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Blockchain Grammars for Validating the Design Process

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Abstract

This paper presents and develops the concept of Decentralised Autonomous Organisation (DAO) as a platform for collaboration, via a design scenario in which Blockchain (BC) technology is implemented for validation purposes. The envisioned scenario simulates designers proposing multiple solutions for a given task and adopting shape grammars and environmental analysis and regulations as design drivers. Proposed solutions are uploaded, stored, presented, and evaluated in a DAO in which the decision process gets validated via the reputation of the participants and its governance system. This study lays the foundation and ignites the development of a larger framework in which design collaboration and competition are fostered and results secured, impacting design value and financial transactions.

Keywords: Shape grammar; Blockchain; Decentralised autonomous organisation; Design validation .

INTRODUCTION

Decision making and project governance in architectural design rarely receive scrutiny by researchers within the discipline of architecture. In a previous paper (Lombardi, Dounas 2019) we described and established a theoretical mechanism for project governance using the Ethereum Blockchain, via the creation of a Decentralised Autonomous Organisation, i.e. an organisation that makes decisions via smart contracts that are executed on the Blockchain platform.

In our system, we described a group of shape grammarists making decisions collectively by using the voting mechanisms of the DAO to accept or reject decisions that are encoded as shape grammars. The present paper is the validation and implementation of that system.

BLOCKCHAIN AND DECENTRALISED LEDGERS IN THE BUILT ENVIRONMENT

Blockchains are decentralised state machines with Turing equivalence (Turing, 1936). They employ a Proof of work or Proof of stake consensus mechanism to establish a common truth, and depending on their architecture they can be used to run software, which are called smart contracts. Due to their decentralised and immutable record nature they have been used for cryptocurrencies applications but their potential is vastly wider. In the built environment they already showed an excellent fit for the fragmented nature of the industry, with successful applications promoted from researchers in the field of supply chains, (Li et al, 2019; Kifokeris et al,2019), while their use in design proves to be still overlooked (Li et al, 2019).

For the purposes of validation, we introduce a design exercise and a DAO that is used to make decisions for a design problem. The design exercise seeks to maximise the light conditions in a series of apartment towers in China, and is explored using via a generative plugin for shape grammars and a plugin for lighting condition simulation and analysis.

Our Decentralised Autonomous Organisation has been created using automated tools created by D.Org. For the purposes of testing it has four members, that can create proposals, vote, and administer the DAO. Our validation test does not use yet any tokens or financial incentives while relying only on incentives of reputation within the DAO. However, since we have conducted our experiment on the live Blockchain, it is trivial to test with real tokens as well. The DAO is located on the following address 0xa71f15913d0ac603ad886e16c0568afb9ab45537 and can be accessed via the web from the related (https://alchemy.daostack.io/dao/0xa71f15913d0ac603ad886e16c0568afb9ab45537).

Note that the use of an Ethereum wallet to connect to a Blockchain node will be needed to access the full functionality of Alchemy, the web interface set up by DAOstack. (https://daostack.io) to facilitate the creation and management of DAOs. While the Etherum Blockchain is excellent for the recording of numerical values or hashes, it is not really optimum for the storage of real files as it is very expensive and it would happen in the normal design practice. To store files for proposals, we use IPFS, the interplanetary File System which is a decentralised file system allowing to have full decentralisation in our governance for design project.

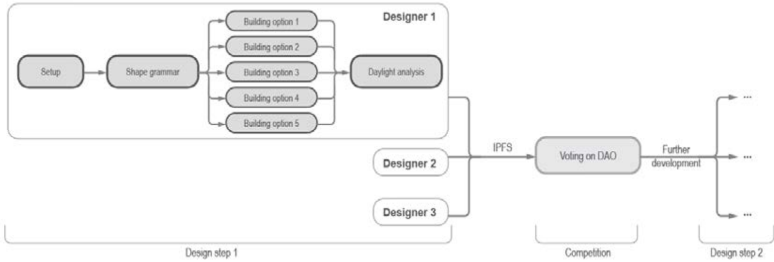

Figure 1: Schematic of the applied workflow

1 CASE STUDY INTRODUCTION

CASE STUDY BUTTERFLY BAY / HUDIEWAN COMPOUND IN SUZHOU INDUSTRIAL PARK

Butterfly Bay HuDieWan is a compound built twenty-five years ago in the Suzhou Industrial Park (Dounas, Spaeth, Wu, Zhang, 2017) on the Yangtze River delta. It is based on the repetition of a series of towers which its typology can be commonly found in most of the modern Chinese residential development.

