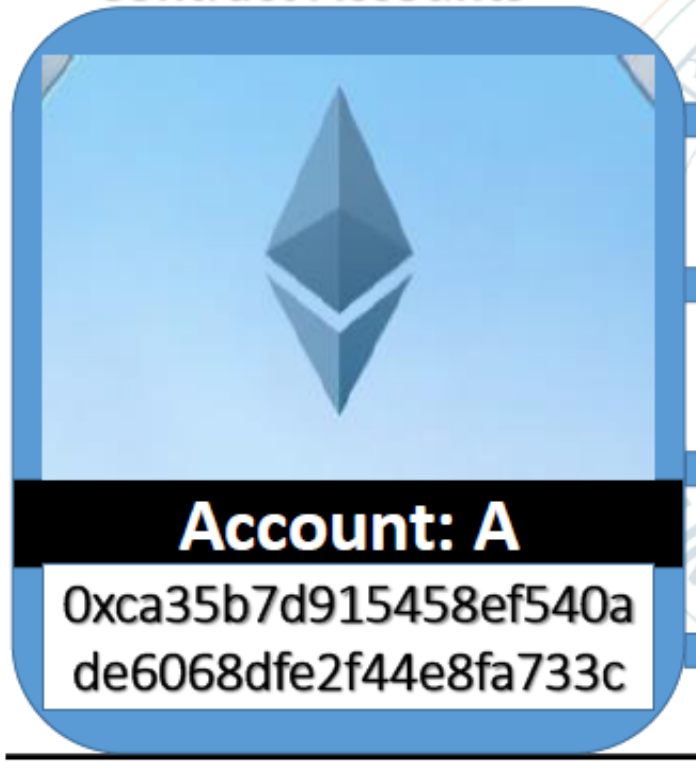
- Every transaction has a specific amount of gas associated with it

No mid-execution-refueling

Credit: Gavin Wood

Ethereum State: Accounts

- **Externally Owned Accounts**
- **Contract Accounts**



nonce => $\sigma[A]_n$ **|T| |Contracts|**

balance => $\sigma[A]_b$

storageRoot => $\sigma[A]_s$

codeHash => $\sigma[A]_c$ **"" H(code)**

Ethereum

- **From developers viewpoint:**
  - a global, open-source, publicly available, distributed platform for decentralized applications
- **From researchers perspective:**
  - set of consensus rules & algorithms, P2P network and communication protocols, EVM, Data structures, interoperable clients, **security protocols** and many more including **original specification and EIPs**
- **For a layman:**
  - It is a blockchain

Ethereum Client

- an application that implements the **Ethereum specification**
- implemented by **different developer groups** and in **different programming languages**
- **provides an interface** to interact with Ethereum
- communicates over the P2P network with other nodes
- **selection of an Ethereum client**
  - ✓development purpose
  - ✓deployment purpose

Ethereum Network

- Ethereum-based blockchain maintained by Ethereum clients
- **obey the formal specification** however they may or may not interoperate with each other
- Mainnet
  - ✓the live public **Ethereum production blockchain**, where actual valued transactions take place on the distributed ledger visit: here
- Testnet
  - ✓provides **platform to test software** before deploying on the Mainnet

Popular Ethereum Clients..

- **Geth (Go)**
- **Parity (Rust)**
- Webthree (C++)
- ruby-ethereum (Ruby)
- ethereumH (Haskell)
- ethereumj (Java)
- pyethereum (Python)
- ***Ganache/testrpc (Ethereumjs)***

many more…… check here

Ethereum Client: Geth

- “official” Ethereum client
- implemented in Go language implementation
- developed by Ethereum Foundation

- Download and Install
  - Geth: **here**

Ethereum Client: Ganache

- Download: here
- Provides personal Ethereum blockchain which you can use to run tests, execute commands, and inspect state while controlling how the chain operates.
  - Ganache (GUI)
  - Ganache develop
  - Ganache CLI

Geth: Useful commands and options

- **init** *…for Bootstrap and initialize*
- **account** *…for managing accounts*
  - **--unlock value** …comma separated list of accounts to unlock
- **console** *…for an interactive JavaScript environment*

- **--datadir** "<path>"
  …for data directory for the databases and keystore
- **--identity** <value> *…for providing custom node name*

Setup Private Blockchain Network

- Prerequisite
  - Ethereum client
  - Genesis block configuration file
  - Need to setup a network

Details will be covered in lab session

Setup: Truffle

1. World class development environment for **blockchain** dapps (decentralized applications) and smart contracts.
2. Download and Install
   - GIT: here
   - Node.js: here (provides npm)
3. Setup Path variable for GIT and Node.js
4. Execute following commands::

   Execute following from an administrative PowerShell!
   - **npm install -g npm (npm Package Manager & Installer)**
   - **npm install -g windows-build-tools (install & configure the Visual Studio Build Tools and Python)**
   - **npm install -g ganache-cli truffle (** ethereumjs-testrpc along with truffle**)**

Introduction to Solidity

file: **HelloExample.sol**

```
1  //First Example.. Single line comment
2  pragma solidity 0.5.2;
3  //import './other_solidity_source_file.sol';
4  /*
5  * @title    HelloExample
6  * @author   Fajge Akshay M.
7  * @guide    Prof. Raju Halder
8  * @notice   Blockchain and Solidity tutorial for course CS577
9  */
10
11 /*
12 Multiline comments
13 reachus@email   fajge_1921cs12@iitp.ac.in; halder@iitp.ac.in
14 */
15
16 contract Hello {
17     function getMessage() public pure returns (string memory) {
18         return "Hello From Solidity";
19     }
20 }
```

- *Layout of source file*
  - contain an arbitrary number of
  - ✓ ***pragma directives***
  - ✓ ***import directives***
  - ✓ ***contract definitions***

Introduction to Remix IDE

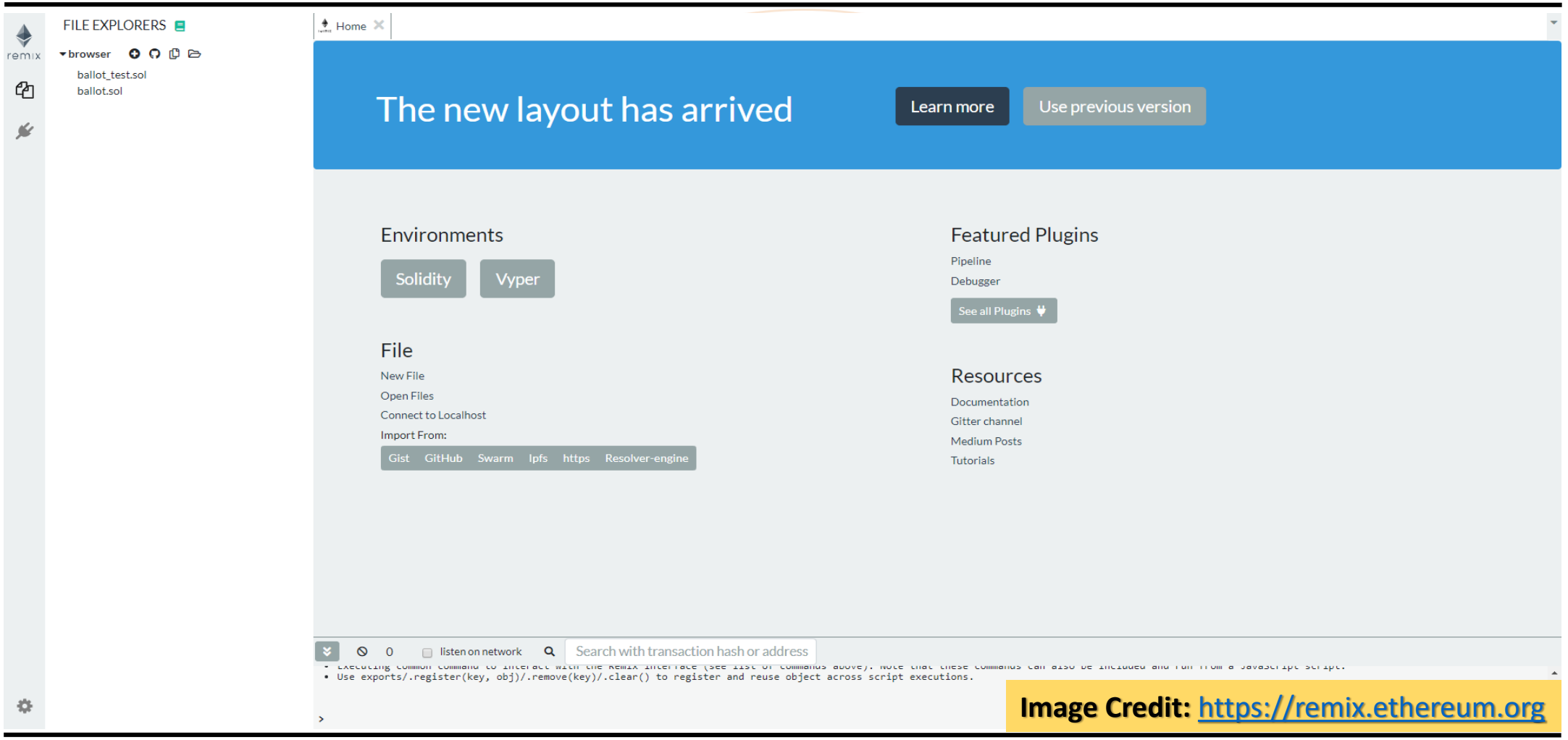


Image Credit: https://remix.ethereum.org

Fajge Akshay M. **Dr. Raju Halder**

Remix IDE: Plugin Manager

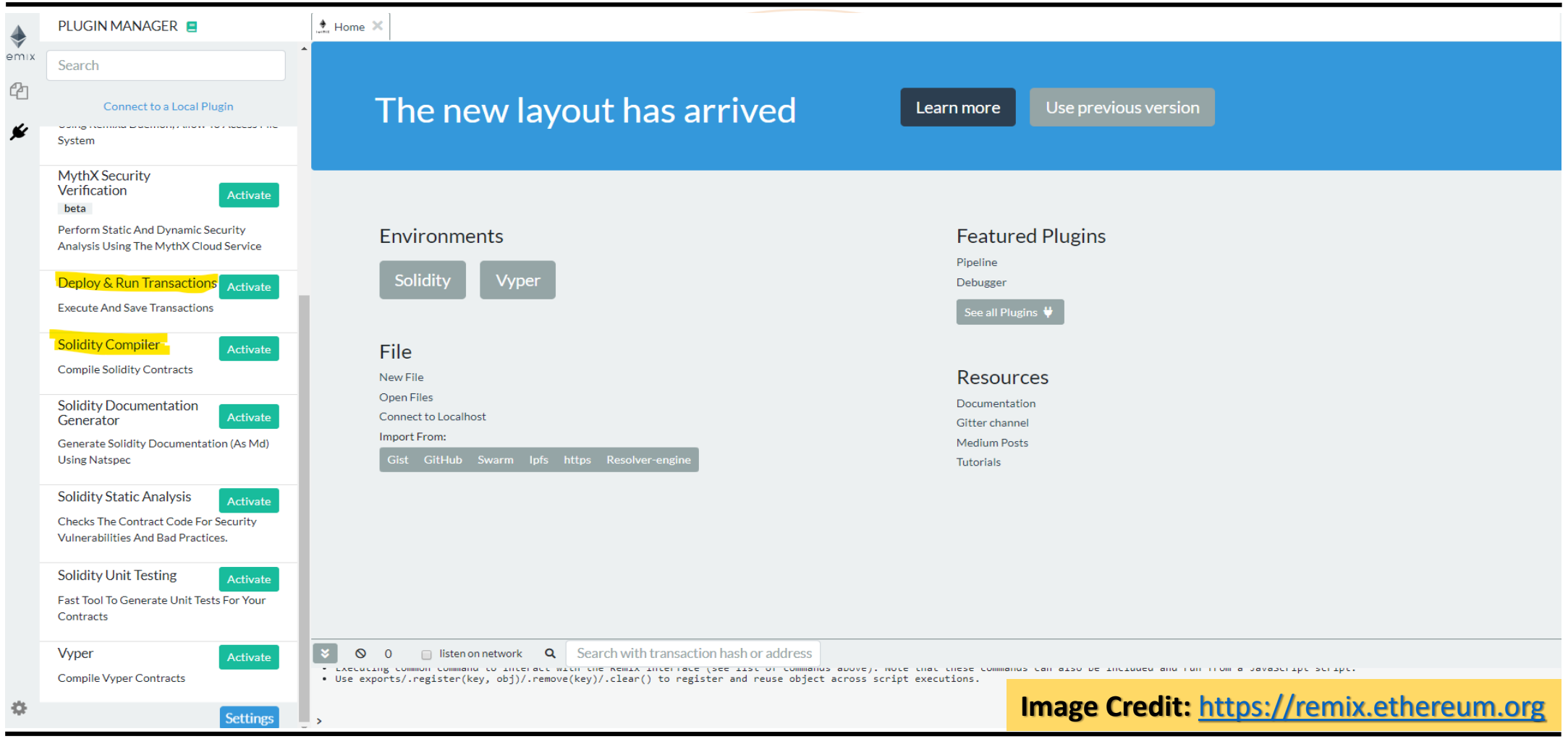


Image Credit: https://remix.ethereum.org

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Solidity: Types

- Solidity is **statically typed** (like C, Java)
- **No concept** of "undefined", "Garbage" or "null" values
  - ✓**Uninitialized variable holds default value based on the type of the variable**
- Support complex types (combination of elementary types) like struct

❑ **Different Types supported by Solidity**

- ✓ Value Types
- ✓ Contract Type
- ✓ Fixed-size and Dynamic-size byte arrays
- ✓ Enum Types
- ✓ Function Types
- ✓ Reference Types (struct, array, mapping, etc.)

