

# A CAD-Blockchain Integration Strategy for Distributed Validated Digital Design

## *Connecting the Blockchain*

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*We present a proof of concept implementation of an integration strategy for connecting CAD with Blockchain. We explain the components of most blockchains and the value they bring to the built environment ecosystem, the potential impact a complete integration might have and we demonstrate the first two of four levels of integration we have identified between CAD and blockchain technologies. For the purposes of the paper we use Rhino / Grasshopper and Ethereum as the two components of integration.*

**Keywords:** *Blockchain, Cryptography, CAD, BIM, distributed ledgers, cryptocoin, distributed CAD*

## **INTRODUCTION**

Blockchain technologies have emerged since the appearance of Bitcoin [Nakamoto year?] as a key digital infrastructure powering various functions within the economy [Kinnaird et al 2017] and cities [Coyne et al 2017]. Beyond the hype, reports have described the potential of Blockchain [BRE report year?] to profoundly affect the digital infrastructure [Kinnaird et al 2017] that runs the build environment but also the digital tools that we currently use to design architecture. We present the first connection of a CAD system with a Blockchain on two levels of integration, along with the strategic description of two other possible levels with current technology. Connecting CAD and BIM systems with a blockchain can have a profound effect on the design of cities but also on their operations [Lombardi et al 2018, Tamke et al 2014]. Previous efforts in distributed, interconnected systems have gone so far as creating protocols for plat-

form agnostic communication between 3d software over the internet [Hnidek, J 2011] without though connecting CAD and 3d modellers with other programmes and protocols. We believe that blockchain has the potential to unravel a lot of the locked potential in interconnecting CAD and BIM tools with economic life, and in extension directly with the physical world.

## **RATIONALE**

The paper presents a first attempt at connecting blockchains with a cad system. While the connection is not at the level of a full BIM system, but rather remains on the conceptual level, the rationale of implementing this drives a desire to advance the state of the art in CAD and BIM integration with various other digital infrastructures but also the aspects of the physical world.

Longest Proof-of-Work Chain

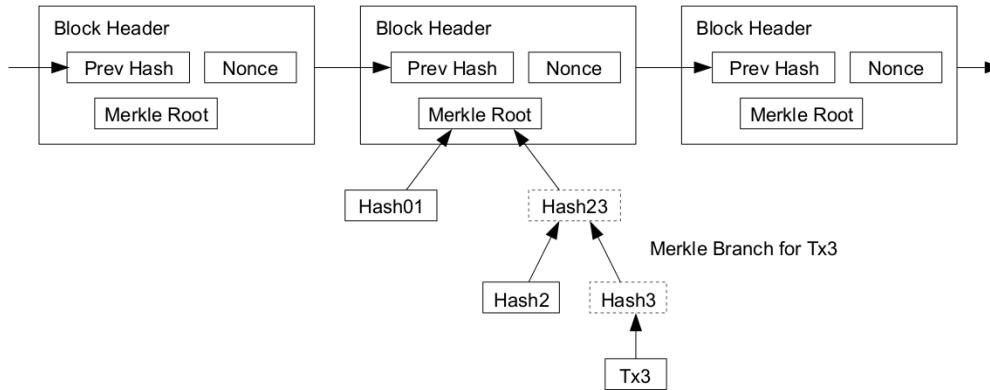


Figure 1  
Diagram of a  
blockchain- from  
the Ethereum  
whitepaper

## BACKGROUND

To explain the potential of Blockchain and the impact of integration between CAD and Blockchain some definitions are needed first. A blockchain is a distributed database which is build out of blocks of data (figure 1). Various computer nodes on a network share the database and have the task of creating new blocks. The blocks contain an index number, a timestamp, data that we want to store in them, usually a monetary transaction in the case of cryptocurrencies, and a crypto-hash of the previous block. The whole block then gets cryptographically 'hashed', i.e. encrypting the data it has and the previous block's hash, into a new hash of specific length. Within this mechanism a chain is created between blocks hence the name 'blockchain'. In parallel Nodes listen for transactions between other nodes, and when a transaction is to take place, they will verify the validity of the transaction by collectively checking the record or ledgers of the blockchains that they have stored. This is a validation process that takes place in most blockchain technologies- the node(s) which validates a transaction first is rewarded by the system with a small amount of cryptocurrency. Once this cryptocurrency gets generated, its block is added to the blockchain by the listening nodes, which then

