Master Thesis Proposal

BIM data management using smart contracts

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January 16, 2020

1 Problem statement

During the last decades, building information modelling (BIM) has emerged as a technology that can improve significantly the efficiency of the planning, construction, and management of buildings.[1] By making a digital twin of the building, all stakeholders are promised detailed and up-to-date views of the state of the building at any given point in time.[2] However, the Architecture, Engineering, Construction, Building Owner / Operations (AECOO) Industry has not had high BIM adaption rates. [3] Some factors have been identified that have had a negative impact. Among them are challenges related to data storage, access, and security, the management of cash flows between contractors, the handling of changes done to the building model, and the collaboration and trust between the parties involved, which in the case of the AECOO industry, is important and complex.[4][5]

On the computer science front, the last few years have seen developments in new technologies built around security and decentralisation. This was, in a way, kickstarted after the introduction of Bitcoin, a peer-to-peer electronic cash system that eliminated the need for a central entity to provide trust or verification services. [6] Bitcoin uses blockchain, otherwise known as distributed ledger technology, which handles the transactions between the peers. Because of the inherent properties of security, decentralization, efficiency, and the elimination of the need for trust (trustlessness), blockchains are now being looked at as a technology that could play an important role in the transformation towards more decentralized and secure systems. This led to the creation or developments of other related technologies that move away from the server-client paradigm. Smart contracts and distributed file systems are examples of such technologies that complement and extend blockchains to provide added functionality.

The process of constructing a building involves multiple phases. During each of them, multiple and different stakeholders take part by providing their inputs to the building model. Each stakeholder has competency in creating certain parts of the building information model. Additionally, the stakeholders typically involve many third parties who specialize and provide their expertise in different areas. For example, the building owner would value that the architects get input from the electricians regarding the placement of the different equipment, but also from the authorities to guarantee compliancy with the latest regulatory standards. Having a platform where such collaboration is available can not only streamline the process, but also prevent unexpected costs at later stages of the project. The collaboration usually involves some decision making that can be encoded in computer programs, which is why smart contracts are suitable. Finally, in order not to have any loss of information, all of these updates and changes to the model should be stored in such a way that they can be tracable and secure.

2 Expected result

The expected result of this thesis is a formal description of a tool that will allow collaboration between stakeholders during a building's lifecycle. In the context of building construction and facility management, BIM is applied in environments where there is lack of trust between entities, even though they need to exchange valuable and sensitive information. Based on the methodology proposed by Wuest and Gervais, it was evaluated that the use of blockchain is suitable for this given application.[7] This methodology will be used to decide what kind of blockchain will be used.

Subsequently, a blockchain based model will be devised, which will focus on the management of BIM data in a distributed environment. The data that will be generated and accessed by the IoT devices in the building will also be taken into account.

An important component of the model will be how the BIM data is stored and accessed. In this regard, different technologies will be evaluated in order to identify a way to store BIM data in a distributed file system. This includes looking into an efficient and suitable method how this data can be structured and represented, in order to also provide version control and tracebility. Additionally, smart contracts will be looked at as a means to run automated or intelligent tasks that will simultaneously provide reliability and consistency.

For the practical part, use cases will be defined which will be used to make a proof of concept, finally to be evaluated and validated. This will present a tool that can ultimately be extended and used in the AECOO industry.

3 Methodological approach

The thesis will be structured as following:

- Literature review

  Given that the technologies like blockchain and smart contracts and their BIM applications are a fairly recent development, research will be carried out as to what would be the most suitable way to use them for this purpose. Additionally, trends and future perspectives are important factors here, since the technologies are still rapidly changing and evolving.

- Description of a theoretical model

  The model that will be described here will serve as a description of a system that encompasses the goals of the thesis.

- Proof of concept

  The proof of concept will be based on the model described previously. By using use cases, which will capture the most important aspects of the problem, it will be shown that the technologies described can be used to implement such a system.

- Analysis

  An analysis of the resulting work will determine what are the advatages and shortcomings of the solution. Additionally, alternative implementations will be discussed.

4 State of the art

The academic sphere has expressed interest in exploring how BIM could be used in conjunction with the decentralized technologies mentioned above. A few of them are mentioned below.

In their paper, Turk and Klinc point out the importance of proper management of legally significant information in the AECOO industry. For example, what entity did the BIM modification and what was its timestamp can prove to be very valuable information on later stages of the project. Furthermore, four different scenarios are described how building information models can be combined with the blockchain or stored on it. Among them, according to the authors, the proper way would be to separate the large data files containing the building information model from the operations done on the model. For example, a BIM server will store the BIM data while the transaction data will be stored on the blockchain.[8]

With arguments against centralization, Nizamuddin et al. provide an alternative perspective, where the BIM data can be stored in a decentralized file server. Since current blockchain implementations are very inefficient at storing large files, another file system is used. This runs in parallel to the blockchain and stores the files in a decentralized and secure manner, while providing a hash value that points to the file. The hash is stored on the blockchain, linking both components of the system together. Additionally, the authors propose a version control system. Every time an entity submits a change to a file, a smart contracts handles the approval process and stores the file into the file system while simultaneously linking it to the previous version of the file. [9]

Smart contracts in combination with IPFS are also explored by Dounas, Lombardi, and Jabi. Here, a collaboration mechanism has been described that allows participants to submit design solutions to problems raised by a stakeholder. The design optimisation performance is the used of as a consensus mechanism. Again, BIM data is stored on a distributed file system, while a hash is stored corresponding to the data on the blockchain. Smart contracts are used to compare the most optimal solution against a predefined

threshold. Once a new optimum has been established, the smart contract updates the state of each node to the current optimum. [10]

Another attempt to provide an architecture of a system that combines BIM with blockchains was made by Zheng et al. The system described consists of what they call a BIMaaS part that facilitates BIM data management. The idea is to have a platform that will allow data sharing and thus collaboration between the stakeholders. Blockchains are used as means which guarantee to trace, authenticate, and prevent the tampering of BIM data. [11]

By arguing that blockchains, IoT, and smart contracts complement each other, Li et al. suggest that BIM implementations can benefit greatly from them. The idea is to link the physical and the digital worlds with each other. By means of smart contracts the agreements can be represented digitally. In their work, the authors give some use cases as proof of concept. These simulate different scenarios that can occur during building construction and show how smart contracts can be coupled with project delivery. [12]

5 Relation to Computational Intelligence (Logic and Computation)

The thesis proposed is expected to touch some areas covered by the master's programme Computational Intelligence (now Logic and Computation). Noteworthy to mention here is the strong focus on theoretical computer science. Courses such as Formal Methods in Computer Science will help with the formal description of the system as mentioned above. Furthermore, in Discrete Mathematics the basics of cryptography are mentioned, which is a very important component of blockchains. The course Graph Theory covered different data structures, such as trees, that are a very important part of blockchains but will be also taken into consideration as a method to efficiently store BIM data. The material covered in Database Theory will also serve as the basis for some aspects of the thesis. On the other side, multiple courses have practical parts, which taught the modeling and implementation of different algorithms. These are related to the use cases that will be implemented in the work proposed here.

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