Value Types

- **Booleans**
  keyword: bool **Literals:** true, false
- **Integers**
  Keyword: intX , uintX where X varies from 8 to 256 in steps of 8
  Literals: -4, 5, etc.
- **Fixed Point Numbers (fixedMxN , ufixedMxN) … *Not fully supported***
  M: the number of bits taken by the type
  N: the number of decimal points available must be between 0 and 80
- **Address**
  - Equivalent to size of Ethereum address i.e. 20 byte
  - Members of Address types:
    - ***balance, call, delegatecall, staticcall***

  Keyword: address, address payable
  - **address payable** supports additional members like ***transfer*** and ***send***

Other Types

- **Contract Type**
  - Keyword is the **name of already defined contract**

    ex: contract Hello …*if it is already defined then*

    Hello newHello = new Hello()
- **Fixed-size byte arrays**
  - **Keywords: bytesX** … where **X** varies from 1 to 32
  - Ex: bytes1, bytes2, …, bytes32
  - comes with Member "***length***"
- **Dynamic-size byte arrays or String Types**
  - **Keywords: string, bytes**

Few more types…

- **Enums**

  enum Feeling { Bored, Interested, Excited }

  Feeling student_feeling = Feeling.Bored

- **Function**

  function(<parameter types>) {public|internal|external|private} [pure|view|payable] [returns (<return types>)]

Reference Types

- **structs**, **arrays** and **mappings** types
- unlike Value Types, can have multiple reference variables
- need to provide data location explicitly

❑Data Locations

- ✓ **storage (location of state variables)**
- ✓ **memory (lifetime limited to a function call)**
- ✓ **calldata (special data location that contains the function arguments, only available for external function call parameters)**

- Assignments between `storage` and `memory` (or from `calldata`) always create an independent copy.
- Assignments from `memory` to `memory` only create references. This means that changes to one memory variable are also visible in all other memory variables that refer to the same data.
- Assignments from `storage` to a **local** storage variable also only assign a reference.
- All other assignments to `storage` always copy. Examples for this case are assignments to state variables or to members of local variables of storage struct type, even if the local variable itself is just a reference.

Example: Struct, Enum

file: **StructExample.sol**

```
1  pragma solidity ^0.5.3;
2
3  contract StructExample {
4      enum PersonType { Faculty, Staff, Student}
5      struct Person {
6              string regNo;
7              address pAddress;
8              PersonType pType;
9      }
10     Person[] persons;
11
12     function register(string memory _regNo, PersonType _pType)
13     public returns(uint uid) {
14         uid = persons.length;
15         Person memory newPerson;
16         newPerson.regNo = _regNo;
17         newPerson.pType = _pType;
18         persons.push(newPerson);
19         return uid;
20     }
21
22     function getPersonType(uint uid)
23     external view returns (PersonType) {
24         return persons[uid].pType;
25     }
26 }
```

- *compiler version*
- *enum type*
- *struct type*
- *dynamic array*

- *How, when, and where "person" gets stored?*

Mapping Types

- **mapping**(Key => value)
- Key: any built-in Value Type including bytes and string
- Value: any Type including mapping type
- We can mark them as public

- In previous example to store persons we used Dynamic Array

Mapping vs Dynamic Array ?

Example: Mapping

file: **MappingExample.sol**

```
1  pragma solidity >=0.5.0 <0.6.0;
2
3  contract MapStructExample{
4      enum PersonType { Faculty, Staff, Student}
5      struct Person {
6              string regNo;
7              PersonType pType;
8      }
9
10     mapping (uint => Person) persons;
11     uint noOfPersons;
12
13     function register(string memory _regNo, PersonType _pType)
14     public returns(uint){
15         uint uid = noOfPersons;
16         Person memory newPerson;
17         newPerson.regNo = _regNo;
18         newPerson.pType = _pType;
19         persons[noOfPersons] = newPerson;
20         noOfPersons += 1;
21         return uid;
22     }
23
24     function getPersonType(int uid)
25     external view returns (PersonType) {
26         return persons[uint(uid)].pType;
27     }
28 }
```

- *compiler version*
- *enum type*
- *struct type*
- *mapping type*
- *array vs mapping*

? any difference

Global Namespace

❑ Global Variables

✓ Ether units: **wei**, **szabo** (1e12), **finney** (1e15), **ether** (1e18)

✓ Time units: **seconds**, **minutes**, **hours**, **days** and **weeks**

❑ Special Variables and Functions

- **Block and Transaction Properties**

  Ex: **msg.value**, **msg.sender**, **now**, **gasleft()**, **block.number**, etc...
- **ABI Encoding and Decoding Functions**
- **Error Handling**
- **Mathematical and Cryptographic Functions**

  addmod(uint a, uint b, uint m) *returns (uint)*

  keccak256(bytes memory) *returns (bytes32)*

Error Handling

- solidity uses **state-reverting** exceptions
- can throw error to the caller however no support for catching exceptions
- **Functions**
  - **assert(condition)** // for internal errors
  - **require(condition**, [errorMessageInString]**)** // for external components
    - ✓ **false** condition causes an invalid opcode which leads state change reversion
  - **revert(**[errorMessageInString]**)**

Example: Transfer

file: **TransferExample.sol**

```
1  pragma solidity 0.5.3;
2
3  contract TransferAmountExample{
4
5      function transferAmount(address payable recipientAccount, uint amount)
6      public
7      payable
8      {
9          recipientAccount.transfer(amount);
10     }
11
12     function getBalance(address account) public view returns(uint) {
13         return account.balance;
14     }
15 }
```

- **address payable** supports additional members like ***transfer*** and ***send***
- **Not a proper way…**

address payable?

payable?

What is the unit of the "amount"?

send vs transfer ?

Remix IDE: Deploy & Run

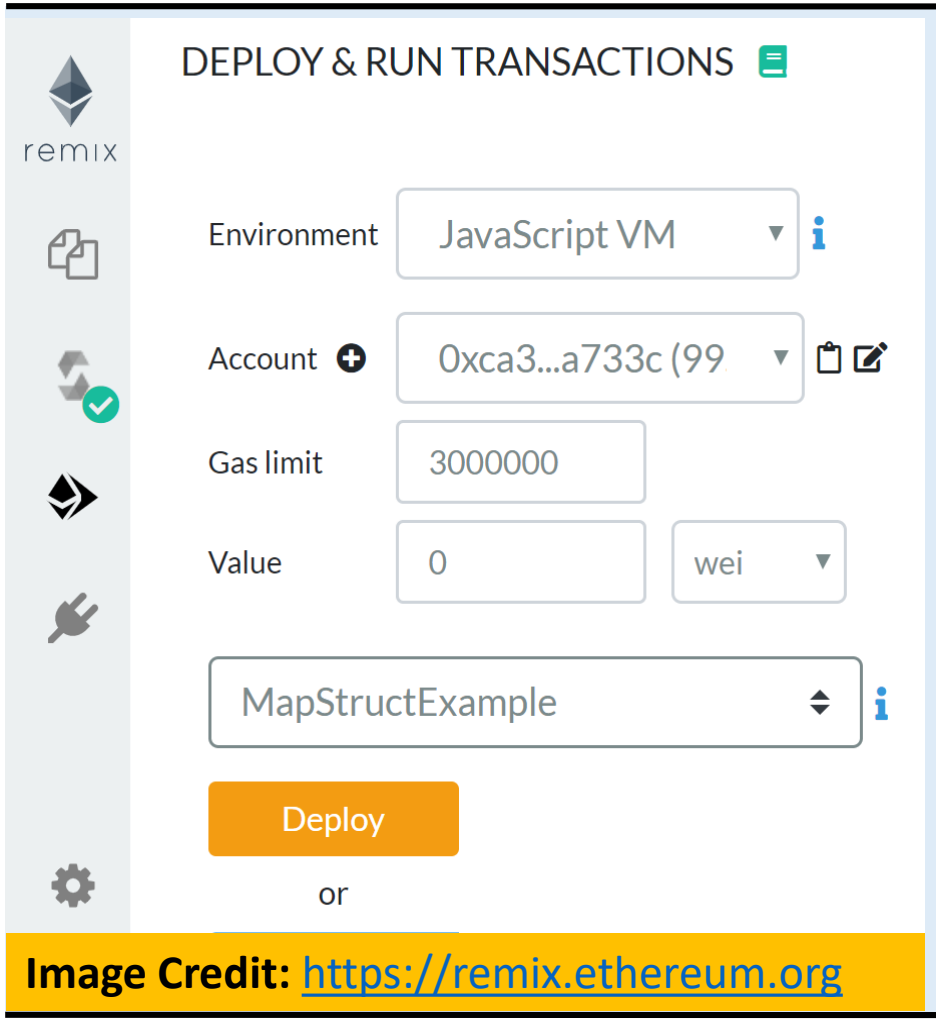


Image Credit: https://remix.ethereum.org

- **Environment**
- **Account**
- **Gas limit**
- **Value**
- **Compiled Class**
- **Deploy**

Example: require, assert

file: **ErrorHandlingExample.sol**

```
1  pragma solidity 0.5.3;
2
3  contract ErrorHandlingExample{
4
5      function transferAmount(address payable recipientAccount, uint amount)
6      public
7      payable {
8          recipientAccount.transfer(amount);
9      }
10
11     function getBalance(address account) public view returns(uint) {
12         return account.balance;
13     }
14
15     function modifiedTransferAmount(address payable accountAddr)
16     public payable returns (uint) {
17         uint avlBalance = msg.sender.balance;
18         require(msg.value <= avlBalance, "Insufficient Balance");
19         uint oldBalance = accountAddr.balance;
20         accountAddr.transfer(msg.value);
21         uint currBalance = msg.sender.balance;
22         assert(accountAddr.balance == oldBalance + msg.value);
23         assert(currBalance == avlBalance - msg.value);
24         return accountAddr.balance;
25     }
26 }
```

Previous transferAmount method?

Modified transferAmount method?

msg.sender
msg.value

Can we transfer 0 ethers?

Is code working?

- Any questions?
- Any issues with Remix?

Solution…

modified ErrorHandlingExample.sol

```
1  pragma solidity 0.5.3;
2
3  contract ErrorHandlingExample{
4
5      function transferAmount(address payable recipientAccount, uint amount)
6      public
7      payable {
8          recipientAccount.transfer(amount);
9      }
10
11     function getBalance(address account) public view returns(uint) {
12         return account.balance;
13     }
14
15     function modifiedTransferAmount(address payable accountAddr)
16     public payable returns (uint) {
17         uint avlBalance = msg.sender.balance;
18         require(msg.value <= avlBalance, "Insufficient Balance");
19         uint oldBalance = accountAddr.balance;
20         accountAddr.transfer(msg.value);
21         uint currBalance = msg.sender.balance;
22         assert(accountAddr.balance == oldBalance + msg.value);
23         //assert(currBalance == avlBalance - msg.value);
24         return accountAddr.balance;
25     }
26 }
```

require vs assert?

****Homework****

What is the issue with the line number 23?

