Smart Contracts and Formal Reasoning: "Should we trust in code after all?"

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- Introduction to blockchains
- In code we trust? Or the need for Formal Methods
- A brief case study (RegTech - Reporting Analysis)

Blockchain Origins: A brief history

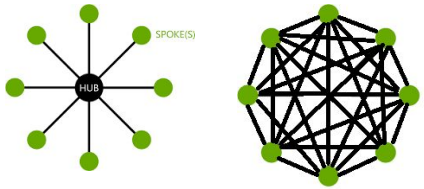
- **Satoshi Nakamoto** released the **Bitcoin White Paper** outlining a *purely peer to peer electronic cash/digital asset transfer system (2008)*
- **First** popular implementation of Blockchain
- **Ethereum**, **Hyperledger**, etc.

What is a blockchain?

- **Distributed database** that maintains a continuously growing list of **transactions** secured from **tampering** and **revision**.
- **Blocks** contain a **timestamp** and a **link** to a previous block.
- The **first** implementation of a blockchain was a public ledger of cryptocurrency transactions known as **Bitcoin**.
- This has led to the development of various **decentralized platforms**, which allow the execution of tamper free programs, called **smart contracts**, on top of such a blockchain.

Blockchain main features

- **Transactions**
  - Blockchain is a historical archive of decisions and actions taken
  - Proof of history, provides provenance
- **Immutable**
  - once written to the chain, the blocks can be changed, but it is extremely difficult to do so
  - In DBA terms, **Blockchains are Write and Read only**
- **Decentralized Peers**
  - each NODE has a copy of the ledger



Blockchain main features

- ## Consensus Algorithm
  - Ensures that the next block in a blockchain is the one and **only version of the truth**
  - Keeps adversaries from derailing the system and successfully **forking** the chain
- ## Smart Contracts
  - Computer code
  - Provides **business logic** layer prior to block submission

Blockchain	Smart Contracts?	Language	
Bitcoin	No		
Ethereum	Yes	Solidity	
Hyperledger	Yes	Various	GoLang, C++, etc, depends
Others	Depends	Depends	

Why are blockchains useful?

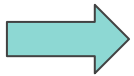
- **Tamper-proof data structure**
  - **No central trusted authority** exists
  - Participating parties do not need to **trust** each other
- **Improved traceability**
- **Enhanced security**
  - Blockchain has an opportunity to really change how critical information is shared by helping to prevent fraud and unauthorized activity.

- **Execution of smart contracts**
  - **Enforce** the negotiation or performance of a contract
  - Allows for **fair-exchange** (blockchain is the mediator)
  - **No direct interaction** between parties
  - **Open/verifiable** business logic

Disruption via Blockchains

Blockchains offer:

- Open business logic
- Immutability
- Verifiability



dApps:

- Cryptocurrencies
- Supply Chains
- Betting
- Self Sovereign Identity
- Funding (ICOs, securities etc.)
- ...

In code we trust!

or
Understanding the need for Formal Methods

But Should we?

- Blind trust in critical systems is not a good idea
- Open/Verifiable code does not mean **correct code**
- **Examples**:
    - theDAO hack
    - Parity freeze
    - Parity's multisig wallet
- **Fixing** (if possible) is very expensive (hard forks, updating clients etc.)

Software development Testing strategies?

Developer:

- Unit tests
- Integration tests

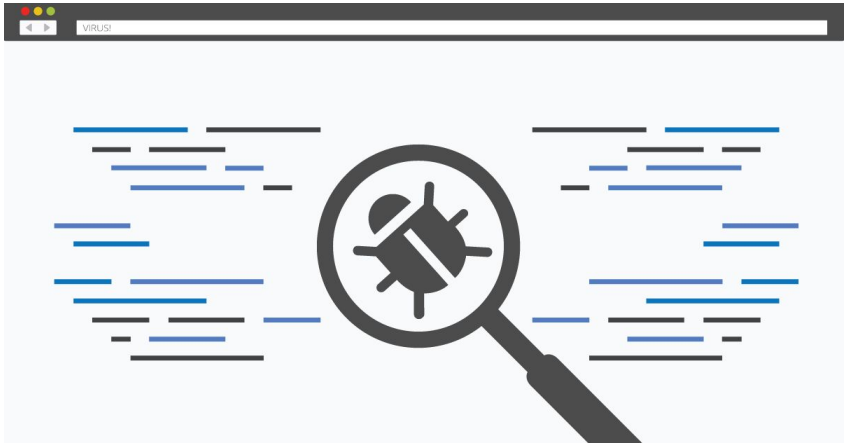
QA:

- Functional tests
- Performance tests
- Stress tests
- Failure tests

Security requires **reasoning**!

Informal Proofs

- Require deep thinking which promotes a better understanding of the system/algorithm
- Hard to get right!



High complexity
Errors (bugs) can be found in proofs as well

Automated reasoning is required!

Maybe we can!

- Raise the bar on security
- **Automated reasoning** in mathematical logic to provide **additional assurances**

Formal Methods

- **Precise** specification of system/algorithm
- **Tools** to validate correctness
  - Computer handles complexity and correctness
- **Human intuition** makes reasoning possible

$$
\begin{array}{ll}
\mapsto p & \\
\mid \text{Intermediate steps} & \\
\mid q \wedge \sim q & \\
\mid \_\_\_\_\_ & \\
\therefore p \rightarrow (q \wedge \sim q) & : \text{CP} \\
\sim (q \wedge \sim q) \rightarrow \sim p & : \text{Transposition} \\
(\sim q \vee q) \rightarrow \sim p & : \text{DeMorgan} \\
\sim q \vee q & : \text{EMI} \\
\sim p & : \text{Modus Ponens}
\end{array}
$$

Formal verification allows us to prove conclusively that certain error states can never occur or that a state will eventually be reached

Key point

- *“The introduction of a blockchain doesn’t magically make the system secure”*
- Companies proposing to join or use blockchains should ensure that they are **designed** and **configured appropriately** and processes are supported by their own internal controls**
- **Formal Methods can help!**

**https://www.icas.com/technical-resources/the-interaction-between-blockchain-and-corporate-reporting

A case study:

RegTech Project verification

What is the deRegtech Project?

