Decentralised Autonomous Organisations for the AEC and Design industries

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Abstract The chapter presents the concept of Decentralised Autonomous Organisation (DAO) and discusses what the current and possible applications are in relation to the AEC, design and design-linked industries. The chapter first introduces theoretical aspects of traditional organisations and then develops the ones behind the creation of automated, computer-based ones. Consensus mechanisms and smart-contracts integration are also presented in conjunction with diffused systems of DAOs' regulation. Scenarios are presented where DAOs are applied as coordination tool for competitive and collaborative use within the design field. A comparison table of Ethereum based DAOs as well as reflections of pros and cons of DAOs applications are provided to better frame what the current boundaries are of a technology that is also expanding its range of utilisation thanks to the interest of town councils and institutions.

Introduction

Decentralised Autonomous Organisations (DAOs) can be described as completely transparent organisations run by automated programming codes and operated by the members of the organisation itself. In order to achieve and retain those characteristics, DAOs require to be built and supported by an infrastructure allowing automation, shared control and validation of decisions and actions, as well as participation. A suitable infrastructure for this purpose has been found in the

combination of two emerging technologies: Distributed Ledger Technologies (DLT) / Blockchain (BC) and Smart Contracts (SC). The first allow, thanks to their distributed nature, to share across all participants the power of decision making as well as ensuring that all decisions and actions are transparently recorded; the second instead are automated codes that run when certain conditions are met.

Beyond the narrow technical description, DAOs represent a form of governance that can be in theory applied to any sort of organisation, public or private, lucrative or no-profit, with their governance model scaling to the level of theoretically substitute entities like town councils and even governments.

The recent rise of DAOs and their development finds (Gitcoin report, 2021) its roots in the discourse concerning the limits of current governance schemes, which have been almost intact for centuries, and the opportunity provided by the Internet in terms of connecting people, fostering collaboration and, with the implementation of DAOs and BC, creating and ensuring trust via transparent processes, that are then supported by automation, distribution and uniqueness of information.

In the early stage of history, humans used to live in small isolated groups, with little or no contact with others and living in a pretty much self-sufficient way.

With the introduction of agriculture and the shift towards a more organised living system, humankind faced the necessity of creating media to large groups of individuals and started basic collaborations for defence, food production and supply, commercial purposes; it appeared natural that also some sort of more structured arrangement and hierarchy was necessary in order to coordinate and govern people activities.

As a result, pyramidal structures with robust top-down approaches became and remained the most diffused, if not the only way for people to live and operate together in a coordinated manner. Alongside individuals, a number of central organisations, often ruled by few selected people, were created over the centuries to manage the more diverse activities: banks for controlling currencies and financial exchanges, governments for ruling empires and nations, companies for managing the workforce and producing wealth to be somehow redistributed. Through the time, legitimacy was then gained in different ways based on the nature and scope of each specific form of organisation: via elections and representation for example in the case of democratic governments, or via the trust refunding loans in the case of the initial forms of banks and insurances.

This approach, which has been tested through centuries demonstrating to be effective but far away from being perfect, relied chiefly on the relation between two kinds of entities, the agents and those who get represented by them, as well as in the intrinsic trust between the two parties. Referring to politics, democracy and parliaments can be taken as a perfect example of this symbiosis, where a restricted number of agents, Members of Parliament, represent those who technically hold and enforce the power via voting, citizens.

Furthermore, what was described above found further support in the limited possibility of people to connect with and trust others, which can be related to the concept drafted via the well-known Dunbar's number (Dunbar, 1992). By acknowledging that each person can only well remember and trustfully interact with no more

than 150 people, it appears immediately clear how, in a society counting millions of members, concentrating the power of decisions via layers where the number of points of control is further reduced appears to be like the only feasible solution to maintain social order.

In this scenario, the transfer of power from a majority of people to a selected minority helped to streamline and to take fast decisions; however, it also presented significant drawbacks when it came to agents taking excessive risks or acting for their own interest rather than for the collective's one.

While the above scheme remained unchanged for centuries, other fields which can be generically encompassed under the term information technology have seen advances that led people to slowly create tools that could represent a new way to organise societies. Starting from the past, one could refer, for example, at the invention of the press and the movable type, which created the concept of an expanded distribution of knowledge and data with potentially no limits in terms of numbers of reachable people and amount of sharable data.

