smart contracts

principles and beyond

Blockchain and the Law. March 2022, seminar UCP

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smart contract

- term introduced by Nick szabo in the 1996

Smart Contracts: Building Blocks for Digital Markets

Glossary

(This is a partial rewrite of the article which appeared in Extropy #16)

Introduction

The contract, a set of promises agreed to in a "meeting of the minds", is the traditional way to formalize a relationship. While contracts are primarily used in business relationships (the focus of this article), they can also involve personal relationships such as marraiges. Contracts are also important in politics, not only because of "social contract" theories but also because contract enforcement has traditionally been considered a basic function of capitalist governments.

Whether enforced by a government, or otherwise, the contract is the basic building block of a free market economy. Over many centuries of cultural evolution has emerged both the concept of contract and principles related to it, encoded into common law. Algorithmic information theory suggests that such evolved structures are often prohibitively costly to recompute. If we started from scratch, using reason and experience, it could take many centuries to redevelop sophisticated ideas like property rights that make the modern free market work [Hayek].

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- ...well before the introduction of blockchain (2008)

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Bitcoin: A Peer-to-Peer Electronic Cash System

Satoshi Nakamoto
satoshin@gmx.com
www.bitcoin.org

Abstract. A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution. Digital signatures provide part of the solution, but the main benefits are lost if a trusted third party is still required to prevent double-spending. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of

Smart Contracts Glossary, Nick Szabo (1995)

“smart contract”

A set of promises,

> *including protocols within which the parties perform on the other promises.*

The protocols are usually implemented with programs on a computer network, or in other forms of digital electronics,

> *thus these contracts are "smarter" than their paper-based ancestors.*

No use of artificial intelligence is implied.

"smart contract"

a bilateral contract is a formal agreement in which both parties exchange promises to perform

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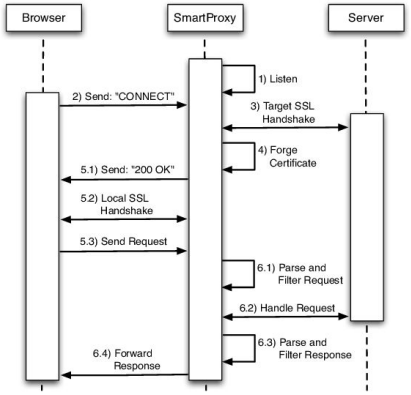

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then, smart in what sense?

- According to the vulgata:
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how? making breaches prohibitively expensive

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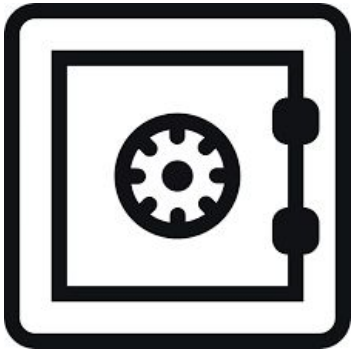
essential idea: technology as a vault



the *possibility* of breaching is
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***ex-ante* enforcement**

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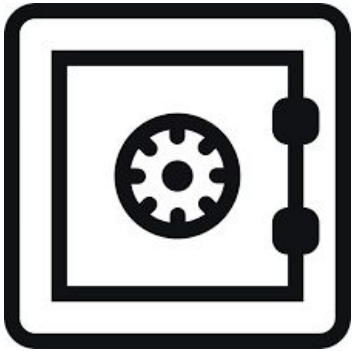

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***ex-ante* enforcement**

tokens!

- What to protect?
  - (valuable?) digital assets
  - “contracts” (reified as assets)
  - automated performance

in terms of medieval technology

- How to protect (the content of) a book from invasions, wars, and plagues?

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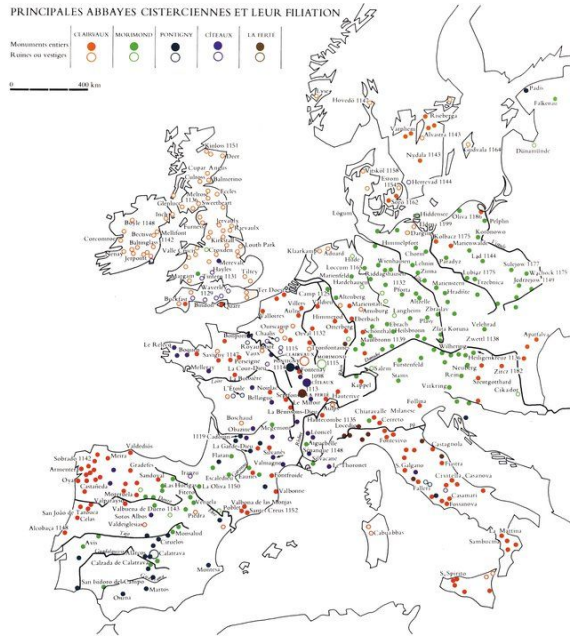
- Copy it, and distribute the copies through a network of monasteries!