Control Structures

- Different Control structures with semantics similar to C programming Language
  - ✓ **if, else, while, do, for, break, continue, return**

Except:

```
if (1921) {
    //body of If block
}
```

```
if (i = 45) {
    //body of If block
}
```

Example: ternary statement

file: **Smallest.sol**

```
1  pragma solidity ^0.5.3;
2
3  contract ExampleDemo{
4
5      uint smallest = 2**256 - 1;
6      uint[] numbers;
7
8      function addNumber(uint number)
9      external
10     returns (uint) {
11             uint oldLength = numbers.length;
12             numbers.push(number);
13             smallest = number < smallest ? number : smallest;
14             assert(oldLength + 1 == numbers.length);
15             return smallest;
16     }
17
18     function getSmallest() public view returns(uint){
19         return smallest;
20     }
21
22 }
```

- *state variables*
- *Array members*
- *Function signature*
- *Ternary operator like C*
- *Assert*
- *view*

Structure of a Contract

- Contract can contain
  - ✓**State Variables**
  - ✓**Functions**
  - ✓**Constructor**
  - ✓**Function Modifiers**
  - ✓**Events**
  - ✓**Struct Types**
  - ✓**Enum Types**

Contracts

- Solidity source file can have multiple contracts
- **Special contracts**
  - **libraries**
  - **Interfaces**
- **Contract Creation**
  - using Ethereum transaction
  - using another contract

Constructor

file: **Constructor.sol**

```
1  pragma solidity 0.5.3;
2
3  contract ConstructorExample {
4      //AutoIncrementor
5      int256 private incrementBy;
6
7      constructor(int256 _incrementBy)
8      public {
9          incrementBy = _incrementBy;
10     }
11
12     function increment(int256 number)
13     public view returns(int256) {
14         return number + incrementBy;
15     }
16 }
```

- constructor is executed **after** contracts get created
- it is an **optional**
- **no** constructor **overloading**
- during contract creation process must know complete binary source code
- once constructor gets executed, code gets deployed on the network

Function

```
function(<parameter types>)
{private|public|internal|external}
[pure|view|payable]
[returns (<return types>)] {
// function body
}
```

- **Function overloading possible**
- **Function can return multiple values**
- **Function Visibility**
- **Function State Mutability**

Check this: Like C language, does it support block structures in function body?

Function Modifier

- frequently used to change behavior of the function
- gets executed prior to actual function call
- no-parameterized or parameterized
- multiple modifiers can be applied to constructor or functions
- code reusability

file: **Modifier.sol**

```
1  pragma solidity 0.5.3;
2
3  contract ModifierExample {
4      //AutoIncrementor
5      int256 private incrementBy;
6
7      modifier onlyPositive(int incrBy) {
8          require(incrBy > 0,
9          "_incrementBy must be > 0");
10         _;
11     }
12
13     constructor(int256 _incrementBy)
14     public onlyPositive(_incrementBy) {
15         incrementBy = _incrementBy;
16     }
17
18     function increment(int256 number)
19     public view returns(int256) {
20         return number + incrementBy;
21     }
22 }
```

Interesting Facts about Functions

- **no need of return statement explicitly** for the functions returning values
- all the variables declared in function parameters and return parameters gets **initialized to default values** based on type
- solidity provides **automatic getters** for the members with **public** access specifier
- can return multiple values

Example Demo: Revisited

Previous version: Smallest.sol

```
1  pragma solidity ^0.5.3;
2
3  contract ExampleDemo{
4
5      uint smallest = 2**256 - 1;
6      uint[] numbers;
7
8      function addNumber(uint number)
9      external
10     returns (uint) {
11             uint oldLength = numbers.length;
12             numbers.push(number);
13             smallest = number < smallest ? number : smallest;
14             assert(oldLength + 1 == numbers.length);
15             return smallest;
16     }
17
18     function getSmallest() public view returns(uint){
19         return smallest;
20     }
21
22 }
```

New Version: modify Smallest.sol

```
1  pragma solidity ^0.5.3;
2
3  contract ExampleDemo{
4      uint public smallest = 2**256 - 1;
5      uint[] numbers;
6
7      function addNumber(uint number)
8      external
9      returns (uint small) {
10             uint oldLength = numbers.length;
11             numbers.push(number);
12             small = number < smallest ? number : smallest;
13             smallest = small;
14             assert(oldLength + 1 == numbers.length);
15     }
16 }
```

Any changes in output?

Fallback Function

- anonymous function without parameters and return types
- **visibility:** must be **external**
- **how do we make a call?**
- gets executed **only when called function which is not existed in the contract**

When a contract gets Ether **without any other data**, the function executes (if it is set as Solidity payable).

Fallback Function

Fallback function is a special function available to a contract. It has following features −

- It is called when a non-existent function is called on the contract.
- It is required to be marked external.
- It has no name.
- It has no arguments
- It can not return any thing.
- It can be defined one per contract.
- When a contract gets Ether without any other data (the fallback function executed if set payable)
- If not marked payable, it will throw exception if contract receives plain ether without data.

Fallback Function

Example

```
pragma solidity ^0.5.0;

contract Test {
   uint public x ;
   function() external { x = 1; }
}
contract Sink {
   function() external payable { }
}
contract Caller {
   function callTest(Test test) public returns (bool) {
      (bool success,) = address(test).call(abi.encodeWithSignature("nonExistingFunction()"));
      require(success);
      // test.x is now 1

      address payable testPayable = address(uint160(address(test)));

      // Sending ether to Test contract,
      // the transfer will fail, i.e. this returns false here.
      return (testPayable.send(2 ether));
   }
   function callSink(Sink sink) public returns (bool) {
      address payable sinkPayable = address(sink);
      return (sinkPayable.send(2 ether));
   }
}
```

Events

- an abstraction on top of the EVM's logging functionality
- on an event call, arguments to be stored in the transaction's log
- log and its event data is not accessible from within contracts
- events are emitted using **emit**

Inheritance

- keyword used: **is**
- supports **multiple inheritance** including **polymorphism**
- function calls are virtual (**except** they called using ***contract_name*** or ***super***)
- like object-oriented programming, only one contract gets created and deployed

Inheritance

- supports **multiple inheritance** including **polymorphism**
- **inappropriate** multiple inheritance may lead to **Type error**
- **linearization of inheritance graph** must be considered

- **what will if inheriting result in different types of members with same identifier?**

Abstract Contract

- contract must have at least one function without implementation
- can be used as a base contract
- can not compile

Interface

- similar to abstract contracts, but without any functions definition
- cannot inherit other contracts or interfaces
- visibility must be external
- no state variables and constructor
- **only Enums, Structs, Functions**

Example:

file: **Inheritance.sol**

```
1  pragma solidity >=0.5.2 <0.5.4;
2
3  contract Person {
4      function does()
5      public returns (string memory);
6  }
7
8  contract Info {
9      string name;
10     constructor(string memory _name) internal{
11         name = _name;
12     }
13
14     function getName()
15     public view returns (string memory) {
16         return name;
17     }
18 }
19
20 contract Student is Person, Info {
21     function does()
22     public returns (string memory) {
23         return "Learning";
24     }
25     constructor(string memory _name)
26     Info(_name) public{
27     }
28 }
```

```
29
30 contract Faculty is Info, Person {
31     string name = "Dr. Raju Halder";
32
33     function does()
34     public returns (string memory) {
35         return "Teaching";
36
37     }
38     constructor() Info(name) public{
39
40     }
41 }
42
43 contract TA is Person, Info("Fajge Akshay") {
44     function does()
45     public returns (string memory) {
46         return "helps Teachers and Studetns";
47     }
48 }
```

Example

```
49
50  contract Test{
51      TA ta = new TA();
52      Faculty faculty = new Faculty();
53      Student student = new Student('Your Name');
54
55      function getTA() public view returns (string memory){
56          return ta.getName();
57      }
58
59      function getFaculty() public view returns (string memory){
60          return faculty.getName();
61      }
62
63      function getStudent() public view returns (string memory){
64          return student.getName();
65      }
66  }
```

Deploy Test contract and verify result…

Change *Person* abstract class as given below to treat it as interface:

```
1  pragma solidity >=0.5.2 <0.5.4;
2
3  interface Person {
4      function does()
5      external returns (string memory);
6  }
```

Is it working?

Libraries

- internal functions of library are visible in all contracts
- worked as an implicit base class, however no trace in hierarchy
- deploy once and use anywhere like base class, library code gets executed in callers context
- improves code reusability

Example: library

file: **myLib.sol**

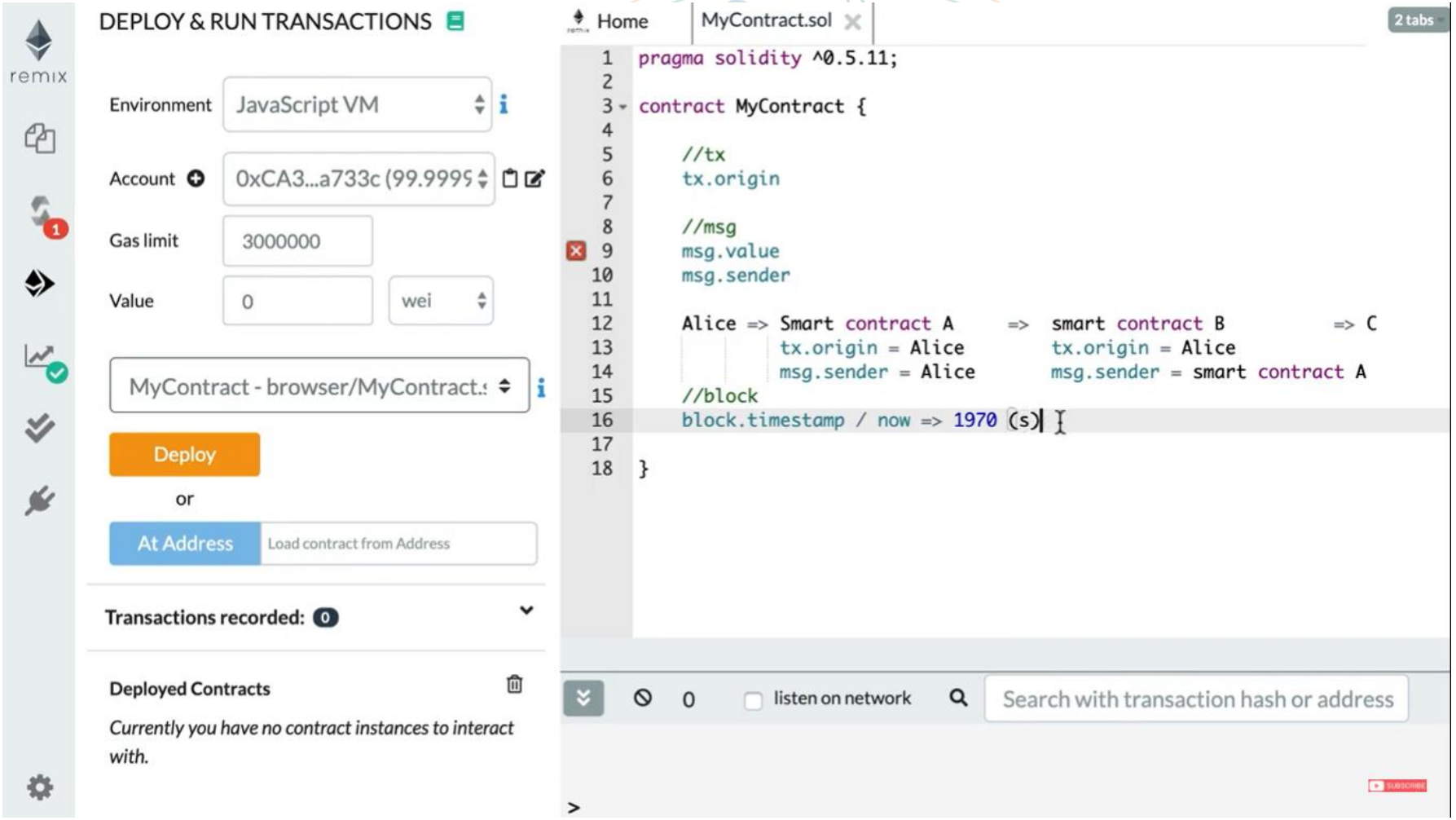
```
1  pragma solidity 0.5.3;
2  library Utils {
3      function arrayContains
4      (uint256[] memory input, uint256 value)
5      internal pure returns (bool flag){
6          flag = false;
7          for(uint i = 0; i<input.length; i++){
8              if (input[i]==value)
9                  return true;
10         }
11     }
12 }
```