The introduction of the Internet and its capacity to reach each corner of the planet and grant access to information and services to everyone dramatically shifted this concept covering all aspects of our daily life. With the spread of internet connections and the world wide web all over the world, and the combination of even more recent and powerful tools such as blockchain and smart contracts, the possibility of shifting the paradigm from a people-based trust (and overcoming the limitations of the Dunbar number) to technology-based trust became real and opened up to the opportunity of moving again towards a more decentralised way of living, where control is no longer kept within the boundaries of few people and institutions.

While this can occur as an idealistic or utopian view of coordinating large number of people life and activities, it is also interesting to note how city governments in different parts of the world are now looking into the implementation of DAOs and crypto technologies in their operations, creating new kind of incentives as well as providing platforms to support the more variegated initiatives. To some extent, those initiatives may recall the attempts taking place during the 70s to create decentralised governance systems in the east of Europe, which clashed against the highly centralised government of the soviet apparatus. (Illner, et al. 2003)

DAO platforms

We present a simple classification of existing DAOs platforms on Ethereum. Note that in true decentralised sense, Blockchains themselves can be considered the first primitive form of a DAO as to maintain a blockchain one needs the coordination of a multitude of agents and their incentivised participation and maintenance of the computer network via consensus.

	Gnosis Multisig	DAO-stack	DAOHaus / Molloch	Aragon	Colony	Compound Governance
Token	Ethereum* / xDai	GEN	Ethereum*/xDai	ANT	CLNY	COMP
Consensus	-	Holografic	Majority / Rage Quitting	Multiple modes	Lazy consensus	-
Governance type	Consensus/majority	Consensus – Holografic	Consensus / majority	Multiple	Cooperation	-
Incentive - Structure	-	GEN & reputation	Increase in value in DAO holdings	Multiple	Reputation	Increase in value in DAO holdings

DAOs projects and explorations in the AEC and design industry

Starting from the description of DAO that can be found in Buterin's words, "[…] a DAO contains some kind of internal property that is valuable in some way, and it has the ability to use that property as a mechanism for rewarding certain activities […]" (Buterin, 2014), a question arises about what impact can have the concept of

DAOs within the Architecture, Engineering and Construction (AEC) industry and what can be intended as internal property in that sector.

While it is widely acknowledged that business models and practices are facing a transformation due to the impact of blockchain technology (Adams et al. 2017, Li et al. 2018), this cannot be directly and immediately applied also to a field such as AEC, that is well-known for being reluctant to changes and slow in implementing innovation, with architects and designers mostly presenting themselves as the sole authors of concepts and designs (Dounas et al., 2019). As a result, a few theoretical and practical projects can be found exploring the potential of combining DAOs into AEC daily operations, with examples related to this field which also come from stakeholders apparently not directly connected with the building industry.

Proposals for the application of DAOs in the early design stage have been explored by envisioning them in both competition and cooperation scenarios, simulating designers who collaborate or compete to create new shape grammars assessed via a voting system deployed into the DAO. The voting system encompassed both qualitative and quantitative aspects, keeping into consideration the experience and knowledge of the participants. (Dounas et al., 2019). Further development of this approach has been later applied against more objective criteria such as building regulations and environmental analysis: application of generative design and shape grammar has been tested as a proof-of-concept for a system where competitors produce solutions that are then shared on the DAO via IPFS system (Lombardi et al. 2020).

Sreckovic et al. (2019) discuss how the DAO can contribute to enhancing trust and value in the workflow of the AEC industry by referring to the need of applying a system where knowledge and expertise, decisional power and blockchain can be integrated; however, the DAO application appears mostly confined to the level of the operations while keeping the innovation and coordination stages centrally coordinated.

An exploration of self-owned built space by Hunhevicz et al. (2020) expands the concept of DAO to the one of DAS (Decentralised Autonomous Space) conceptualising a small meditation pod which is fully autonomous from the point of view of creation, management, finance, operation and maintenance. Being one of a kind attempts of connecting DAO' s-based governance system with the physical world via IoT devices, it opens up to future scenarios where buildings are self-owned, the concept of rent shifts towards self-maintenance only costs and, more notably, the entire set of operations from collecting funds to spend for necessary maintenance is controlled via predefined scripts running on the blockchain.