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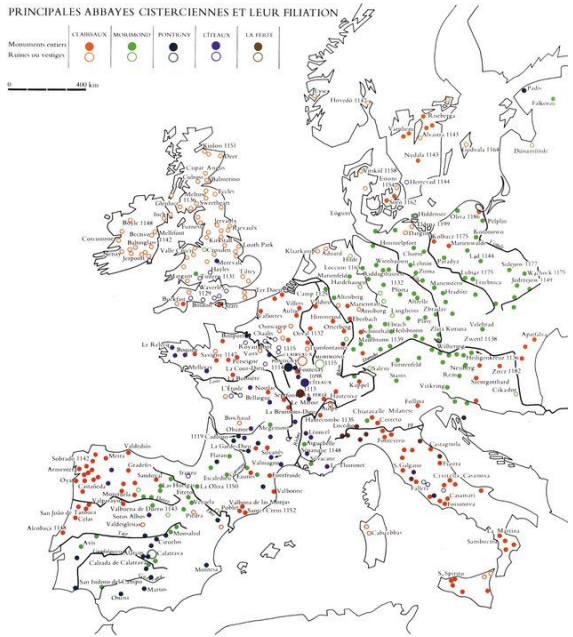

If a node is destroyed, a copy is still maintained in all others!!!

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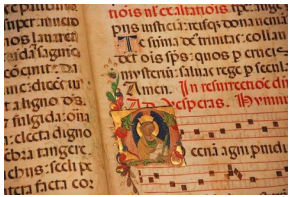
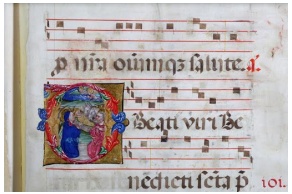
- Typically copying bring errors, exemplars of the book are never identical





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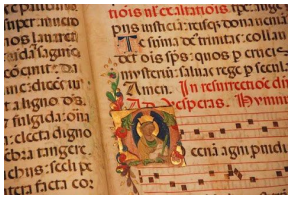
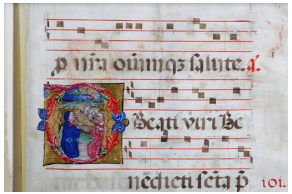
technological improvement:

introduce **error checking** machinery, typically via additional content used to **check integrity**





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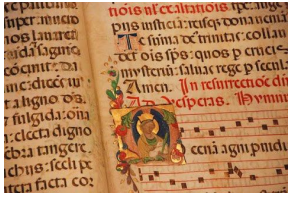

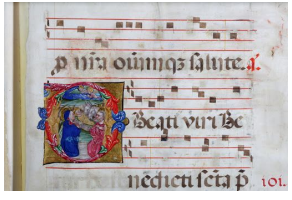

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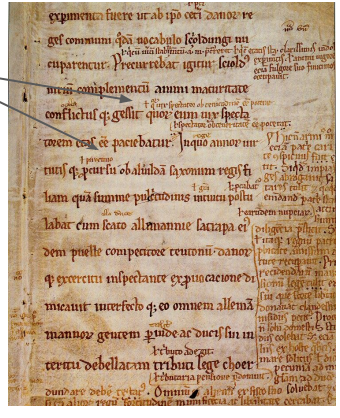

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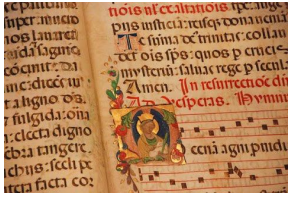

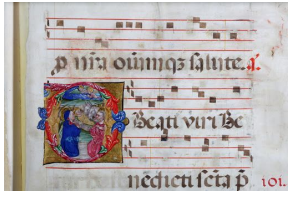

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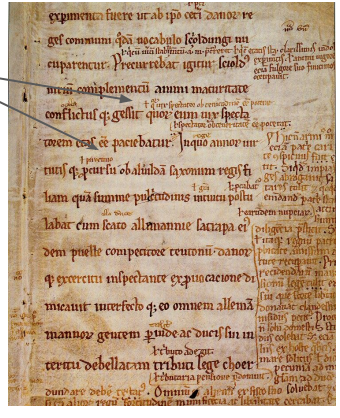
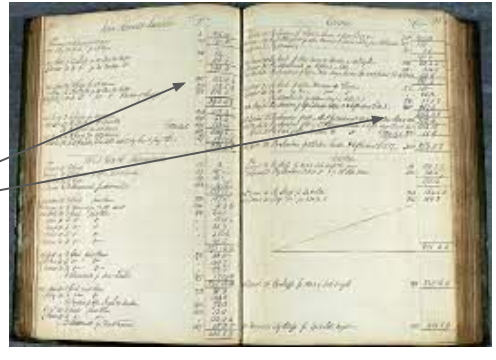


double entry bookkeeping (Florence, Venice ~1300)



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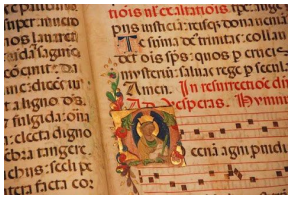


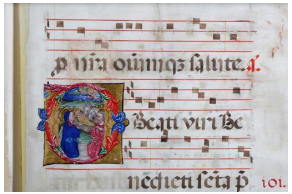

- Introduce **conflict resolution strategies**
  - philology provides several methods to “reconstruct” the original source, e.g. majority of sources, comparative analysis, provenance history

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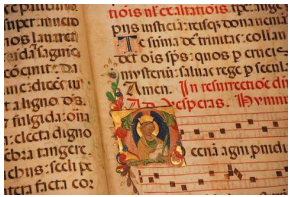