- **Based on:** Blockchain Technology, Algorithmic Financial Contract Standards, and Document Engineering methods and techniques.
- deRegTech project deploys a **permissioned blockchain** that provides a distributed ledger for **collecting**, **publishing** and **storing** **information** related to the **creation** and **evolution** of **financial contracts**.

System Overview

When a contract is agreed between two counterparties:

- **jointly submit** their report to the blockchain part of the deRegTech Service.
- **smart contracts** process these data, based on:
  - **ACTUS*** standards and produce a **DTD**, in the form of a transaction and risk report.
  - follow a specific data model that implements a number of requirements made public recently

Regulatory Authority supervising these counter-parties can:

- obtain a list of all **reports in the system** (automatically)
- obtain for each such report all the **related information** (called state variables) for this contract.

The Regulatory Authority incorporates these data and functionality to its own financial/risk analysis system(s) to assess the risks undertaken by the counter-parties.

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*https://www.actusfrf.org/

DTD document model

types of components

ACTUS standards based interface

DL account

API

BANK

Financial Institutions

C4: market data

DTD

C1: Contract Identity Data
(Date, Instrument Identification Code, typeOfContract, etc)

C2: Counter-parties Identity Data
(essentially LEIs)

C3: Contract Financial Data
(Price, Currency, initialDate, maturityDate, cycleOfInterest Payment etc)

C5: Standard Input for FinAnalysis

states of evolution

Raw results, in particular cash flows

accounting

regulation

economic analysis
(liquidity, value, income, risk)

Important Issues

1. **Data validation**
    a. Is the information inserted in the system accurate?
2. **Access control policies**
    a. Who gains access to which part of the available information

Goals

- How can we develop a **formal framework for reasoning about smart contracts**?
  - Reasoning about smart contract business logic.
  - Implementing business logic correctly.
- Minimum **Safety Property**:

> *"It is not possible to have a "confirmed" contract in deRegTech system without the the approval of all involved parties first".*

Core Ontology for Blockchains

We can identify in a Blockchain system the following basic structures;

- **Subject**
  - The elements of the sort Subject, are used to denote the **users of the blockchain**.
- **Object**
  - Objects denote the **entities** **on which the** **actions** of the system **are** **applied**.
- **Actions**
  - The Action domain contains all the **actions permitted in a blockchain system**
  - The actions defined in our system are the following: createAccount, createContract, updateContract, validateContract, getReport
- **Transactions**
  - The elements of the Transaction domain denote a desire or a **request by the subject to execute an action on the object** of the transaction.

State Transition System and Blockchain

- The information contained within a Blockchain constantly changes!
- To address this, we define a new structure, called **State**, which represents the **state space** of the blockchain system.
- State constructors:
  - A new **constant** is declared, ***init*** : → State, which denotes the **initial state of the system** (i.e. it represents the genesis block of the blockchain).
  - Three **constructor** functions are declared, which define how a **new state of the system can be derived by a previous one**, ***sendTransaction***, ***validateBlock*** and ***Tick***.

State Transition System and Blockchain

- ***State Transitions:***
  - ***sendTransaction***: *State Transaction* → State, denotes that a **new transaction** is sent to the system.
  - ***validateBlock***: *State Transaction Transaction* → State, denotes that a set of received transactions were considered as valid and their actions took effect **altering the state of the blockchain** (i.e. represents the mining of a new block in the blockchain).
  - ***Tick***: State → State, denotes the **passing of time** and is required because the information retrieved by a smart contract may change depending on this.

State Transition System and Blockchain

Two more State Transitions are defined;

- ***pendingTransactions***, which denotes the transactions submitted to the system but are not yet verified, i.e. the transactions which are pending validation.
- ***objects***, which given an element of the sort State returns a set of object sorted elements and **denotes the objects that belong to the blockchain at the given state** of the system.

A blockchain can thus be thought of as a **State Transition system**, where:

- each **state consists**: of the status of the core entities of the system, and
- each **state transition function**: takes as input a previous state of the system and a transaction and gives as output a new state.

Reasoning with Algebraic Specifications

- **Algebraic specification** method is considered as one of the major **formal methods.**
- Systems are specified/designed based on **algebraic modeling**.
- The specifications/designs are tested/**verified against requirements using algebraic techniques.**
- The **behavior** of systems can be nicely modeled by **algebras**.
- CafeOBJ is an algebraic specification language.

Formal verification of the desired goal

- Using the OTS/CafeOBJ approach, we successfully verified that the specification satisfies the desired system property.
- The full specification of the proposed system and the proofs can be found at CafeOBJ@NTUA [https://cafeobjntua.wordpress.com/].

Key Takeaways

- Blockchains build trust
- To trust code, testing is not enough
- Blockchain **benefits** come at a **cost**:
    a. Design Error Resilience
- **Formal Methods** could be a feasible answer to addressing this problem
    a. Correctness by Design Engineering
- Risk reporting using a **blockchain** is **feasible**
- May **aid** regulatory authorities and society at large in **overshighting** the global financial system

Who is involved?

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Thank you for your attention!

Questions?