Example: import

file: **importExample.sol**

```
1  pragma solidity 0.5.3;
2  import './myLib.sol' as Akshay;
3  contract ModifiedSmallestDemo {
4      uint public smallest = 2**256 - 1;
5      uint[] numbers;
6
7      function addNumber(uint number)
8      external
9      returns (uint small) {
10         uint oldLength = numbers.length;
11         numbers.push(number);
12         small = number < smallest ? number :  smallest;
13         smallest = small;
14         assert(oldLength + 1 == numbers.length);
15     }
16
17     function contains(uint value)
18     external view returns(bool){
19         return Akshay.Utils.arrayContains(numbers, value);
20     }
21 }
```

Special Built-in Variables



Transfer

This is used to transfer the ether. **This is recommended.**

```
pragma solidity ^0.4.20;

contract first{
    function() payable { }
    function getBalance() public returns(uint){
        return address(this).balance;
    }
}

contract second{
    function send(address _add)public payable{
      _add.transfer(msg.value);
    }
}
```

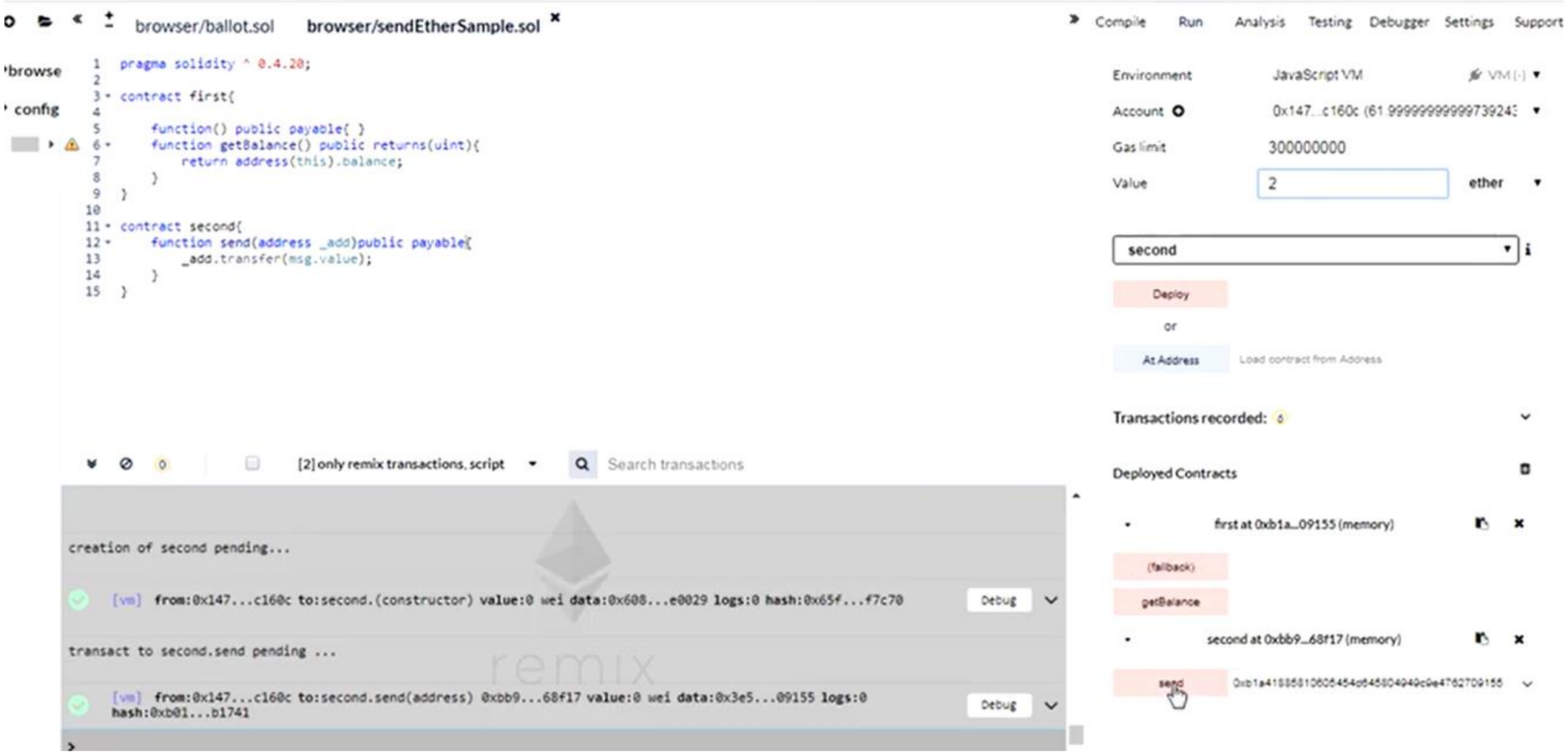
Transfer Limitations

This method has 2300 gas limit.

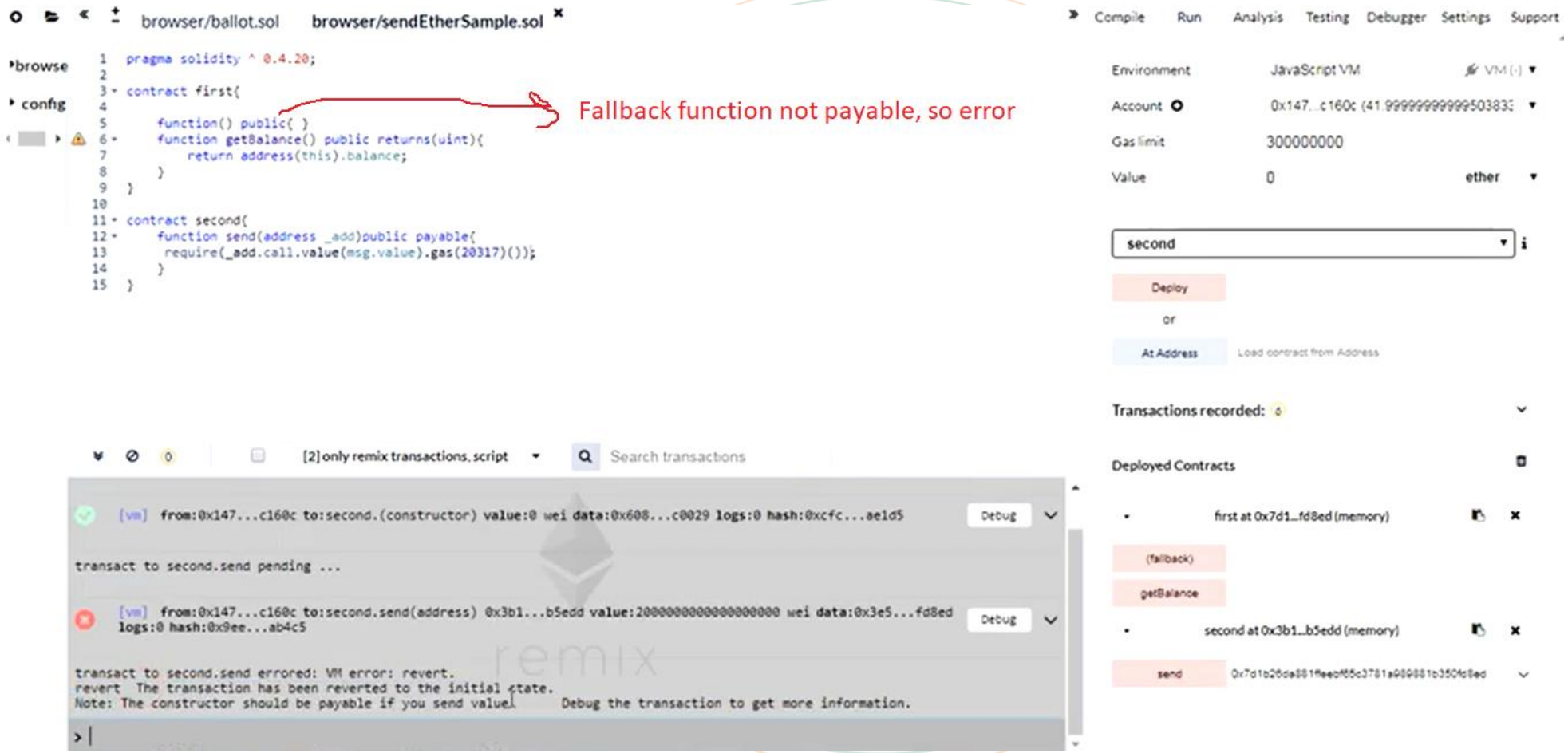
No possibility to add gas limit as of now but this may be expected in future release.

This throw exception and revert the state if unsuccessful which is not the case with send and call.

Transfer


browser/ballot.sol
browser/sendEtherSample.sol
pragma solidity ^ 0.4.20;
contract first{
function() public payable{ }
function getBalance() public returns(uint){
return address(this).balance;
}
}
contract second{
function send(address _add)public payable{
_add.transfer(msg.value);
}
}
Compile
Run
Analysis
Testing
Debugger
Settings
Support
Environment
JavaScript VM
Account
Gas limit
300000000
Value
2
ether
second
Deploy
or
At Address
Load contract from Address
Transactions recorded:
Deployed Contracts
first at 0xb1a...09155 (memory)
(fallback)
getBalance
second at 0xbb9...68f17 (memory)
send
[2] only remix transactions, script
Search transactions
creation of second pending...
[vm] from:0x147...c160c to:second.(constructor) value:0 wei data:0x608...e0029 logs:0 hash:0x65f...f7c70
Debug
transact to second.send pending ...
[vm] from:0x147...c160c to:second.send(address) 0xbb9...68f17 value:0 wei data:0x3e5...09155 logs:0 hash:0xb01...b1741
Debug

Transfer


browser/ballot.sol
browser/sendEtherSample.sol
pragma solidity ^ 0.4.20;
contract first{
function() public{ }
function getBalance() public returns(uint){
return address(this).balance;
}
}
contract second{
function send(address _add)public payable{
require(_add.call.value(msg.value).gas(20317)());
}
}
Fallback function not payable, so error
Compile
Run
Analysis
Testing
Debugger
Settings
Support
Environment
JavaScript VM
Account
Gas limit
300000000
Value
0
ether
second
Deploy
or
At Address
Load contract from Address
Transactions recorded:
Deployed Contracts
first at 0x7d1...fd8ed (memory)
(fallback)
getBalance
second at 0x3b1...b5edd (memory)
send
[2] only remix transactions, script
Search transactions
[vm] from:0x147...c160c to:second.(constructor) value:0 wei data:0x608...c0029 logs:0 hash:0xcfc...ae1d5
Debug
transact to second.send pending ...
[vm] from:0x147...c160c to:second.send(address) 0x3b1...b5edd value:2000000000000000000 wei data:0x3e5...fd8ed
logs:0 hash:0x9ee...ab4c5
Debug
transact to second.send errored: VM error: revert.
revert The transaction has been reverted to the initial state.
Note: The constructor should be payable if you send value.
Debug the transaction to get more information.