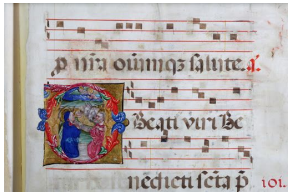

“consensus” protocol

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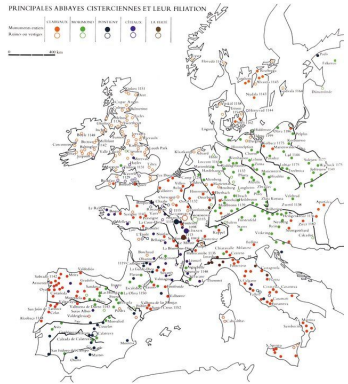
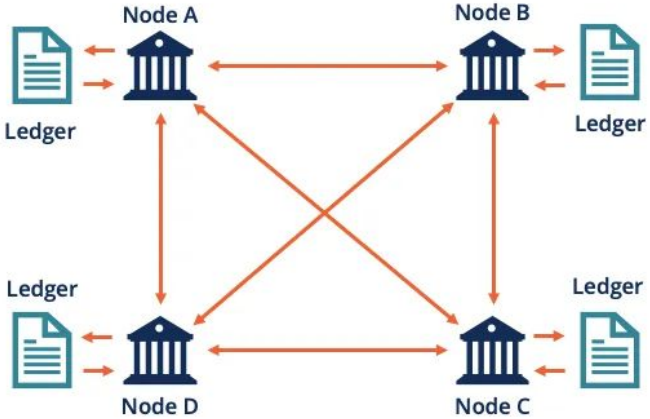
“blockchain” =

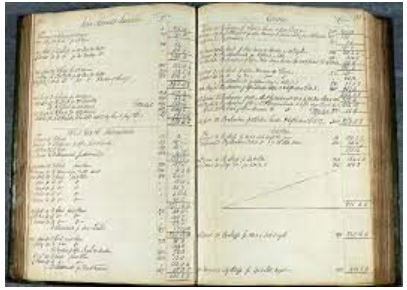
- **distributed** ledger + consensus protocol



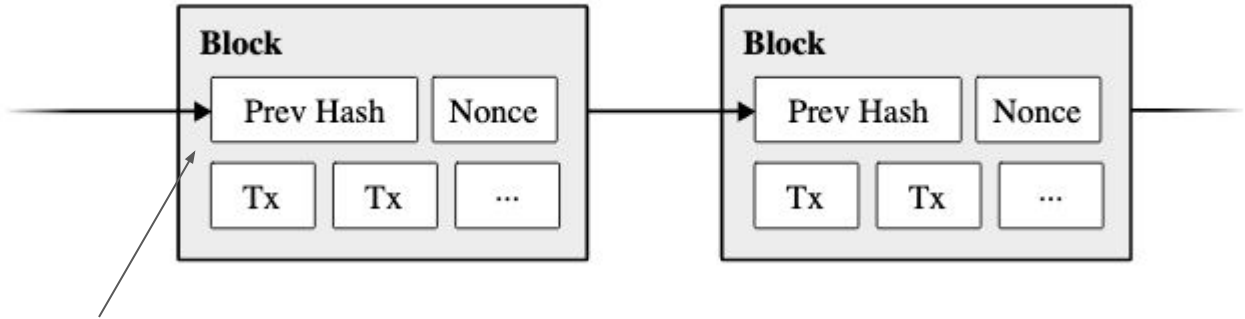


the same ledger is copied across the network

"blockchain" =



- distributed ledger + consensus protocol



the ledger embeds machinery to test its integrity

compressed information (a sort of *fingerprint*) of the previous block, if the previous block is modified its hash is not the same

"blockchain" =

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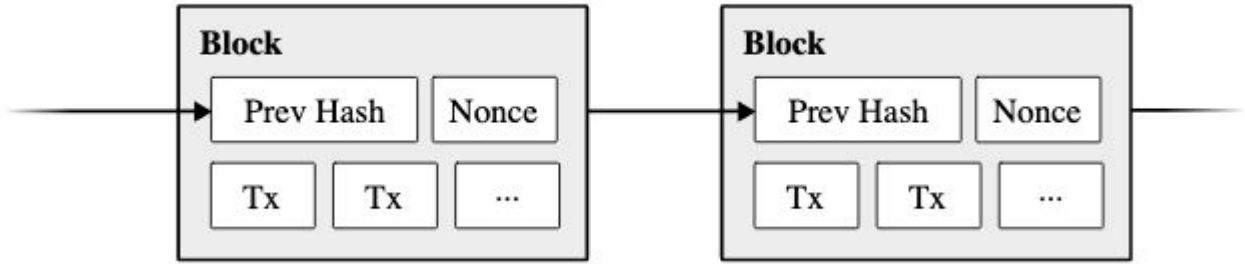

checks for integrity are performed across the network, no central authority

techniques: **Proof of Work (PoW), Proof of Stake (PoS), etc.**

“smart contract”

= code running on blockchain

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in most cases Ethereum

which code?