turn again towards validating the next block. That process is called mining and is hugely energy expensive [Lombardi et al 2018]. Certain blockchains, like Ethereum, have also additional features that allow for true integration with a wider digital infrastructure. Smart Contracts are contracts that are executed within the blockchain autonomously, without human intervention when certain events take place- dApps, or decentralised applications are applications that run on the Blockchain, making good use of smart contracts. A public blockchain can run on a public open network like the internet or a private blockchain where the nodes are cryptographically identified first before they participate. In the public blockchain, the proof-of-work that the original bitcoin paper [Nakamoto2009] describes solves the Byzantine-Generals problem that former distributed systems could not solve. For example the verge protocol running on Blender, had to identify a master and slave nodes to be able to synchronise and avoid corruption of 3d data due to the nodes being in an asynchronous state. Still, in terms of connecting external applications with the blockchain, in case like the ones developed in this paper, one needs to introduce the concept of an 'Oracle', i.e. a node which does not participate directly in the resolution and val-

idation of blocks in the chain, but does provide data for inclusion in the blockchain, more so when these are used for executing or triggering a smart contract. This introduces again the problem of identity verification by cryptographic means, but this is out of the scope of this paper.

## **IMPLICATIONS OF BLOCKCHAIN IN CAD AND ARCHITECTURE**

Less than twenty years ago bank transfers were the only way to send money to someone else located in a different town or country and the whole system was based on a trustworthy process that involved four subjects only: the sender, the bank that sent the money, the bank that received the money and the receiver itself. Since the Internet has been made available to everyone with a computer and a phone line (and nowadays the two things often match in one device only), our habits started a rapid process of changing and now it seems to be unstoppable. Websites and apps like ebay, Paypal, payzone, stripe created a new system in which banks are almost no more necessary for building direct relations between the sender and the receiver. Further, even if their first mission is not to exchange money, companies like AirBNB and Uber have started a process in which centralized services like hotels and taxis become available in a distributed manner and are validated through a system of rates defined by user demand and feedbacks. In this distributed economy context the frame changes from one in which the quality of the provided services and transactions is validated by abstract entities to one in which final users are in charge to evaluate the nature of goods and services and either reward the companies or discard them from their range of choices. Those digital platforms can be seen as early digital cooperatives with incredibly high numbers of people who use them thanks to new paradigms of trust [Coyne et al 2017]. The trust is then based on checking comments and feedback from other users rather than on the validation coming from an official document issued by a bank. But ratings, feedbacks and com-

ments are only the tip of the iceberg. Below the surface, encrypting algorithms control an endless number of transactions and contracts that are stipulated everyday between digital-based companies and final users. Further, because of the digital nature of both companies and user accounts, a process of decentralisation is now almost complete between provider, user and financial intermediary that do not have to be in the same place and in the same time to discuss and finalize the exchange of goods/services for money. Within this radical change on how digital infrastructures enable maximum flexibility of ownership and use, the built environment in contrast remains a conservative fixture.

The built environment is now facing the effects of the changes produced at different levels by Information Technology. The ability of IT of being encapsulated into small components and objects, made by sensors and micro-chips, led to first applications that aimed to improve our daily quality life through the interaction between us and the appliances that populate our houses.

A second most complicated step is now transforming the way in which inflexible physical entities like buildings and cities are actually designed and built. Building Information Modelling is accepted as the standard for designing buildings in which all the components are defined throughout all their life, from production to installation, maintenance and dismissal. Different BIM levels are recognised according to the UK government [Harty et al 2016]: from the Level 0, simply based on CAD and with no interaction and cooperation between designers to the Level 2, currently in use and characterised by “an information exchange process which is specific to that project and coordinated between various systems and project participants” [BimPortal] in which all those involved in the design process share the same data and work in parallel. In this level-based system the next step is defined as Level 3 BIM and presents a wide range of action points in which we find the creation of new kinds of contractual frameworks (i.e. performance-based contracts, smart con-

tracts), data-validation processes and managing fast transactions between builders and clients.