The monotony of the built environment provided the right setting to establish a test-environment in which applying shape grammars as a mechanism to generate diverse design options and evaluate efficiently as a parametric system. Further, the new proposals have been analysed against the criteria of sunlight analysis in order to provide an objective way to compare the different shapes. Firstly, we analysed the mandatory building environmental parameters according to the local building regulations. Then we employed various shape grammars and daylight analysis in order to let the generative and evaluative system improve the current housing composition.

2 WORKFLOW

SETTING PARAMETERS AND CRITERIA FOR THE SUNLIGHT ANALYSIS

The environmental performance focused on a daylight analysis carried out by following the official building code for Jiangsu Province that includes the Suzhou Industrial Park area, 'Jiangsu Province City planning and technical specification – Suzhou implementation detail 2 - "daylight analysis rules" (2018 version)' (Jiangsu, 2018)

For residential building, it is required that the main façade provides a minimum of two direct daylight hours a day on the so-called Great Cold day, 20th January 2001.

For effective comparison between different design options based on the generated shapes, we kept the numbers of building, locations and dimensions consistent with the current built development on site.

IMPLEMENTATION: RHINO- GRASSHOPPER

The applied computational modelling environment relied on Rhinoceros with Grasshopper plugins operating shape grammar transformations and daylight simulations. We adopted the SortalGI plugin (Sortal, 2019) for setting up shape grammar rules and developing shape transformations. The Sunflower plugin (Sunflower, 2020) is applied to run direct sunlight hour simulations. We use shape grammars to generate design variants, as they provide an excellent vehicle to encapsulate design variation and generative options for designs. The shape grammars generative power allows for the creation of various options that would essentially also be created in a real design environment. Hence, since the point of the exercise is to explore design project governance, shape grammars are an excellent tool for creating all of the design alternatives.

The workflow can be divided into four parts:

1) we prepared the overall test and display environment;
2) design alternatives are generated by designers via shape grammars and turned the final shapes into buildings for simulation purposes;
3) we ran daylight simulations according to the regulations as mentioned earlier and specifications;
4) we extracted data for the voting process on the DAO. (Figure 1)

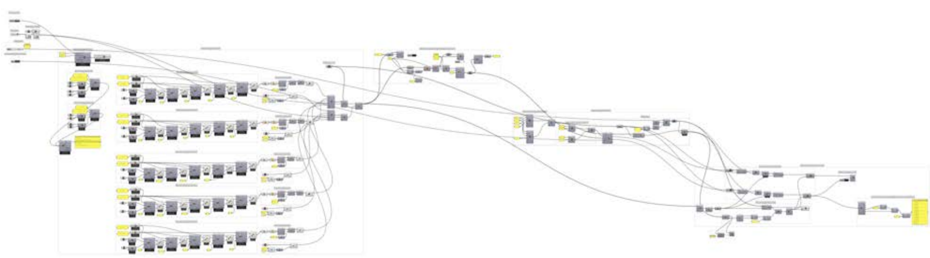

Figure 2: Shape generation and daylight analysis algorithm

(I) SET UP

The initial set-up is meant to create the controllers that will guide the different shape grammar combinations and the following sunlight analysis. The selection of specific design options enables full control over the algorithm (Figure 2) as well as it provides the option of displaying the main façade of each newly designed building to ease the reading of analysis results and files preparation in light of the uploading onto the IPFS platform.

(II) SHAPE GRAMMAR BUILDING GENERATION

We selected three basic transformation types of shapes and then they have been applied in different combinations to create three sets of tests (Figure 3).

	Transformation	Transformation type	Rules
Test 1	Translation only	Eculidean	
Test 2	Translation, mirror	Eculidean	
Test 3	Translation, scale and rotation	Eculidean and similarity	

Figure 3: Rules governing the shape grammar

In order to simulate a competitive or collaborative design environment, three tests have been produced as a simulation of three designers engaging with the same task. The system of the DAO can scale to more than 500 agents or designers operating on this. For the purposes of the paper we have elected to constrain it to three, so as to fit within the resources we have available. Each test follows a set of predefined transformation rules generating five different results via a different sequence of transformations.

We then extracted the outlines of the final shapes as the five floorplan options (Figure 4) to be used as bases for modelling the three-dimensional buildings. The three-dimensional buildings are then allocated to the original site by using one design option for all seven towers on the site at a time.

Figure 4: Summary of the generated floorplans

(III) DAYLIGHT ANALYSIS

After the model preparation is complete, we ran daylight analysis with the specification according to daylight regulations. We then extracted the analysis result of the main facades and checked whether the design option compiled with the regulations or not.

(IV) PACKAGE FOR SUBMISSION

Then, we prepared the model file, daylight simulation result sheet (Table 1) and simulation images (Figure 5) as a submission package onto DAO by uploading through IPFS.