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which code?

source code

```
pragma solidity >=0.4.22 <0.6.0;

contract Ballot {
    struct Voter {
        uint weight;
        bool voted;
        address delegate;
        uint vote;
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    struct Proposal {
        bytes32 name;
        uint voteCount;
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    address public chairperson;

    [...]
```

“human-readable” instructions

[developer’s view]

“smart contract”
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compilation

byte-code or machine code

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9  000012: JUMPI
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11 000015: CALLDATALOAD
12 000016: PUSH29 0x0100000000000000
13 000046: SWAP1
14 000047: DIV
15 000048: PUSH4 0xffffffff
16 000053: AND
17 000054: DUP1
18 000055: PUSH4 0x362186ed
19 000060: EQ
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“human-readable” instructions
[developer’s view]

low-level instructions
[user’s view]

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libraries in byte-code

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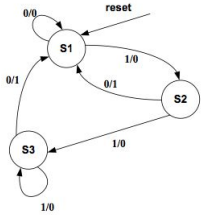
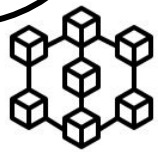
deployment



virtual machine on blockchain



“human-readable” instructions
[developer’s view]

low-level instructions
[user’s view]

“**smart contract**” most used meaning

= immutable low-level instructions
cloned on each node
running in a decentralized fashion

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- Individual primitive operations to be run on the virtual machine

eg. move a value from memory into a register, move a value from register to memory, perform operations between register and put value in register….

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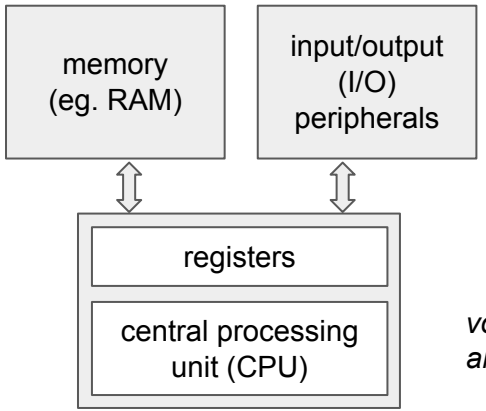

von Neumann architecture

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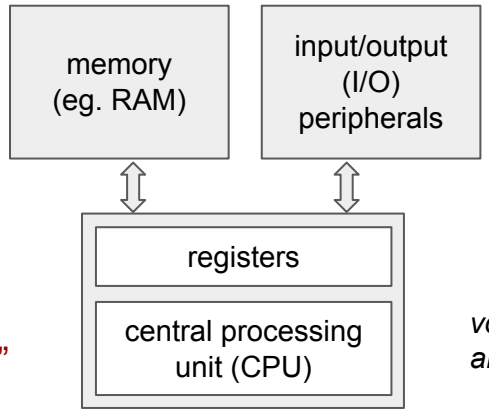
15 000048: PUSH4 0xffffffff
16 000053: AND
17 000054: DUP1
18 000055: PUSH4 0x362186ed
19 000060: EQ
20 000061: PUSH2 0x008d
21 000064: JUMPI
22 000065: DUP1
```

- Individual primitive operations to be run on the virtual machine

eg. move a value from memory into a register, move a value from register to memory, perform operations between register and put value in register….



essentially,
computational “logistics”

von Neumann architecture

and “higher-level” instructions?

(source code)

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Solidity by Example

version 0.8.10

English Auction

English auction for NFT.

Auction

1. Seller of NFT deploys this contract.
2. Auction lasts for 7 days.
3. Participants can bid by depositing ETH greater than the current highest bidder.
4. All bidders can withdraw their bid if it is not the current highest bid.

After the auction

1. Highest bidder becomes the new owner of NFT.
2. The seller receives the highest bid of ETH.

https://solidity-by-example.org/app/english-auction/

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.10;

interface IERC721 {
    function safeTransferFrom(
        address from,
        address to,
        uint tokenId
    ) external;

    function transferFrom(
        address,
        address,
        uint
    ) external;
}

contract EnglishAuction {
    event Start();
    event Bid(address indexed sender, uint amount);
    event Withdraw(address indexed bidder, uint amount);
    event End(address winner, uint amount);

    IERC721 public nft;
    uint public nftId;

    address payable public seller;
    uint public endAt;
    bool public started;
    bool public ended;

    address public highestBidder;
    uint public highestBid;
    mapping(address => uint) public bids;
```

and “higher-level” instructions?

(source code)

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```
constructor(
    address _nft,
    uint _nftId,
    uint _startingBid
) {
    nft = IERC721(_nft);
    nftId = _nftId;

    seller = payable(msg.sender);
    highestBid = _startingBid;
}

function start() external {
    require(!started, "started");
    require(msg.sender == seller, "not seller");

    nft.transferFrom(msg.sender, address(this), nftId);
    started = true;
    endAt = block.timestamp + 7 days;

    emit Start();
}

function bid() external payable {
    require(started, "not started");
    require(block.timestamp < endAt, "ended");
    require(msg.value > highestBid, "value < highest");

    if (highestBidder != address(0)) {
        bids[highestBidder] += highestBid;
    }

    highestBidder = msg.sender;
    highestBid = msg.value;

    emit Bid(msg.sender, msg.value);
}
```

and “higher-level” instructions?

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```
    function withdraw() external {
        uint bal = bids[msg.sender];
        bids[msg.sender] = 0;
        payable(msg.sender).transfer(bal);

        emit Withdraw(msg.sender, bal);
    }

    function end() external {
        require(started, "not started");
        require(block.timestamp >= endAt, "not ended");
        require(!ended, "ended");

        ended = true;
        if (highestBidder != address(0)) {
            nft.safeTransferFrom(address(this), highestBidder, nftId);
            seller.transfer(highestBid);
        } else {
            nft.safeTransferFrom(address(this), seller, nftId);
        }

        emit End(highestBidder, highestBid);
    }
}
```

not very different from computational “logistics”