Decentralised organisations are also currently taking place in areas that are somehow close to the design and architecture industry but still not yet developed in a way in which impact can be recognised in the real-world practice but possibly drafting what the future will be. Examples of DAOs such as the platform Decentraland tries to combine elements of well-known gaming environments such as Minecraft and SecondLife with the proper aspects of a DAO in terms of tokens and decentralised government. Land can be bought and sold, as well as virtual goods, artist and content creators can be contracted to further personalise the owned plot or house,

decisions can be taken, and policies updated via the decentralised governance interface but still under the umbrella of control of a so-called Security Advisory Board (Dedezade, 2020). The example of Decentraland, which makes deep use of a gamified environment also to attract users, addresses questions like the proof of ownership, which can be applied to many aspects of both real and virtual life, but that can be connected to the AEC industry in terms of ownership of lands.

While Decentraland is mostly a platform where the fantasy of the users represents the only limit to expansion, the same concept of proof-of-ownership is applied in emerging countries, i.e. Ghana, for people to claim and demonstrate of being the owners of plots of land bypassing costly registrations (which are often not available due to lacks in cadastral practices) and the standard verbal agreements between parties which are not traceable (Miller 2020, Aitken 2016).

As it often happens, art is ahead of the game in applying cutting edge technologies and exploring new ways of making, as it happens with the Plantoid project run by Primavera De Filippi (Mustatea 2018, Hassan 2021). The project is based on a series of art pieces which exist both physically as well as digitally as a blockchain-based form of life. Each planetoid, physically represented by a mechatronic kind of sun-flower, embeds the concepts of autonomy, self-sustainability and ability of self-reproduction thanks to smart contracts deployed in the Ethereum blockchain and interactions with humans which feed them via bitcoin donations. Donations are later used to hire and fund artists to produce new art pieces that will ensure the reproduction process. Besides being an experiment that challenges people's understanding of what life is and what the extents of human-machine interactions on a DAO are, the research project tackles the limitations of copy right laws in the time of digital design and blockchain, providing at the same time new grounds for expanding the concepts of contractual relationships between people and companies as well as people and machines.

Others and possibly more interesting application and experiments on DAOs are, on the other hand, running by the initiative of local governments. At the date of this text, city governments of Miami, Reno, Busan, Seoul are all looking into how DAOs and blockchain applications can either improve their current operations or to create to new pathways to achieve more citizens' oriented and driven goals.

Seoul is planning to launch its own crypto-currency to sustain and incentivise both private start-ups as well as public welfare initiatives, at the same time pushing for a full set of new national laws to be issued in order to regulate and simplify the access to such technology.

Busan is pioneering a vast application of blockchain based services (spanning from tourism, to retail and finance to supporting local artist via NFTs) via its Blockchain Regulation Free Zone, and with the support of the town government. Applications have been already in place in terms of personal ID management to have access to services, as well as vouchers backed up by the local bank and to be used as a normal currency.

Miami incentives citizens and city supporters to mine within the frame of the MiamiCoin (as part of the CityCoin ecosystem) in order to support the city itself and get a revenue, either as BitCoin or Stacks. It is worthy to mention that 30% of

the revenue is automatically transferred to the city wallet and that the funds can be used for any kind of purpose the city deems fit, apparently without a direct connection to specific projects which could be discussed and voted on a DAO.

In terms of impact on the shape and functioning of our cities, automobile manufacturers such has General Motors and Honda may also have an impact with their ongoing research on a common standard for the application of BC on a smart grid providing a charging network for electric vehicles (Haig, 2020). This would potentially affect the way in which cities may be designed or upgraded in order to accommodate a new full set of devices to support the existence of a new digitalised layer for mobility.

Benefits and drawbacks in DAOs

Traditional companies and organisations, either in simple or more complex forms, are associated by the fact that operations and members' roles and activities are regulated by legal contracts, which define duties and rights and which are enforced via the legal framework of the country they are registered in. Disputes are determined in front of a court of law which acts as an independent third party which as, by default, the trust of the ones disputing.

Decentralised Autonomous Organisations instead operated by people respecting rules which are written in an automated open-source protocol running on a network. The task of maintaining the network operative and active is rewarded by an incentive-based system that has its roots in the network tokens native of the DAO itself. Protocols and tokens are deployed and run on the blockchain, smart contracts act as a further layer of automated cooperation between the involved agents, leveraging on coding and automation to regulate the life of the DAO and to align the interest of the participants via consensus mechanisms.