Send

This is used to send the ether.

```
pragma solidity ^0.4.20;

contract first{
    function() payable { }
    function getBalance() public returns(uint){
        return address(this).balance;
    }
}

contract second{
    function send(address _add)public payable{
      require(_add.send(msg.value));
    }
}
```

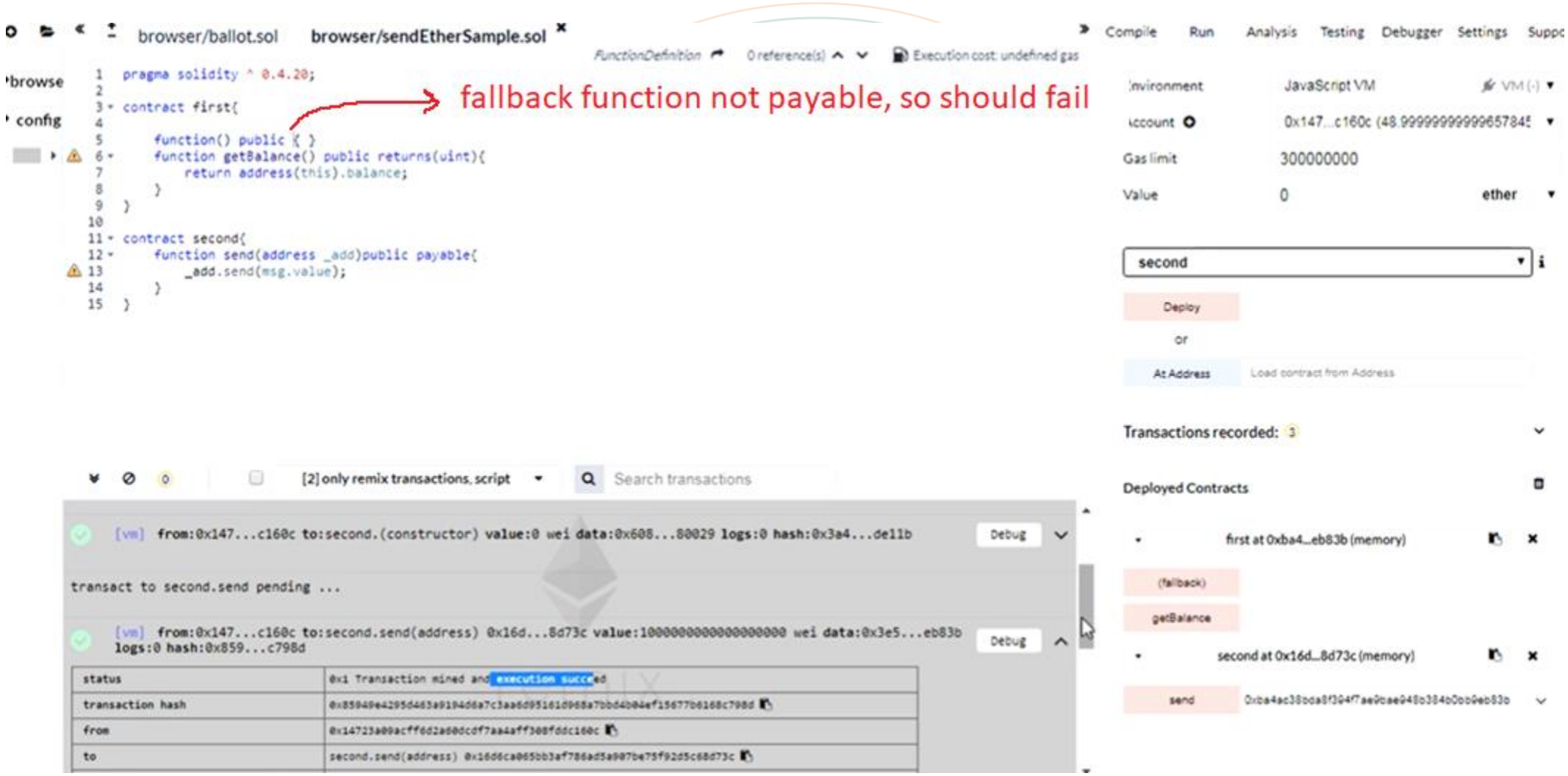
Send Limitations

This method also has 2300 gas limit.

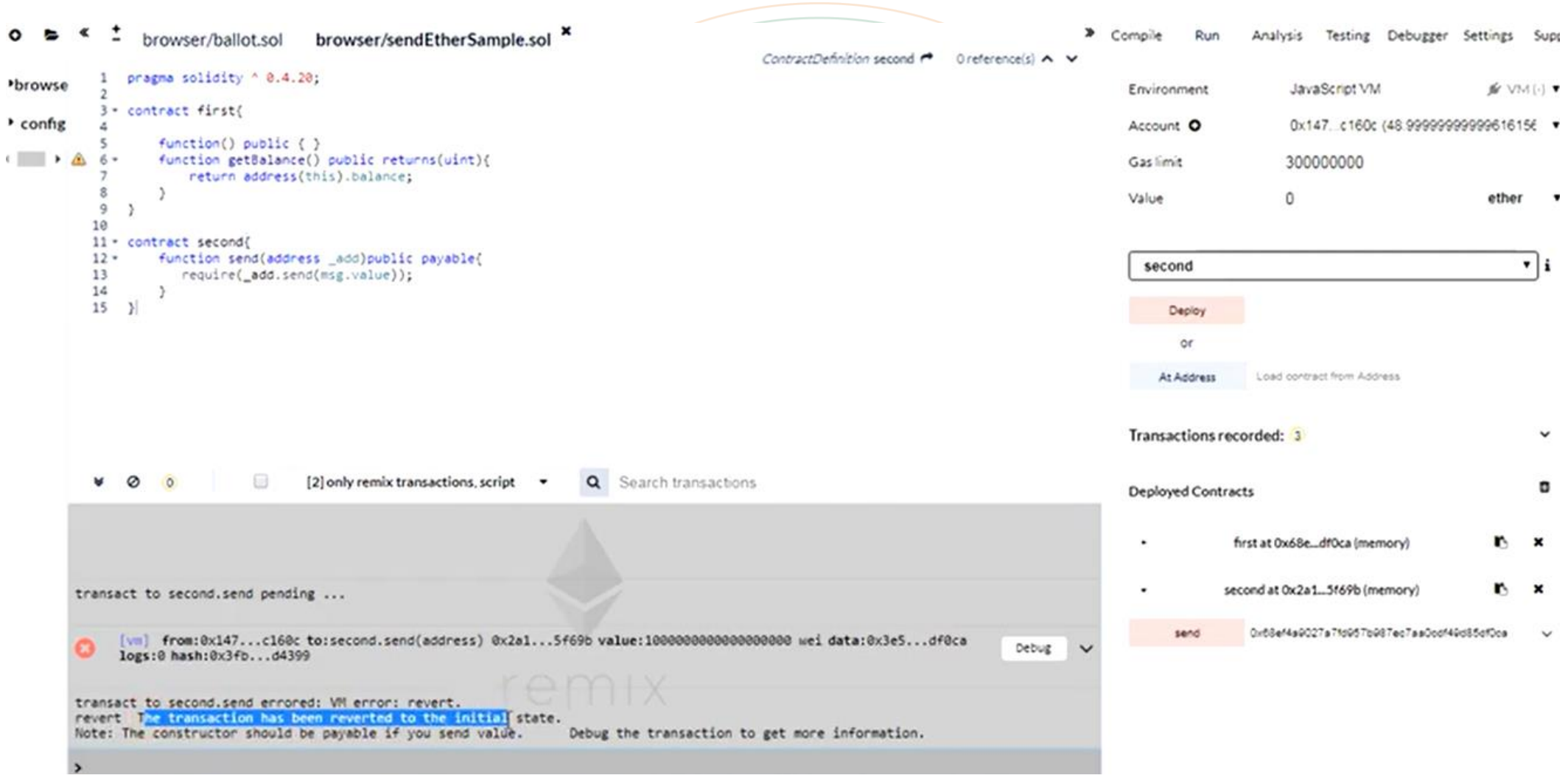
No possibility to add gas limit.

This does not throw exception but return false if unsuccessful and true in case successful. It does not revert the state until we use require function.

Send


browser/ballot.sol
browser/sendEtherSample.sol
fallback function not payable, so should fail
Compile
Run
Analysis
Testing
Debugger
Settings
JavaScript VM
Gas limit
300000000
Value
0
ether
second
Deploy
or
At Address
Load contract from Address
Transactions recorded: 3
Deployed Contracts
first at 0xba4...eb83b (memory)
(fallback)
getBalance
second at 0x16d...8d73c (memory)
send
[2] only remix transactions, script
Search transactions
transact to second.send pending ...
status
transaction hash
from
to

Send


browser/ballot.sol
browser/sendEtherSample.sol
browse
config
1 pragma solidity ^ 0.4.20;
2
3 contract first{
4
5 function() public { }
6 function getBalance() public returns(uint){
7 return address(this).balance;
8 }
9 }
10
11 contract second{
12 function send(address _add)public payable{
13 require(_add.send(msg.value));
14 }
15 }
ContractDefinition second
0 reference(s)
Compile
Run
Analysis
Testing
Debugger
Settings
Environment
JavaScript VM
Account
0x147...c160c (48.999999999996161
Gas limit
300000000
Value
0
ether
second
Deploy
or
At Address
Load contract from Address
Transactions recorded: 3
Deployed Contracts
first at 0x68e...df0ca (memory)
second at 0x2a1...5f69b (memory)
send
[2] only remix transactions, script
Search transactions
transact to second.send pending ...
[vm] from:0x147...c160c to:second.send(address) 0x2a1...5f69b value:1000000000000000000 wei data:0x3e5...df0ca
logs:0 hash:0x3fb...d4399
Debug
transact to second.send errored: VM error: revert.
revert The transaction has been reverted to the initial state.
Note: The constructor should be payable if you send value.
Debug the transaction to get more information.
remix

Call: Another Option

This is used to send the ether and **this should be used as last option.**

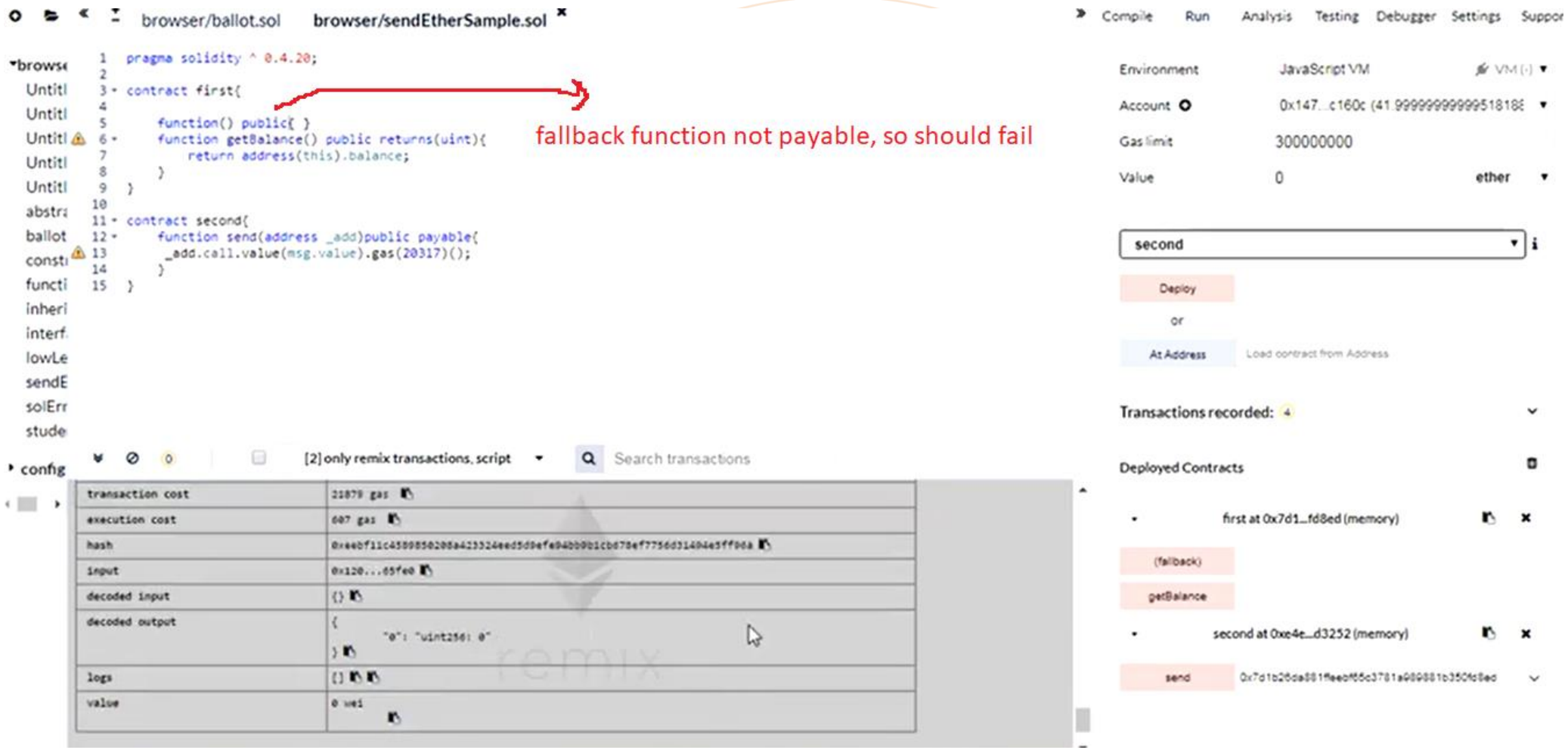
```
pragma solidity ^0.4.20;

contract first{
    function() payable { }
    function getBalance() public returns(uint){
        return address(this).balance;
    }
}

contract second{
    function send(address _add)public payable{
     _add.call.value(1 ether).gas(20317);
    }
}
```