difference between “imperative” and “declarative” programming languages

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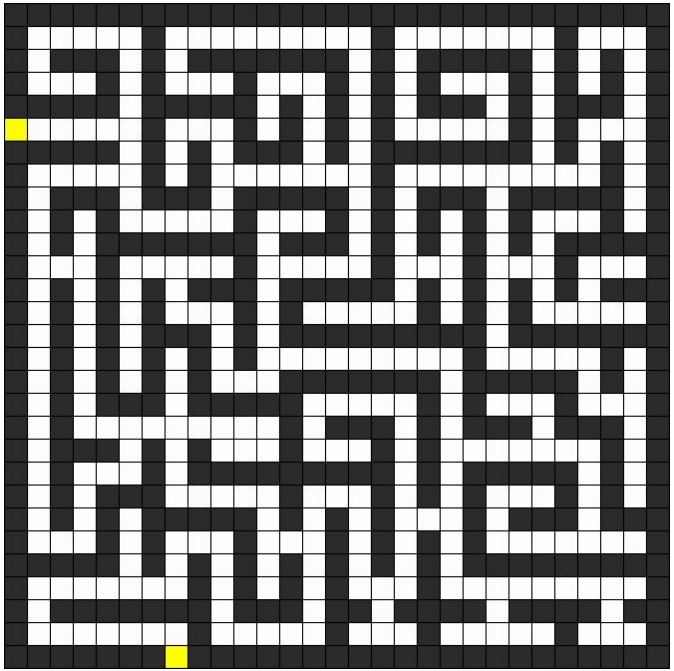
We have a labyrinth.



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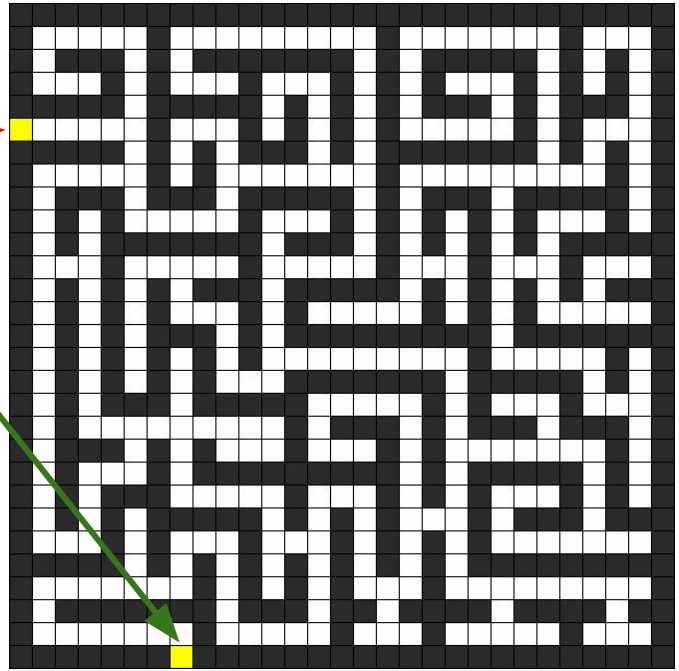

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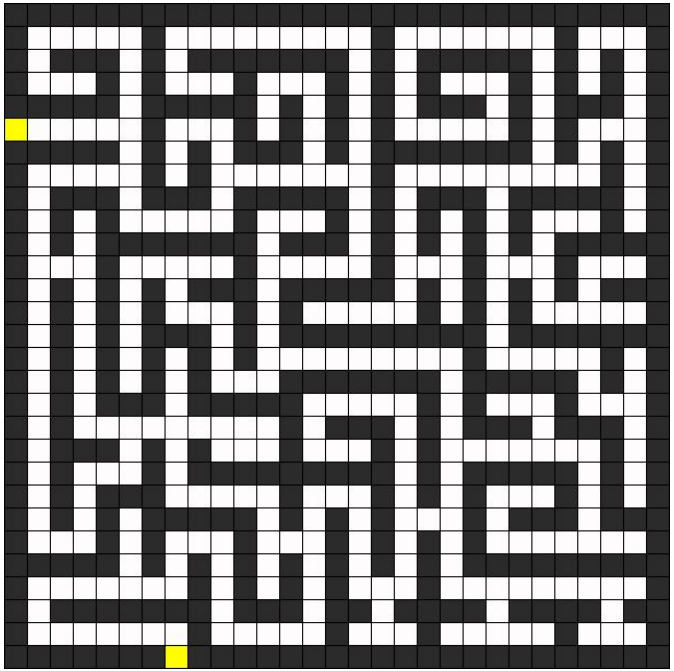

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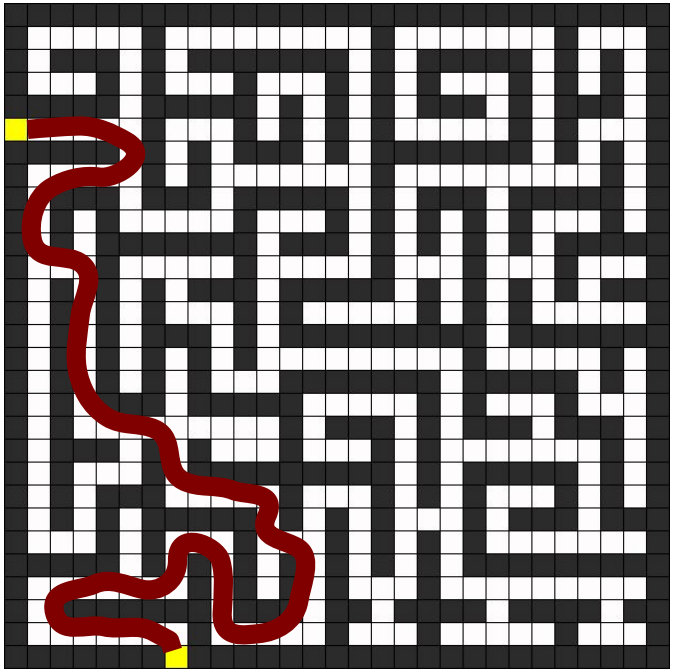