To realize the expectation of the Level 3 it appears then necessary to rely on some other form of technology who allows to track the information and secure them via encrypting algorithms. The blockchain can then represent a tool to be integrated with BIM and able to provide solutions for the above mentioned instances. Distributed Ledgers (DL) such as Ethereum can support the request of smart contracts based on the evaluation of performances against specific criteria. An “if/then” statement could be implemented to help reducing the timing required for delivering payments as well as simplifying the administration of financial aspects related to the construction stage. At the same time the DL will ensure the security of the data through automated validation and predictable cryptographic implementations as well as the ownership of each digital components.

## IMPLEMENTATION

We have identified four levels of connection and integration between CAD/BIM and a blockchain (figure 2). The basic one integrates a simple blockchain

into the CAD/BIM software. The second level of the integration, which is straightforward using current technology, connects the CAD/BIM client with the blockchain, in our case a test network built on Ethereum. The third and fourth cases, involve the inclusion of a computational node of Ethereum within the computational construct of the CAD/BIM software, while the fourth level integration involves the running of the whole database of the CAD/BIM software directly on the Ethereum Blockchain, i.e an implementation of a CAD/BIM dApp on Ethereum.

We chose Rhinoceros/Grasshopper/gHowl for our implementation. However the same can be shown for REVIT or even Autocad, or any CAD package that incorporates a computer language interpreter and the possibility to communicate over a computer network.

### First Level of Integration

The first level of integration incorporates a basic blockchain written in python within the environment of Grasshopper (Gh) on Rhinoceros (figure 3). A basic blockchain ensues the public network capacity of a normal blockchain and records information in a series of blocks that are cryptographically hashed.

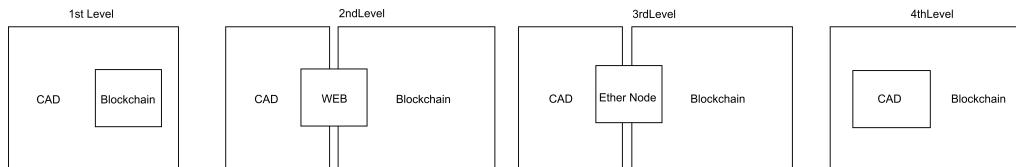


Figure 2  
Four levels of CAD -  
Blockchain  
integration.

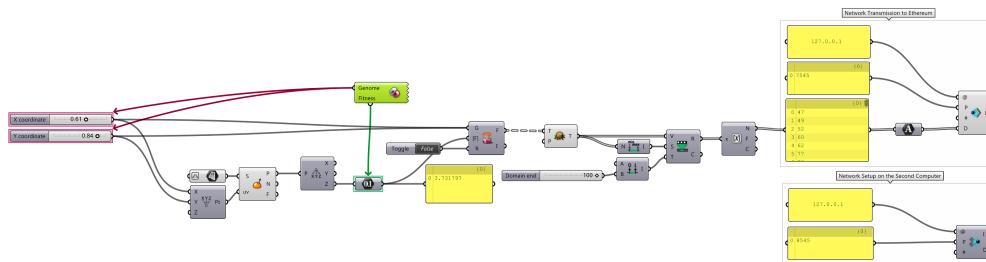


Figure 3  
Level one

In this implementation we have executed a simple command, and copied a circle from one position to another. These have then been referenced inside Grasshopper, analysed into control points, which in turn have been converted into mathematical sets. From these sets we can calculate the difference between the coordinates of the two groups of control points. This difference is then fed into the python blockchain. The blockchain runs autonomously within Grasshopper and no connection to the outside world are created. It comprises of five elements, a definition of a block, a blockchain, a hashing algorithm, the first 'genesis' block and the executive function of the code. Another input into the blockchain is the number of blocks to be generated. This is done for simplicity in the proof of concept. The full implementation would connect each block generated with the actions of the computational designer, one block generated for each action. The difference is fed into the variable 'diff' while a simple string is fed into the first block of the chain. The blockchain then encrypts with a hash the first string, produces the first genesis block and continues by producing the rest of the blocks incorporating in each block the string that represents the difference between the original and the copied circle.