Consensus mechanisms are the real core behind any blockchain application, with DAOs not being an exception. Its role, as per its definition, is to regulate the way in which decisions are taken amongst the participants of the DAO, or more in general, how to agree in a certain record of a computation activity (Van Valkenburgh, 2017). Different applications can have different ways to reach consensus, such as change of state (i.e. Ethereum) or continuous update of the list of transactions (i.e. Bitcoin). However, once the mechanism is defined, a question still remains about how to accept computers, hence users, to participate to the consensus process. Previously, solutions were found in what can be considered a more traditional and permissioned approach, where closed infrastructures such as an intranet were applied. Thus, losing or yet not taking advantage of the full potential of such kind of technology.

The current concept of public permissionless blockchain instead, which can be seen as a mirror of what Internet is nowadays, hence a system where anyone can connect and start communicating with strangers without the need of a previous identification, relies on a level of openness that make BC and DAOs applications potentially applicable to any kind of business and able to coordinate and to be scaled to encompass a large number of participants.

A further layer of discussion is added by the possibility of reaching consensus (as well as other operations) off-chain (Ellul, 2021). While this can appear as a betrayal of one of the main concepts behind BC technology, transparency, it has to be noted how keeping all the computations in the layer 1 blockchain may become too heavy and slow down at the same time single operations and general growth of the organisation. Storage, consensus and computation can be pushed out from the BC with evident pros and cons in terms of time, cost and data integrity. Off-chain data storage brings positive aspects like privacy of the data, when necessary, and alleviating the BC from the burden of redundant storage requirement (Mota, 2019). On the other end data availability is no longer ensured hence potentially interrupting the operations if data are not reachable, as well as their integrity can only be assessed when they are available.

Consensus strategies can be run off-chain and currently two major approaches can be described: the approach developed within Bitcoin, where miners are requested to reach consensus and later add blocks into the public chain (which can be seen as a non-fully decentralised approach to authority and consensus), and applications where the consensus is sought and reached off-chain with the aim of reducing the operational costs for the participants. In the latter case requests from participants are emitted as signals to off-chain miners that perform the computational tasks and send back their response.

In both the above scenarios the IPFS (Inter Planetary File System) is playing an important role being the open infrastructure acting either as storage space or via its pub-sub functionality, which makes possible to create off-chain dedicated space where seeking for consensus, while communicating with interested participants.

DAOs participants do not sign any contract nor are tied to a legal entity. The driver feeding the existence of the DAO is the incentives provided in the form of net-work tokens, regulated by the transparency of the rules represented by the source code of the software running the DAO itself. Agreements are not made between a single or group of participants; the protocol or specific smart contracts encapsulate the governing rules and regulates all the transactions taking place in the DAO.

Thanks to the automated and transparent nature of their roles, as well DAOs are no longer structured in a top-down scheme with CEO on the top, a body of managers and employees. The pyramidal structure is replaced by a horizontal one where contributors are ideally all on the same level and steer towards agreed goals via the selection processes supported by the consensus mechanism. By operating in this way, DAOs can be joined and open to people from different areas of the world

(hence under different companies' regulations) who do not know each other but still rely on a system ensuring trust.

Moreover, the code which regulates a DAO cannot be changed or censored by one single participant nor by its own creator. Only pre-established majority and under specific consensus conditions can modify the original code.

As described, a DAO carries the characteristics of being open-source and transparent, hence on paper incorruptible. All the transactions are stored on the blockchain, with the participants' interests coordinated by the incentive scheme linked with the DAO native token. The main way to decide in a DAO is by entering a proposal that will be voted by the participants and approved if they reach the majority of the consensus. As said, the actors may not share any physical space nor know each other, hence DAOs can be seen as a distributed entity with autonomous rules and lives, at the same time relying on experts to achieve certain tasks which otherwise could not be automated.

The Bitcoin Network can be seen as the first and so far, more resilient decentralised autonomous organisation created around a free consensus protocol. It resisted to any sort of fault and attack since the appearance of its first block keeping its mission to provide a platform for money transaction which runs completely outside the control of any central bank. The existence of the Bitcoin network is so far assured by its contributors, which are incentivised by the token system, which also allows for a fully automated and transparent coordination.

The Ethereum network shifted the potentials of DAO running on the blockchain to the level of smart contracts, exponentially opening up to possible applications. Smart contracts simplified the operations to set up a DAO with the only need of a few lines of code and mostly removed the necessity of setting up a proper blockchain network.