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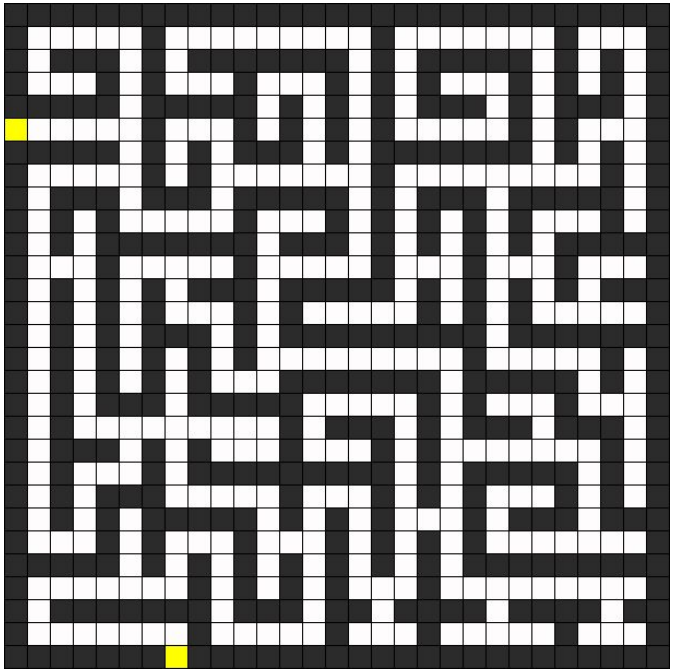

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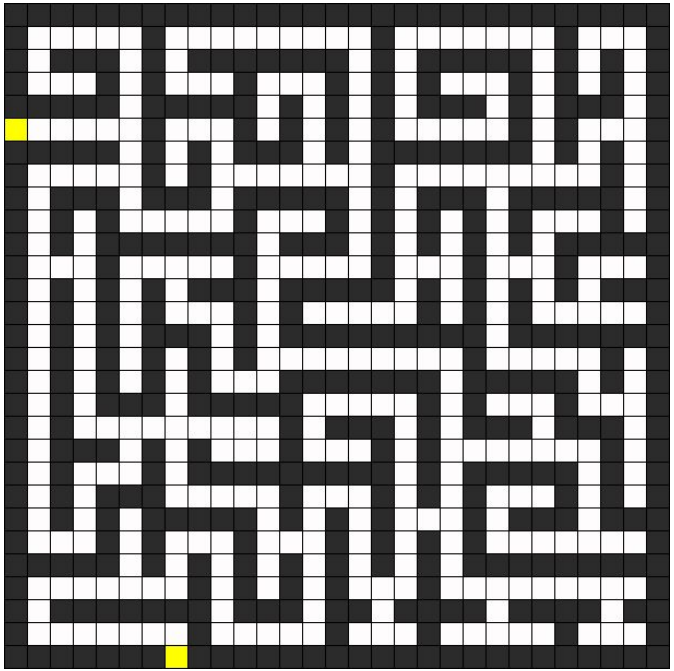

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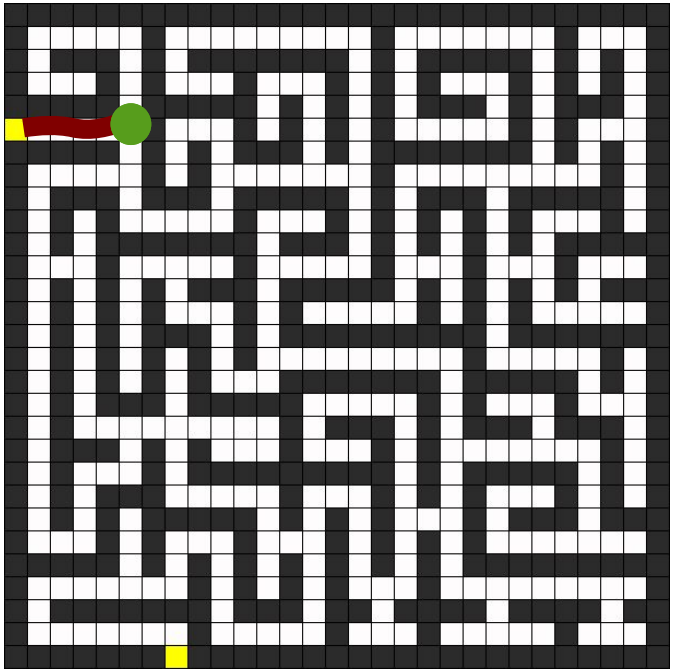