This is a basic implementation of the CAD / Blockchain integration. Due to its simplicity there is no distributed, and thus trust-less verification, of the contents of the blocks. The implementation points towards the importance of recording difference within the software, from a state to another. Similarly, Grasshopper's beginnings were the creation of an explicit modelling history [Tedeschi 2014], which fits conceptually with the understanding that this first implementation of blockchain creates an immutable record, capturing the history of a difference between an original and a copy.

### **Second level of integration:**

We then present a proof-of-concept optimisation algorithm that attempts to find the highest point on a curved surface. The algorithm then transmits the

optimisation value as a percentage over the internet where a smart contract on Ethereum is listening, so that it pays in issued tokens on the Ethereum blockchain as soon as they receive a value above the required minimum threshold.

```
pragma solidity ^0.4.21;

contract CAD {
    uint public value;
    address public seller;
    address public buyer;
    enum State { Created, Locked,
        ↪ Inactive }
    State public state;
    function CAD() public payable
        ↪ {
        seller = msg.sender;
        value = msg.value / 2;
        require((2 * value) == msg.
            ↪ value);
    }
    modifier condition(bool _condition
        ↪ ) {
        require(_condition);
        _;
    }
    modifier onlyBuyer() {
        require(msg.sender == buyer);
        _;
    }
    modifier onlySeller() {
        require(msg.sender == seller);
        _;
    }
    modifier inState(State _state) {
        require(state == _state);
        _;
    }
    event Aborted();
    event CADConfirmed();
    event SolutionAccepted();
    //abort function truncated

    function confirmCAD()
        public
        inState(State.Created)
```

```

condition(msg.value == (2 *
↪ value))
payable
{
emit CADConfirmed();
buyer = msg.sender;
state = State.Locked;
}
function confirmCAD()
public
onlyBuyer
inState(State.Locked)
{
emit SolutionAccepted();
state = State.Inactive;
buyer.transfer(value);
seller.transfer(this.balance);
}
}

```

To determine that, the smart contract on Ethereum is set up to receive the optimization values over the web, with the identity of the computational designer received simultaneously on another part of the Smart

Contract. Essentially in this scenario the CAD system Rhino/Grasshopper acts as an 'Oracle', a node external to the Ethereum blockchain providing information to the Blockchain. Within our implementation identification is not required as we are executing the contract in a private blockchain. In the public Ethereum blockchain identification would be needed on the Rhino/Grasshopper side, which means that each CAD node would need its own ETH Address on the network, which would be closer to the third level of implementation.

The technical implementation of the second level follows as such (also see figures 4, 5):

Computational designer registers her identity with first aspect of the smart contract. -say port 1111 at address 127.0.0.1. Her identity is represented by an ETH address 0xC2EeD2f6717a895090601fAc01F501201d3E1490. Then on CAD: Rhino/Grasshopper (acting as Oracle) the computational designer solves the problem using Gh, and communicates with GHowl on port 2222 to a webpage hosted by web3.js. The server passes