DAOs present then a number of benefits due to their intrinsic nature, such as coordinating participants who do not know each other in a manner that leads to achieving certain results, keep a record of contribution to a project which can be carried out in a collaborative or competitive way (much useful in the context of design), creating human-computer or human-objects interactions via external IoT applications and SCs (Shin and Kim, 2019).

The novelties and benefits provided by DAOs have been so far mostly related to financial applications, specifically with the evident benefit of preventing frauds and possible fund mismanagement carried out by delegating power to single points. Decisions and rules are enforced via codes that automate the operation of the institution itself, allowing the possibility of limitless and theoretically timeless expansion to new members and proposals. The current standard workflow of a DAO sees users submitting proposals that are voted and, if approved, they go to the next stage of getting funded via tokens or to the next step of the life of the proposal. Embedding

SC in the process, hence removing almost completely any arbitrary aspect of human interaction, appears an even most secure way to operate.

In terms of voting systems, currently there are different ways in which proposals get voted and either passed or rejected, with a range of techniques spanning from the more familiar quorum voting to those embedding stock-exchange inspired approaches.

Quorum voting is based on a predetermined threshold above which a proposal can have the opportunity to pass. It represents the most well-known and common system of voting since it has been implemented as one of the basic tools of democracy since this concept exists. As in real life democratic processes the defined threshold has to be carefully assessed in order to ensure that the final decision actually reflects the will of the majority of the community (Arsenault, 2020). In the case of DAOs a low quorum may lead to an easy-to-pass system and, as a consequence, an easy-to-attack DAO. On the other hand, high quorums may lead to very few proposals to advance, hence the need of incentives as well as to allow more time for the voting process.

Holographic Consensus brings a component borrowed by the stock exchange processes into the voting system. It allows people to predict which proposal will pass in a similar manner in which brokers can predict which stock option will increase or decrease value in the stock exchange market. If the prediction is correct, predictors gain a financial reward and the involved proposals are then no longer assessed via a quorum voting but via a simpler relative majority. The whole system is based on the possibility and will of predictors to stake vote on this or that proposal, hence by staking funds on them. Since the HC is based on funds it automatically cut off all of those who are not really interested in the proposal or, in a worse scenario, those who aim at tampering the system by misleading the vote.

As mentioned before relative majority comes into place as one of the voting systems, nevertheless it is never used as a single and autonomous way of voting. Its simplified nature where even one single vote is enough to take a decision would expose the organization to high risks of getting attacked if other members of the DAO are not looking into the voting process. To overcome this situation, DAOs also implemented a sponsor-based approach that acts as an anti-chamber of the real vote. Proposals need to be first sponsored by members of the DAO before going into the voting stage. This voting system is pretty simple to be implemented and does not require many activities from the members.

All the previously described voting strategy have in common the characteristics of being based on a A vs B approach and that the voting takes place in a definite time with a definite result, A wins over B or vice versa. Conviction voting instead brings two more components into the voting system: the time and the possibility of diversify one support. Rather than asking members of the DAO to decide between two options, they are allowed to stack their voting power on one or more proposals and their

preference can change overtime, so that proposals can accumulate of lose support. The more one proposal is supported the more its weight grows as well as its chances to get finally approved. The CV simulates somehow bio-inspired processes (Emmet, 2019) of growth and decay, and with this approach aims to prevent large stake holders from suppressing minority voters.

Lastly, the so called "lazy consensus" mechanism allows proposals to get approved if no one objects against them. In case of objections, further steps may take place, such a reputation-based vote, in order to decide how to proceed.

Current DAOs are developing more robust safety systems to protect investors and stakeholders from users with intents that go against the community. However, drawbacks are still recognisable in a system that relies on codes written by humans, hence perfect in running the operations they have been written for but possibly wrong in their overall scope due to lack in coding knowledge or more deliberate ability to write codes for purposes which are beyond the common good.
To some extent, one could argue that having the responsibility of each action distributed across the entire DAOs and its participants means inherently that no one is accountable for the DAOs decisions. Furthermore, the immutability of BC, which represents its most great quality, also represents a limit when it comes to the time of updates and bug fixing, which are the norm when dealing with information technology-based tools. A possible way to balance between the above aspects that characterise the current state of the art among DAOs could be by relying on them only for handling certain decisions and operations which do not require a full blind trust on a code, or more in general, for DAOs where the sole governance and interface for decision making is a public permissionless blockchain.

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