3 COMPETITIVE SCENARIO

COMPETITION AND VOTING SCENARIO

The described workflow has been used as a base for simulating the presence of three designers working on the same design task in a competitive scenario. After we ran the test of simulating proposals from the three designers, we had five alternatives with daylight hour simulation results from each candidate.

In our simulated scenario, Designer 1 firstly submitted the design proposals with modelling file and simulation data onto DAO system via IPFS system. After participants' voting, the proposal was being rejected because of its poor daylight performance was not meeting the regulatory requirement. Designer 1's had no design options which had over 90% of the main façade passing the minimum regulation's requirement.

Afterwards, Designer 2 and 3 were delivering their proposals by improving from Designer 1 design file. As they both provided design options that were compatible with the daylight regulations, participants voted after considering their design quality too.

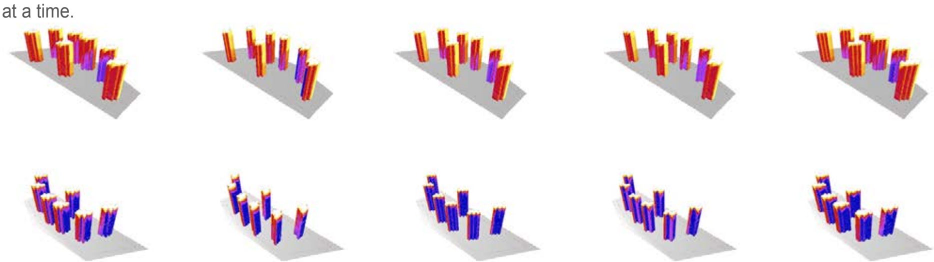

Figure 5: Visual outputs of the daylighting simulation analysis

Followed by a further comparison of the building design, Designer 3's proposal has been voted as the best proposal to be further developed.

There is a summary of the analysis results below.

Table 1: Percentage of main facade passes daylight regulations of the proposals A-E by the three designers

Designer	op. A	op. B	op.C	op.D	op. E
1	86.9 failed	77.0 failed	73.9 failed	66.6 failed	60.1 failed
2	69.7 failed	82.5 failed	95.7 best	94.9 passed	91.4 passed
3	58.9 failed	94.7 passed	93.3 passed	57.0 failed	99.9 best

4 VOTING ON DAO

VOTING SYSTEM ON BLOCKCHAIN ENVIRONMENT

The Distributed Autonomous Organisation acts as a platform in which the design problem and the solutions are hosted and the latter evaluated through a vote.

The voting system is based on unique Ethereum accounts that each participant holds and on their reputation level. In our scenario, a pool of experts with a given amount of reputation express a selection via a pass/reject vote after analysing the submitted files and optimized values. As described in previous works, the level of reputation represents a driver for the selection process, ensuring that participants with high level of expertise in a specific field can have an impact on the decisional process.

Designers and juries can access "Proposal" section through the (i) menu, (ii) shows the proposal content and the IPFS download link of the submission package. while (iii) shows the voting for/against percentage. (Figure 6)

Further, as a platform for decision-making that offers the possibility of being applied in both a collaborative or competitive context, the DAO carries the crucial positive aspect of ensuring a level of trust amongst participants even though they do not know one to each other (Hunhevich et al.2020). Design teams operating in the field of the AEC normally have the need to define not only their identities, prior to cooperate, but also to go through a number of legal steps in order to ensure the respect of contracts and payments.

In design competition, even if the identity of the participants is hidden till the revealing of the results, it is on the other hand mandatory a high level of trust and respect of the rules by the jury, that can be somehow compared to the client in a non-competitive scenario. In both cases, the DAO can act as a solution by relying on the technical capabilities of the Blockchain of providing unique identities to designers, clients and data.

In terms of rewards, operating on a decentralised autonomous organisation capable to run codes supports the option of deploying simple software that acts as smart contract between two or more parties. Thus, operating in a situation of trust based on the described inner nature of the Blockchain, allows the participants to be rewarded, i.e. paid with digital currency, as long as they meet specific design or performance criteria defined a priori, ensuring that the value of the design process is preserved.

ADVANTAGES AND CONSTRAINTS OF BLOCKCHAIN IMPLEMENTATION

From this case study and simulation workflow, we have observed several advantages and challenges to be further discussed.

Compared to conventional cloud storage services, IPFS is has no file size limit and allows to overcome the use of centralised cloud systems that would jeopardise the described decentralised approach. This aligns with previous works (Luo et al., 2019) in which private cloud infrastructures have been recognised as lacking of those systems for validation and verification that are crucial in a fully decentralised system. In the presented context the Ethereum Blockchain provides also the opportunity to perform codes, hence also to potentially support CAD and BIM applications.

The Blockchain, thanks to its intrinsic nature, currently represents the optimal solution to ensure immutable recording of design decisions and transactions, ensuring the required trust in the process.