Call Limitations

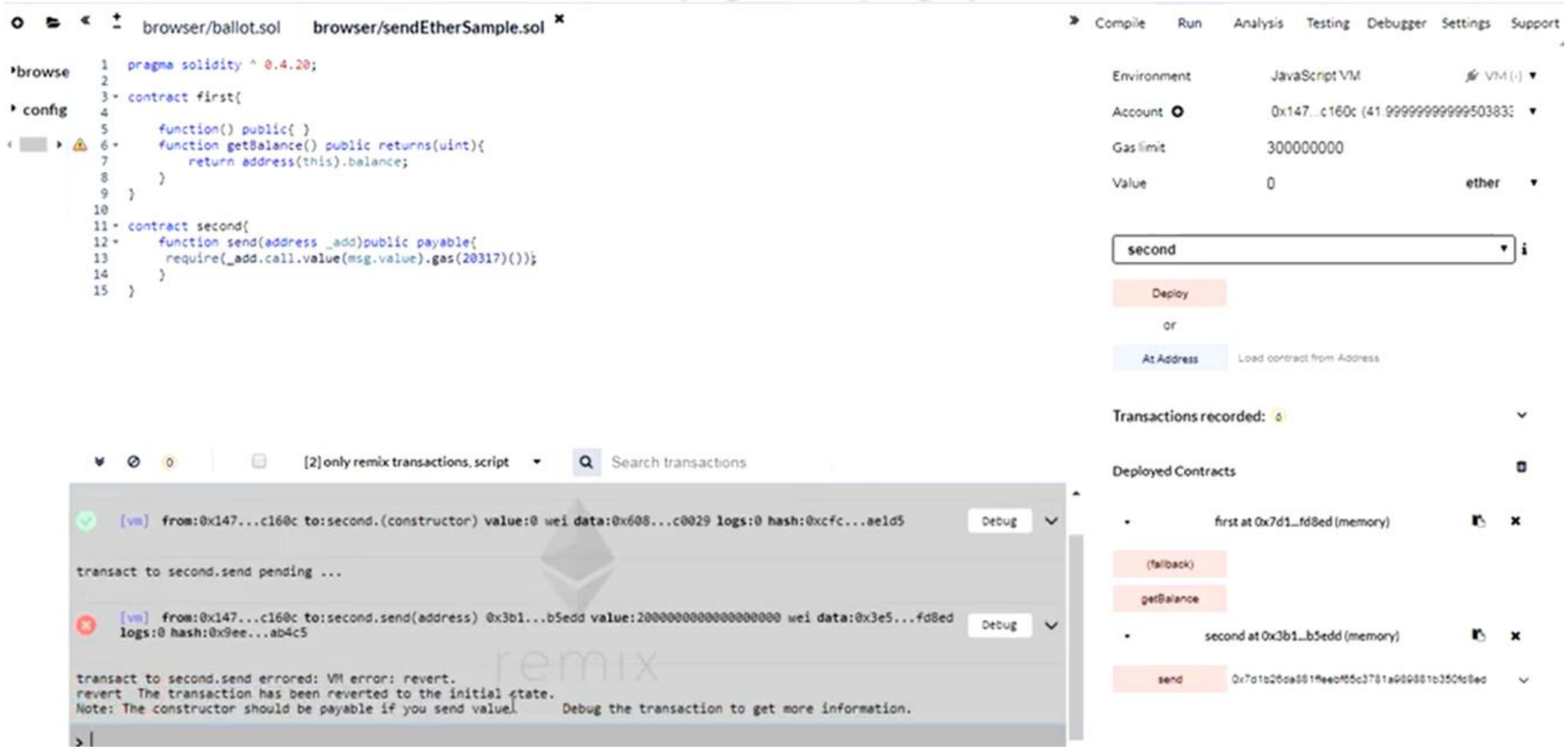
This method support setting gas and does not limit to 2300.

This does not throw exception but return false if unsuccessful and true in case successful. It does not revert the state until we use require function.

