CS 252:

Advanced Programming Language Principles

Ethereum and Solidity

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Bitcoin (BTC)

bitcoin

- Protocol designed by Satoshi Nakamoto in 2008 https://bitcoin.org/bitcoin.pdf
- First Bitcoin client launched in 2009
- Peer-to-peer – no centralized control
  - Every client keeps track of the history of all bitcoins

Bitcoin "Script" Language

- Forth-like
  - Reverse-Polish notation
  - Stack based
- Lock: `scriptPubKey`
- Unlock: `scriptSig`
- https://en.bitcoin.it/wiki/Script

Sample Transaction Output

```
"vout": [
   { "value": 0.01500000,
     "scriptPubKey": "OP_DUP OP_HASH160
         ab6802… OP_EQUALVERIFY
         OP_CHECKSIG" },
   { "value": 0.08450000,
     "scriptPubKey": "OP_DUP OP_HASH160
         7f9b1a… OP_EQUALVERIFY
         OP_CHECKSIG" },
]
```

Sample Script

```
2 7 OP_ADD 3 OP_SUB 1 OP_ADD 7 OP_EQUAL
```

(in-class)

Sample Script
Pay-to-public-key-hash (P2PKH)

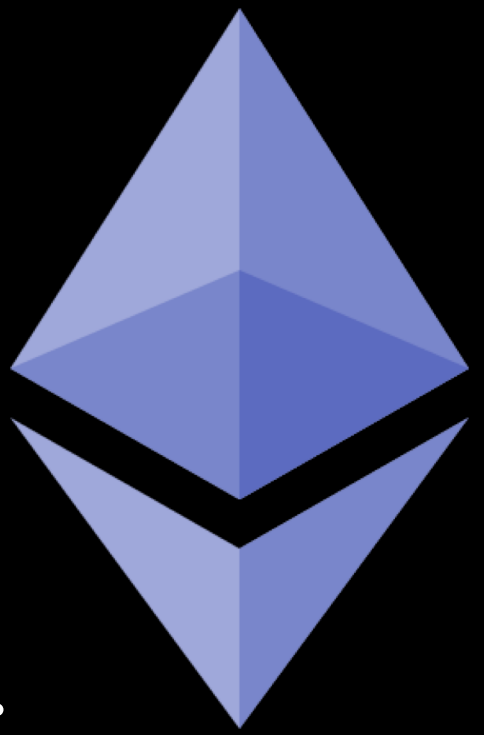
```
<sig> <PubK> DUP HASH160 <PubKHash>
                    EQUALVERIFY CHECKSIG
```

(in-class)

Script Limitations

- No loops.
- No complex control flow.
- Not Turing complete.
- No division.

Ethereum



- Smart contracts for building distributed applications (dApps).
- Almost Turing complete.
  - "Gas" to pay for computation.

Some Brief Ethereum Facts

- Number 2 cryptocurrency by market cap.
- Core developers
  - Vitalik Buterin (creator)
  - Gavin Wood
- Block 0 mined July 30, 2015

Account Types

- *Externally owned accounts* (EOAs)
  - Have a private key
- Contract accounts
  - Have contract code
  - No private key
    - Cannot initiate transactions
  - Can react to transactions and call other contracts
  - Contain data

Common Features with Bitcoin

- Digital currency
  - Called *ether* (ETH)
    - **Not** "ethereum"
  - Smallest unit: *wei*
- Proof-of-work blockchain
  - Ethash – designed to be ASIC-resistant
  - Much quicker: 14-15 second block time
  - Plans to move to *proof-of-stake* (Casper)
- Peer-to-peer network

Differences from Bitcoin

- Quasi-Turing complete virtual machine
  - Brings up a lot of security issues
- Gas
  - Prevents denial-of-service attacks
  - Transactions specify:
    - ETH earmarked for gas
    - gas-rate

Lab, Part 1

Create Ethereum MetaMask wallet.

Details in Canvas.

Decentralized Applications (DApps)

- Also referred to as dApps, Dapps, and ĐApps
  - Đ is the Old-English letter 'Eth'
- Written in a smart contract language
  - Solidity is the most prevalent

Smart Contracts

Smart Contracts
(Definition from *Mastering Ethereum*)

Immutable computer programs that run deterministically in the context of an Ethereum Virtual Machine as part of the Ethereum network protocol—i.e., on the decentralized world computer.

Smart Contract Life Cycle

1. Published to the *zero address*.
   - **0x0000000000000000000000000000000000000000**
   - Author has no special rights to a contract, unless the contract is written that way.
2. Invoked by transaction.
3. May be destroyed.
   - Only if creator configured it that way.

High-level Languages for EVM

- LLL – Lisp-like language.
  - Oldest, but rarely used.
- Serpent
  - Python-ish
- Solidity
  - JavaScript-ish
- Vyper
  - Also Python-ish
- Bamboo
  - Erlang-ish

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Solidity

- Created by Gavin Wood.
- Most popular HLL for Ethereum today.

Solidity Data Types
(not exhaustive)

- `bool`
- `int`, `uint`
  - Variants in 8, 16, 32, …, 256
  - Default is 256
- `fixed`, `ufixed`
- `address`
- Arrays
- Time units
- Ether units: `wei`, `finney`, `szabo`, and `ether`

Global Variables

- `msg` – the transaction call.
  - Fields: sender, value, gas, data, sig
- `tx` – the transaction.
  - Fields: gasprice
- `block` – the block the transaction is in.
  - Fields: coinbase, difficulty, gaslimit, number, timestamp (in seconds since epoch)

Constructing and Destroying Contracts

- Created with `constructor`.
  - –Older versions used contract name
- Destroyed with `selfdestruct`.
  - –Person who destroys it claims the contract's ether.
  - –Only if enabled by author.

Function Syntax

```
function FunctionName
([parameters])
{public|private|internal|ex
ternal}
[pure|constant|view|payable
] [modifiers]
[returns (return types)]
```

Function Modifiers

- Functions that modify other functions
- Use an underscore (_) as a placeholder for the modified function

```
modifier onlyOwner {
    require (msg.sender == owner);
    _;
}
```

Function Restricting Access

```
function takeFunds(amt) public {
    require (msg.sender == owner);
    msg.sender.transfer(amt);
}
```

Using Function Modifier

```
function takeFunds(amt) public onlyOwner {
    msg.sender.transfer(amt);
}
```

Error handling

- Guarantee state.
  - Throw an exception if false.
- `assert`
  - Used only to catch internal programming errors
- `require`
  - Used to validate external input
  - May be given 2nd argument for better error handling

Review Test Faucet Contract

(in-class)

Suggested Reading

- The Beige Paper
  - https://github.com/chronaeon/beigepaper/blob/master/beigepaper.pdf
  - Less formal version of the Yellow Paper (https://ethereum.github.io/yellowpaper/paper.pdf)
- *Mastering Ethereum,* by Andreas M. Antonopoulos and Gavin Wood. https://github.com/ethereumbook/ethereumbook

Lab: Distributed Lottery in Ethereum

There can be exactly 3 players.

Each player contributes ether and pick a random number.

Once the last player has contributed, the winner's address is selected.

The winner can then destroy the smart contract to claim the winnings.

More details in Canvas.