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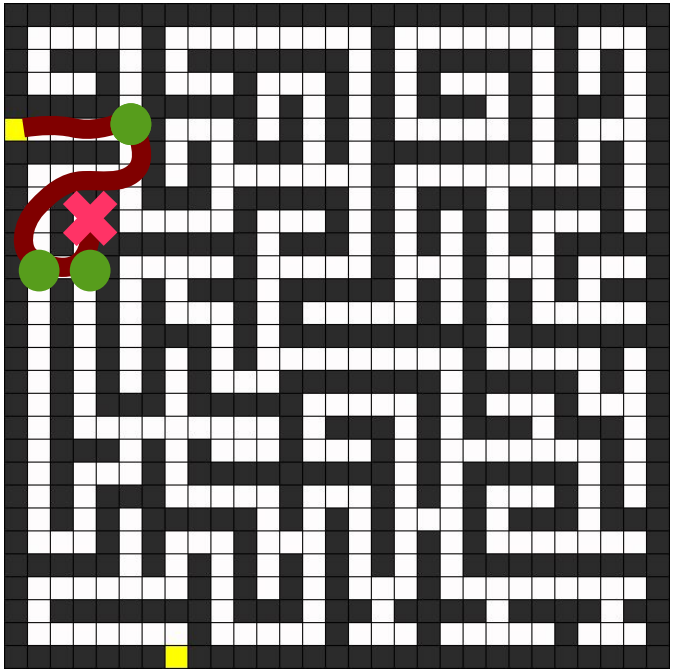

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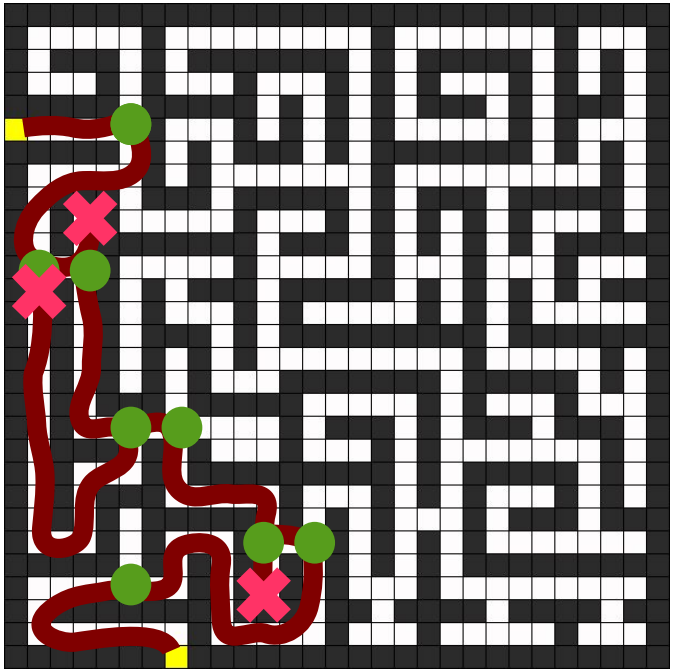

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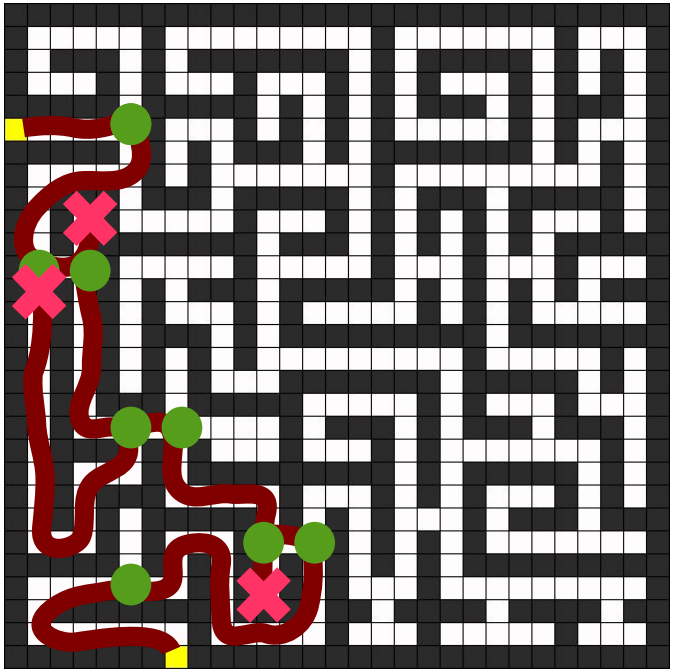

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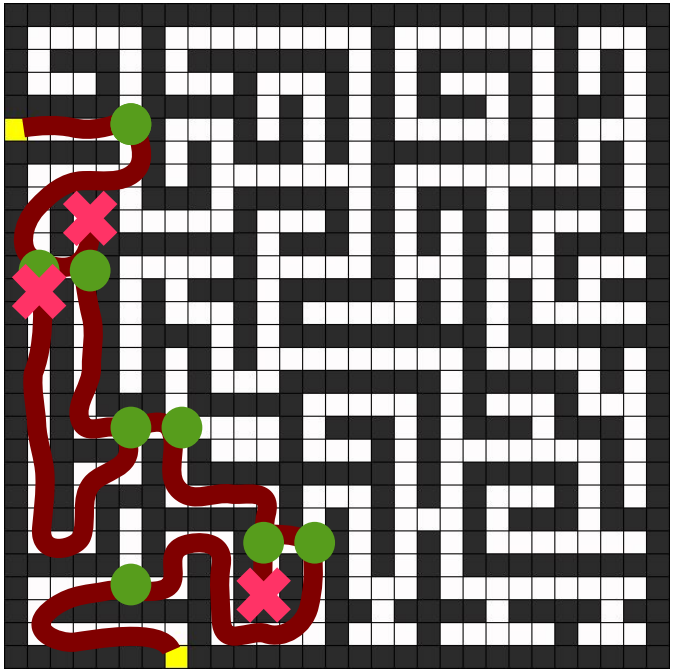
Why they haven’t been considered so far?