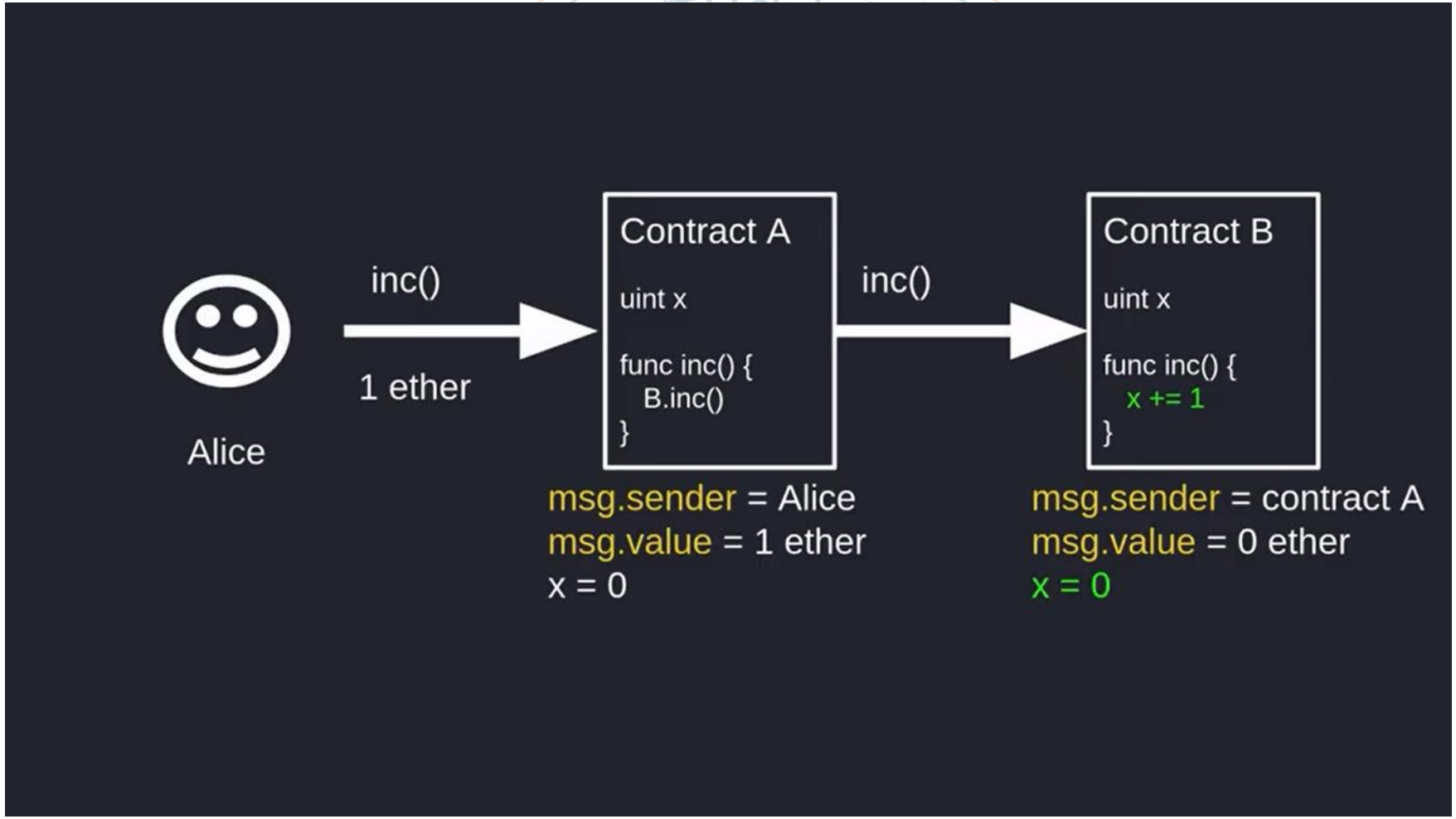
Call: Another Option



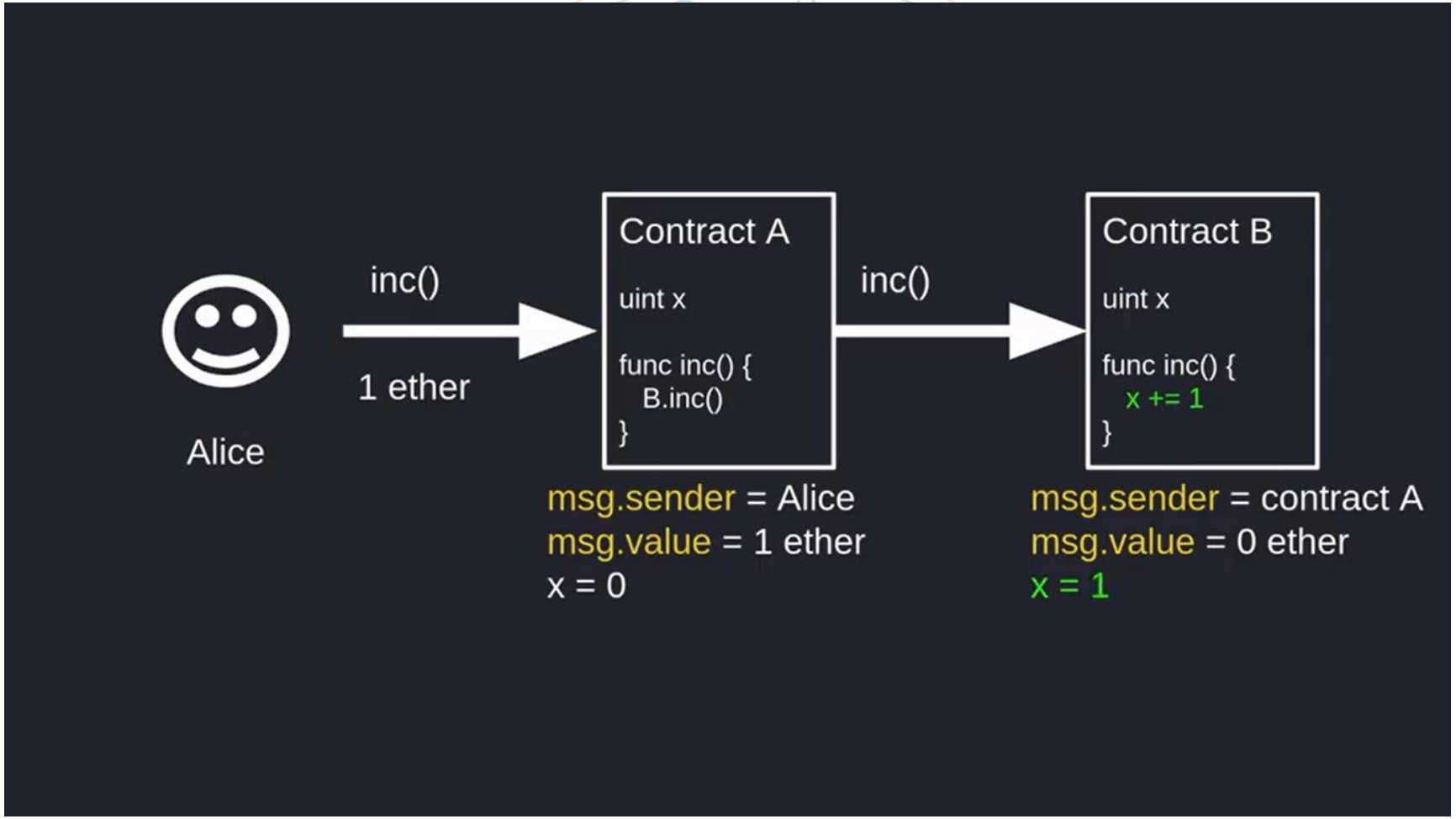
Call: Another Option



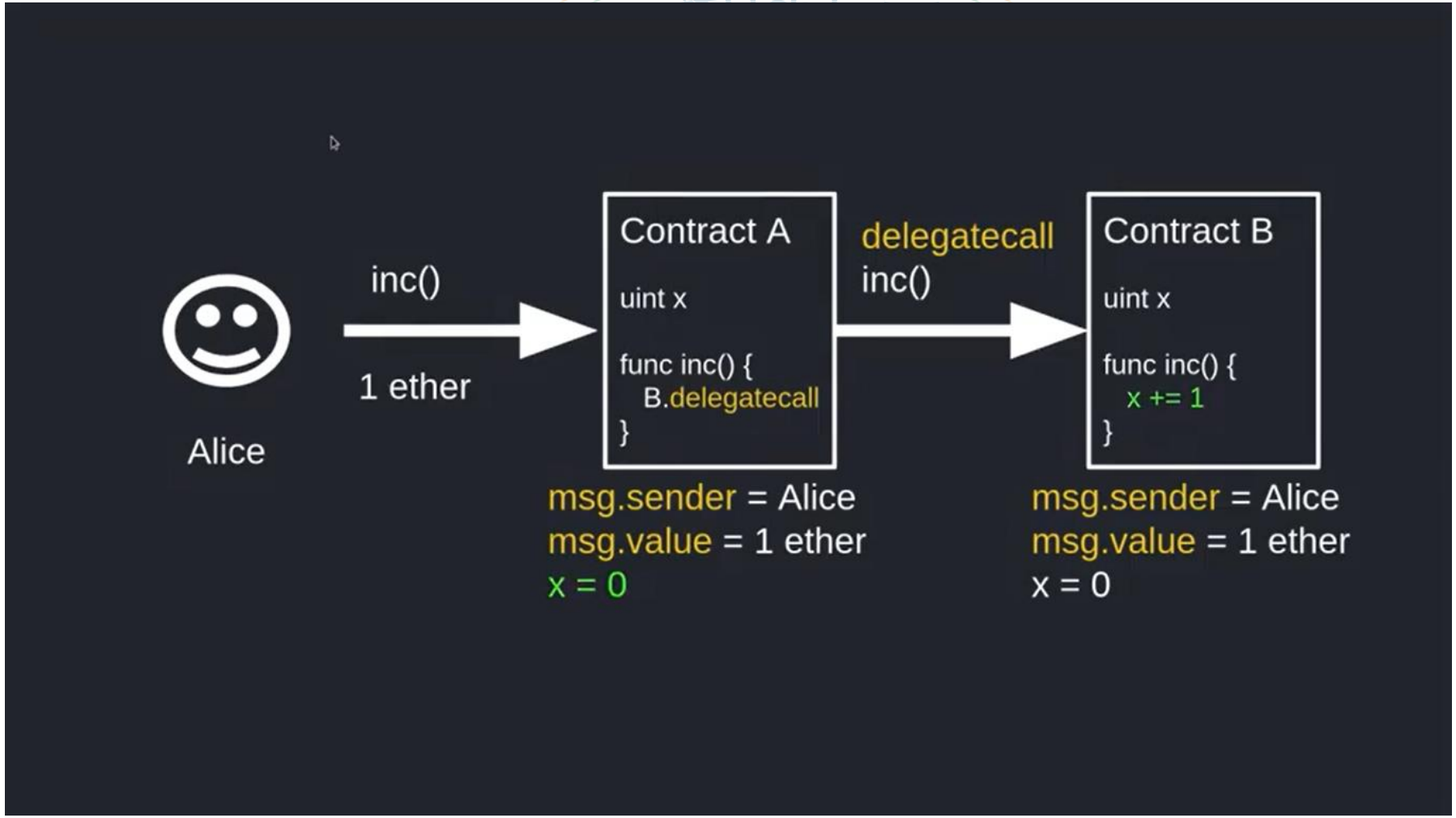
Delegate call



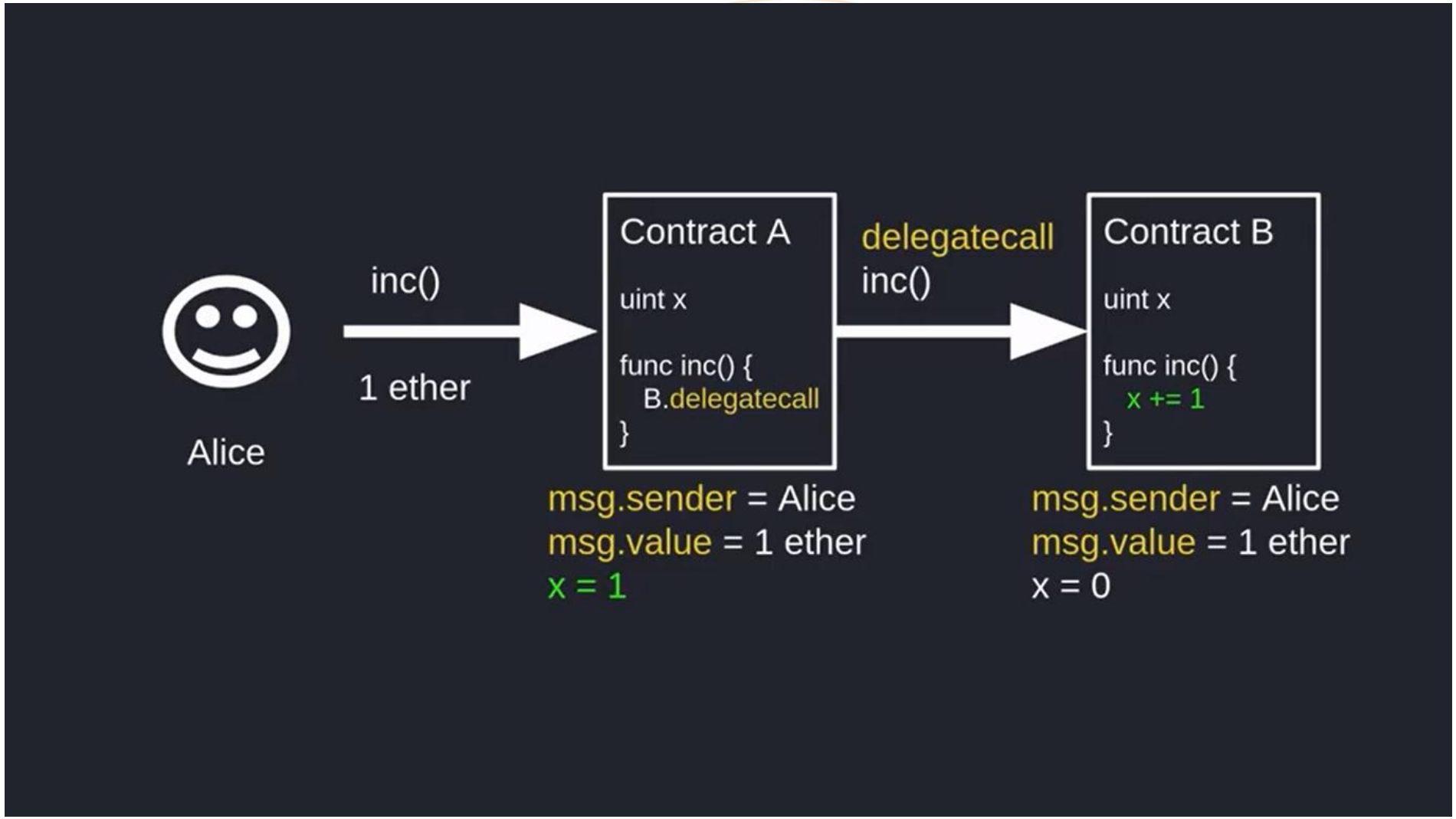
Delegate call



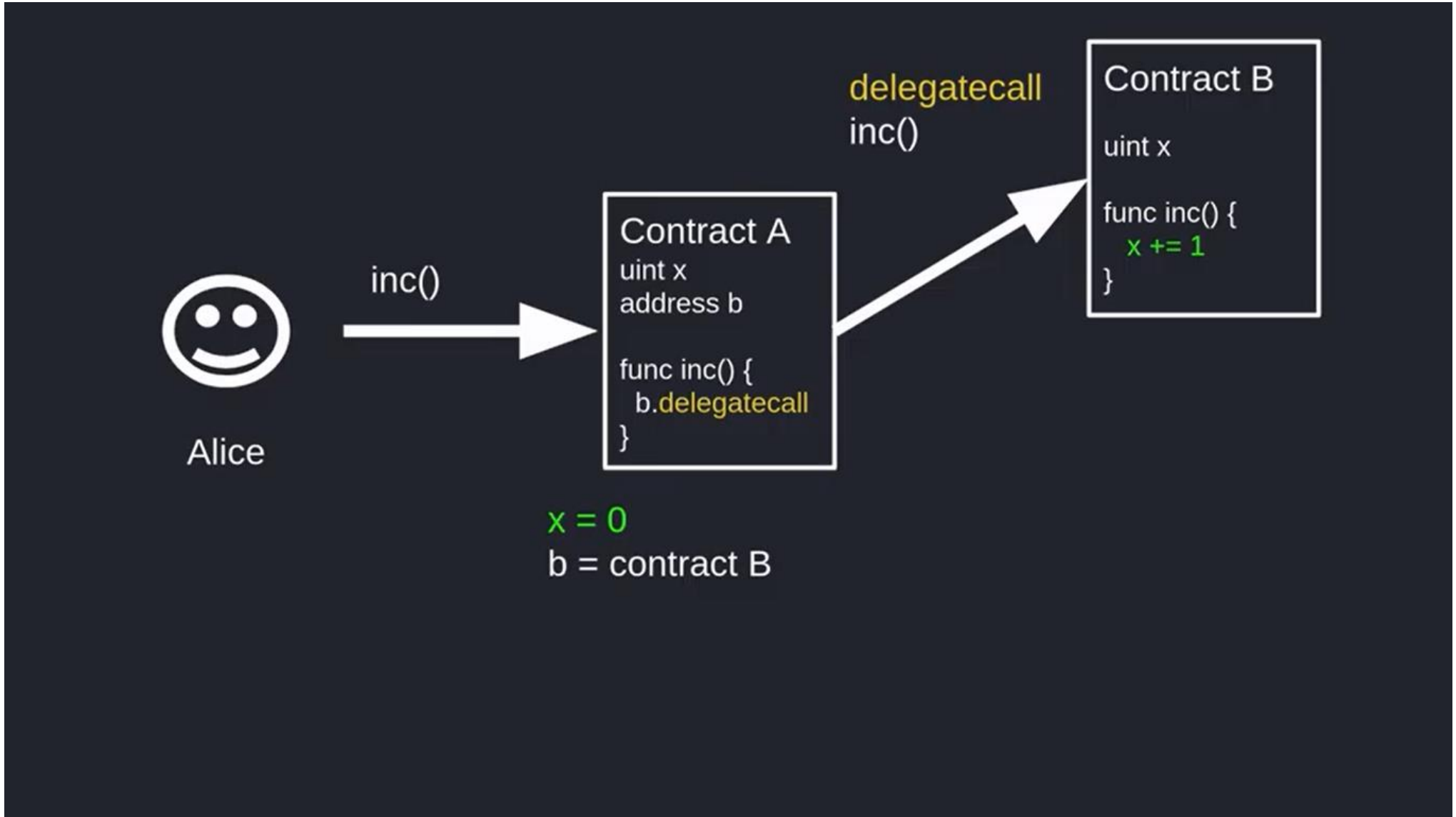
Delegate call



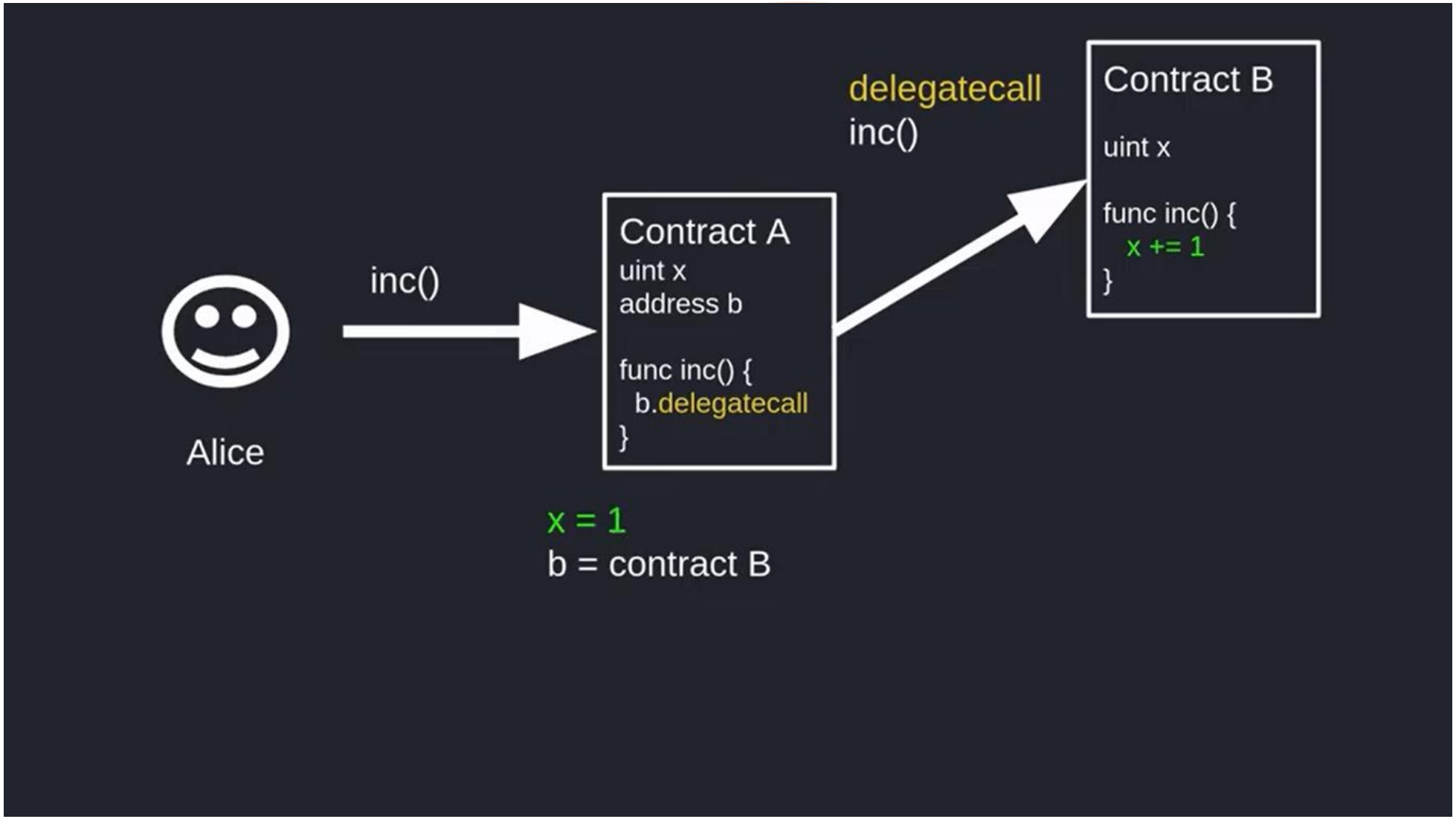
Delegate call



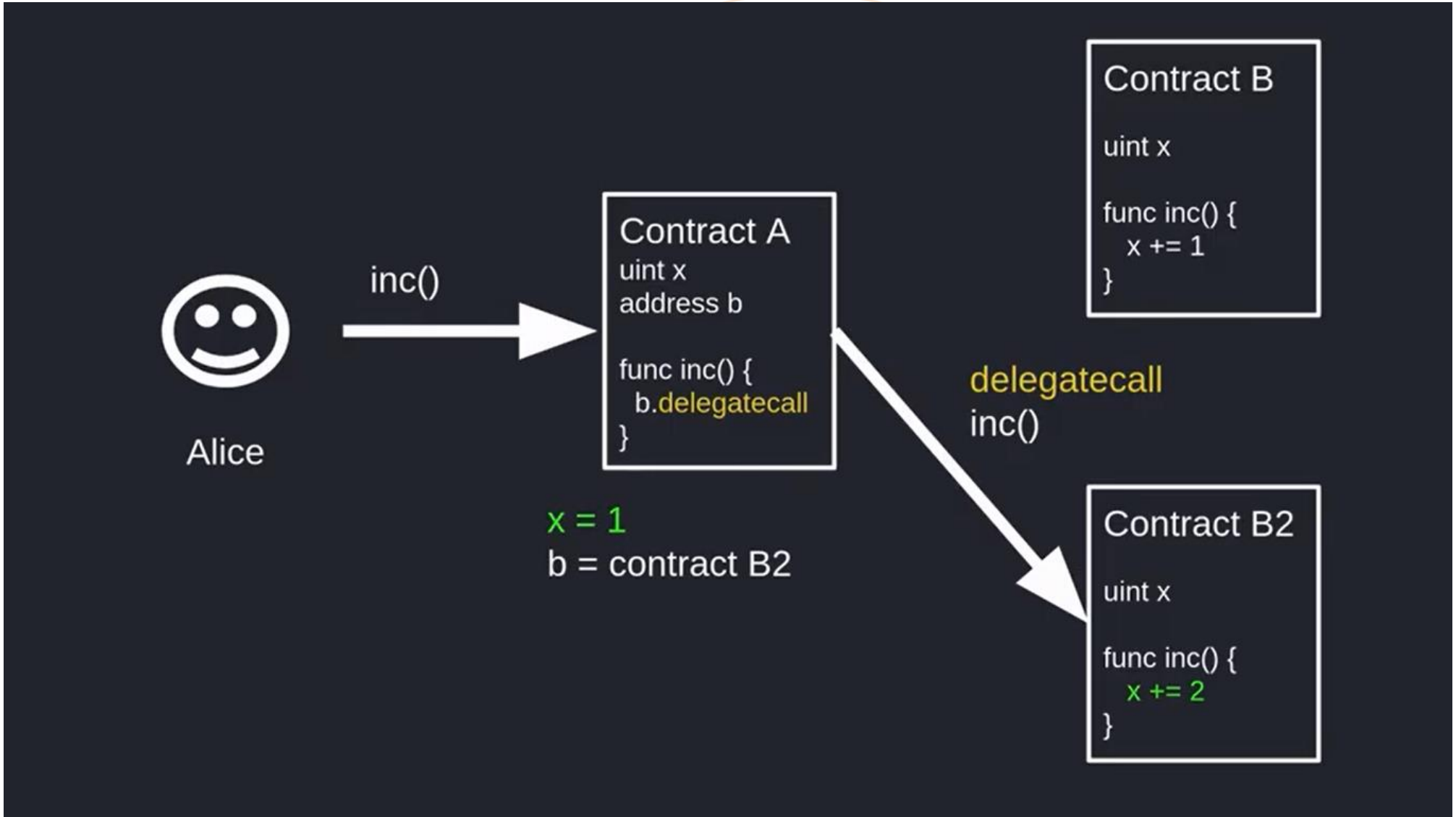
Delegate call: Its Use



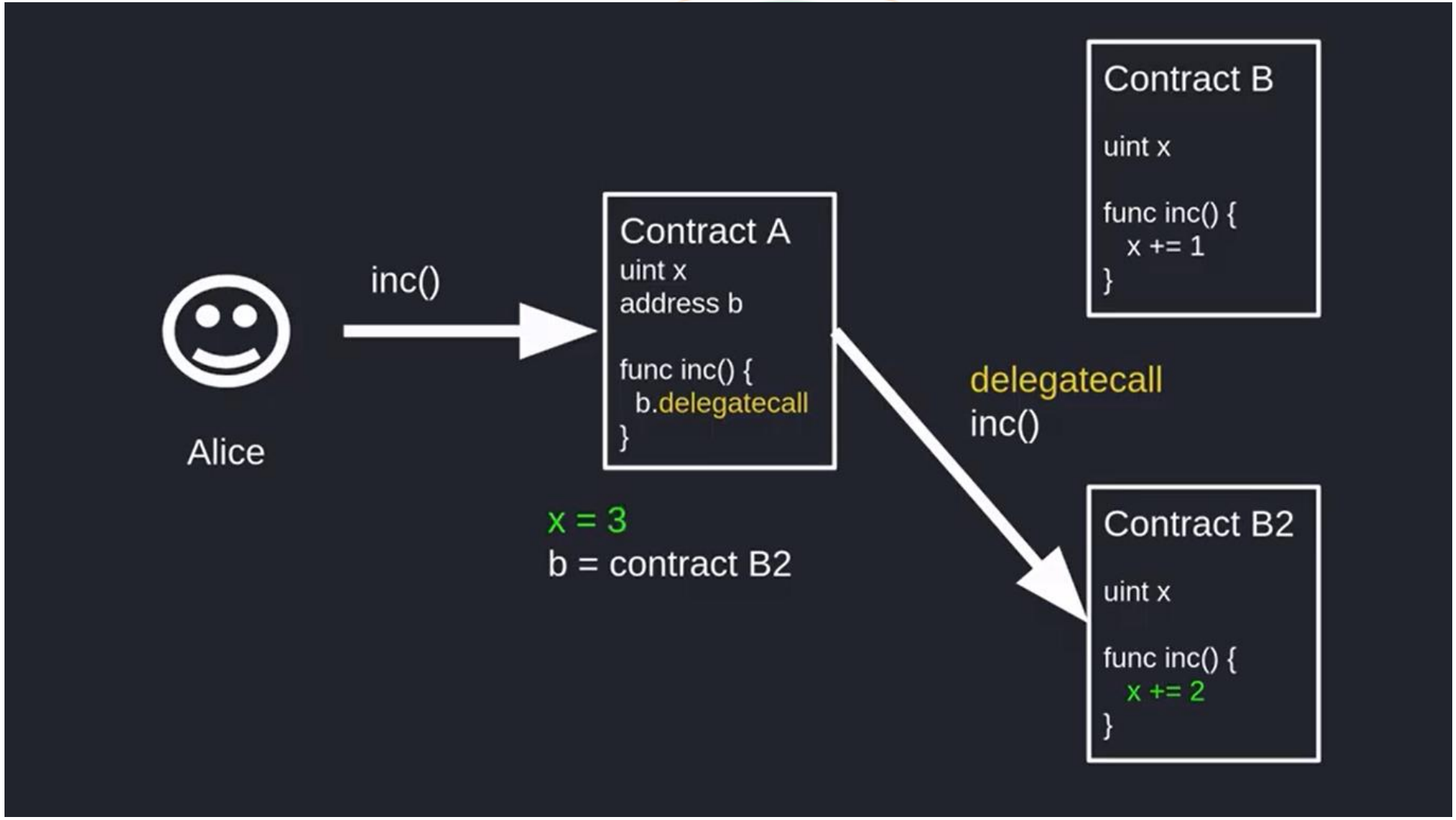
Delegate call: Its Use



Delegate call: Its Use



Delegate call: Its Use



Source Code of Examples:

SCAN

or

Visit here

Ethereum Development: Language

- **Smart Contract**
  - ✓ **Requires knowledge of how to write Smart Contracts**

  - **Languages:**
    - **Solidity (Javascript based)**
    - **Vyper (Pythonic programming language)**

  - **IDEs:**
    - **Remix - Ethereum IDE (for beginners) online editor: here**
    - **Visual Studio Code (extension:: juanblanco.solidity)**
    - **Eclipse (extension:: YAKINDU Solidity Tools)**
    - **IntelliJ-Solidity**
    - **Atom**

Ethereum Development: Network

- **Mainnet**
  - ✓the live public Ethereum production blockchain, where actual valued transactions take place on the distributed ledger. **visit:** here
- **Testnet**
  - ✓**Provides platform to test software before deploying on the Mainnet**
  - **Local Testnets**
    - **Ganache**
    - **Ganache CLI**
  - **Public Testnets** ***(ethers requested via faucet)***
    - **Ropsten (Geth/Parity) (Minable)**
    - **Görli (Multi-client)**
    - **Kovan (Parity)**
    - **Rinkeby (Geth)**

Ethereum Development: Interface

- **Front-end interface**
  - **Web3.js (Ethereum JavaScript API)**
    - collection of libraries which allow you to interact with a local or remote Ethereum node, using a HTTP or IPC connection. **(documentation: here)**
  - **Ethers.js**
    - a complete and compact library for interacting with the Ethereum Blockchain and its ecosystem along with Ethereum wallet implementation **(documentation: here)**
- **Back-end interface**
  - **Web3j**
    - a lightweight, reactive, type safe library for Java, Android, Kotlin and Scala to connect with Ethereum clients **(documentation: here)**

Ethereum Development

- **Testing and Deployment:**
  - **Truffle suite, Embark, Waffle**

- **Storage:**
  - **IPFS**
  - **Swarm**

Happy Learning!

Thank you!

For Examples

Scan Me

Fajge Akshay M.

Dr. Raju Halder