Besides the positive aspects, a few drawbacks have been observed at the current stage. Due to the inherent properties of the Ethereum system, uploading and getting a proposal synchronised can require more time than what users are currently accustomed with in using digital devices and technologies. Further, working on open DAOs like DAOstack Alchemy, requires the use of ETH (Dounas, Jabi, Lombardi, 2020), the currency on which the platform itself is based, and incurring in what is perceived as an extra-cost for the users.

Lastly, the current state of the user interfaces of DAOs (Figure 7) and Blockchain platforms is still far from what could be defined as a conductive to design environment, especially if evaluated from the designers' point of view. Current DAOs and BC visualisation relies on simple UI hosted by browsers that mostly provides alphanumeric data and codes related to the completed and ongoing transactions, with none or little design feedbacks for the users.

An effective introduction of such a kind of technology into the field of design, in its broader sense, would require a radical change in the way in which computational operations are displayed, moving out from the. digital-currency based displays.

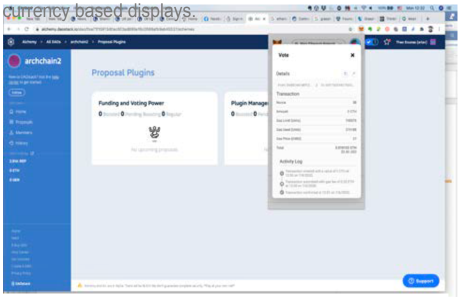

Figure 7: Transaction confirmation user-interface

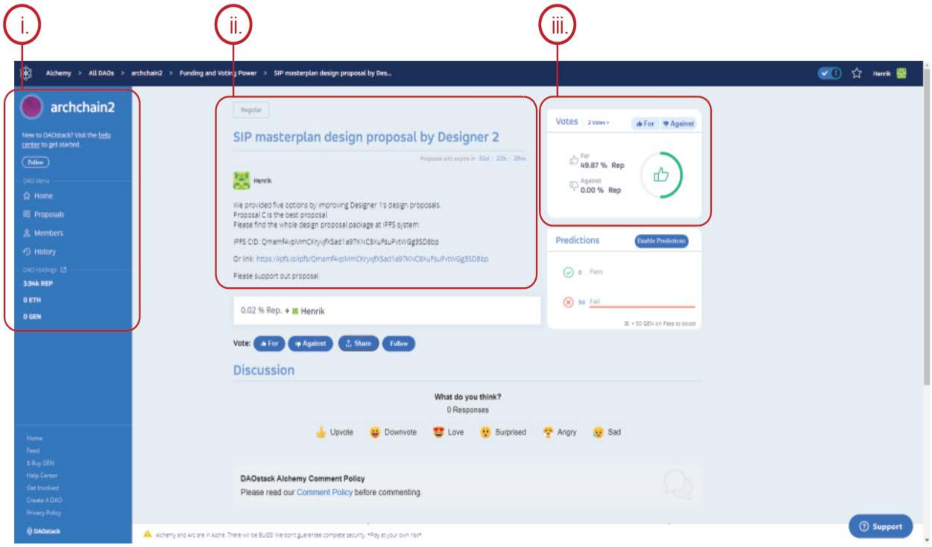

Figure 6: DAO interface with one of the design proposals uploaded and voted by participants

5 CONCLUSION AND FUTURE DIRECTIONS

FUTURE OPPORTUNITIES

We have presented a two-steps-based integration of design processes into a Distributed Autonomous Organisation on the Ethereum Blockchain. The described mecfutureehanism has been elaborated around a competitive scenario, with participants allowed to vote and push for different design solutions provided, remotely, by different designers. The design scenario based on shape grammars and sunlight simulation verified against real regulations, provided the framework to simulate a potential real situation in which clients upload design tasks on a DAO and designers compete via uploading and recording their proposals on the same platform.

The experience and the tests lead us to predict possible future steps for the research to address the previously mentioned drawbacks. A more user-friendly workflow and interface are required to streamline the process and adapt the DAOs and BC technology towards the needs of designers and AEC stakeholders. The current speed of the system does not make it suitable for practice in a real world scenario. For this to take place, either a private Blockchain with sped up processes can be set up, or a faster Blockchain can be used as an alternative to ethereum. We envision that the conditions for testing with a real scenario do exist, and we would look forward to collaborate with built environment stakeholders to set up a DAO for project governance to test our system further. In the context of Algorithms-Aided Design (Tedeschi, 2014), a live connection between the design definition and the IPFS – DAOs can be envisioned with further applications and expansions towards the automation of both design optimisation processes. Further efforts will be allocated to explore the set-up and connection of private Blockchain to provide a faster testing environment unbound from any specific digital currency and enabling a faster uploading process of data sets.

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