…generally computationally more expensive



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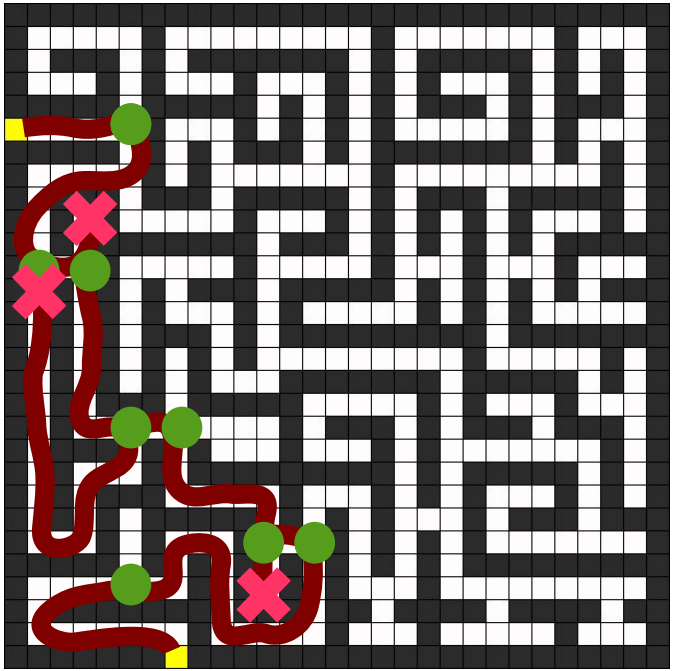
Yet, higher-abstraction constructs are more intelligible to humans.



“smart contract” most used meaning

= immutable low-level instructions
cloned on each node
running in a decentralized fashion

- What are the **differences** with respect to other programs?

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- What are the **gaps** with usual contracts?

“smart contract” most used meaning

= immutable low-level instructions
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- What are the **gaps** with usual contracts?

a bilateral contract is a formal agreement in which both parties exchange promises to perform

contracts vs “smart contracts”

- **Readability**: parties should understand what the agreement is about

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- **Control**: parties should maintain autonomy on performance. e.g. non-foreseeable conditions may cause justifiable release of duty, that can be assessed only *ex-post*

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- **Regulation:** there is not an equivalent of contract law or private law regulations (a sort of meta-contracts) in smart contracts
- **Informational model (e.g. normative primitives):** contemporary smart contracts allow to specify *imperative instructions* driving performance mapping only to positive duties. What about prohibitions? What about permissions, legal competences?

cf. normative systems, computational theory of law

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- Control and *ex-post* enforcement
- Amendment, Delegation, Mandate
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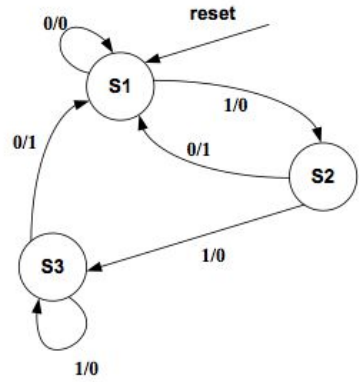

In most practical applications smart contracts depend on offline events, triggered by oracles. The environment “sets” the pace of execution.

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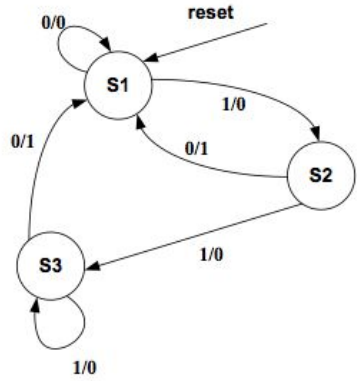

However, the **"dynamics" of contracts** depends not only on performance-related elements, but also **on contextual factors** (legal, social, physical) that ***modify the contract semantics*** itself.

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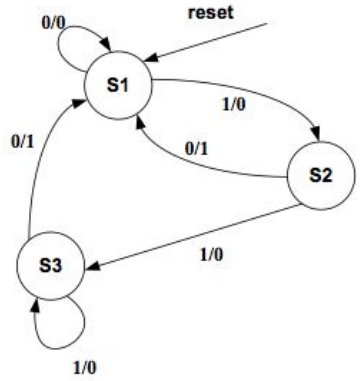

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The question is: **Can any socio-institutional systems (legal or not) be sustainable without these capacities?**

contracts vs "smart contracts" vs digital enforceable contracts?

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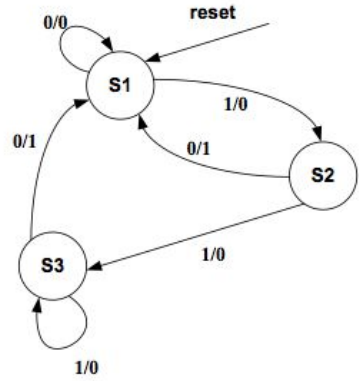

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