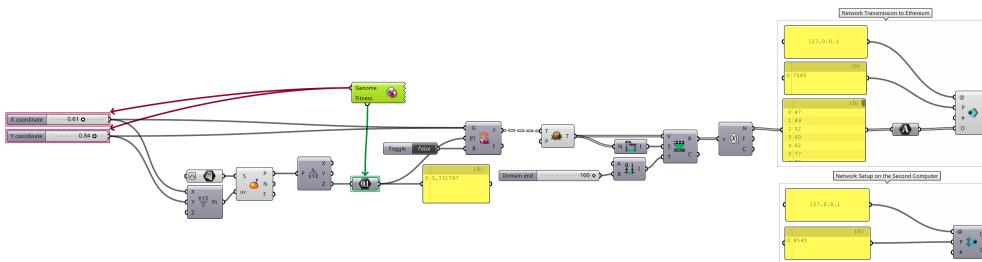


Figure 4  
Gh-gHowl  
communication  
plus optimization  
problem

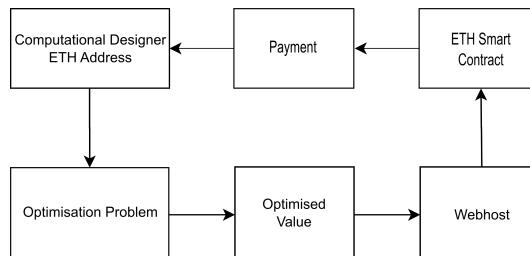


Figure 5  
Technical  
implementation of  
the second level of  
integration

the value to the Oracle service, for example realitykeys.com, or Oraclize. This in turn passes the value to the smart contract which on Ethereum checks for compliance, then executes a monetary transaction, sending an amount of ETH or tokens to the address the computational designer registered with. The contract then closes or regenerates accordingly.

### ***Third and Fourth level of integration***

In a future third level of integration the system would involve the building of an Ethereum node inside Gh. This would take care of communicating and registering the Gh definition with an Address on the Ethereum network. Then as a sequence, the node could record the differences between subsequent versions of the file, encoding them as blocks. This would enable the production for example of an immutable record. The fourth level of integration would involve running a complete application of CAD/BIM on the Blockchain directly, hence transforming CAD/BIM into a decentralised application.

### **IMPACT**

The impact had by digitalization and the Internet on daily life is currently affecting the way in which human activities are both conceived and organized. There do exist Architecture offices which are already operating as decentralized autonomous organizations who shares ideas and develop products before selling them in a digital market. This can take place from the second level of integration and above, or it can take place by just creating an independent dApp that triggers payments every time a digital CAD asset is used. Examples of community of architects who share ideas or take part to on-line competitions announced directly by clients are already a reality that exists thanks to the fastest way of communication we have ever had, the Internet. Indeed, being immersed within an invisible network which carries every kind of information and connects devices that allow people to develop and share both ideas and business from all over the world, is putting into discussion many of the traditional concepts of collaboration, au-

thorship and monetization. Within these concepts a public blockchain seems to be an infrastructure that can sustain and govern the next level of authorship and collaboration on a trustless level, i.e a plateau where smart contracts will guarantee execution. The need of a platform and a system who can assure the correctness of the design transaction between the designer and the client is far more evident when most of the contacts and documents between those two entities have no more a physical aspect, and are readily enforceable using the Blockchain, with no possibility for dilution, skewed information or uncertainty on who edited which file or aspect of a CAD or BIM model. Current digital technologies such as BIM and Blockchain can provide together a secure way for designers to engage with the both a new enlarged market and building requirements without losing the control of their projects [Carpo, M, 2017].

### **CONCLUSIONS AND FUTURE CHALLENGES**

This paper presented an integration strategy between CAD and blockchain technology in an algorithmic platform. The integration was experimented at two different levels: first level to test the feasibility of recording differences between two sets of cad objects and a second one in which the differences are recorded, evaluated and sent to a blockchain platform as Ethereum. Both have been conceived as starting points for the following step in which Ethereum nodes will be implemented into the algorithm allowing the recording of immutable strings of blocks. On the integration level, open APIs and interoperability capacities in certain software will prove crucial for complete integration.

Further questions to be tackled will concern the feasibility of writing codes who are able to run on private and public networks as well as moving from CAD to BIM systems. The first implies the necessity of testing them across countries and checking potential issues due to firewalls and local internet limitations. The latter will require the implementation of further BIM levels as defined by standards specifications and integrate a cryptocurrency payment method, along with other potential financial instruments.

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