WHAT IF PROPERTIES ARE OWNED BY NO ONE OR EVERYONE? FOUNDATION OF BLOCKCHAIN ENABLED ENGINEERED OWNERSHIP

Hongyang Wang[1*], Jens Hunhevicz[1], and Daniel Hall[1]
[1]Institute of Construction and Infrastructure Management, ETH, Zurich, Switzerland
*Corresponding author: wang@ibi.baug.ethz.ch

Abstract

Blockchain and smart contracts enable the network of hybrid autonomous human and machine agents. In this paper, we propose the concept of engineered ownership, a blockchain-based socio-technical governance system. A system of coded rules that defines the boundaries, shapes incentives and distributes rights among such autonomous agents. To lay a foundation for engineered ownership, we first study the nature of ownership by examining the concept of property. Shaped by history and ideologies, property rights are the most formalized and studied ownership system. We then untangle the layered structures and system design impacts of property by investigating three property rights theories. Finally, we derive from these learnings the system features of engineered ownership, identify related challenges, and present a roadmap towards a holistic theory of engineered ownership.

Introduction

The advancement of cryptography provided part of the most important scientific foundation for the first blockchain powered digital currency, Bitcoin (Nakamoto, 2008). Bitcoin started the evolution of blockchain into the new standard for digital assets. Anonymity, decentralization and security are among the most praised features of blockchain. Ethereum introduced the "second generation" of blockchain, popularizing the use of smart contracts (Buterin, 2013). A smart contract is essentially a special type of account, which encodes the logic of transactions between agents in the blockchain network. Smart contracts allow the storing of funds and encoding of rules in the same account. In other words, smart contracts enable self-executing and self-owning autonomous agents on the blockchain. These agents can be individuals or code-driven.

With the capability of storing and governing digital assets by one or a group of autonomous human and/or machine agents, the concept of Decentralized Autonomous Organization (DAO) was established. A DAO envisions a community of self-organizing agents. Blockchain is the underlying peer-to-peer (P2P) network where the agents can transact crypto tokens, vote for governance decision and communicate with other peers.

Such communities formed by autonomous agents challenge the traditional perception of ownership. Ownership describes the state, relation and fact of being an owner. Property rights is a set of formal rules; a legal instrument to protect the rights of owners. An example is the radical project no1s1 (no-one's-one) (Hunhevicz et al., 2021). This project is a self-owning house on the blockchain. The house has its own account on the blockchain where it stores its funds and defines its operational functions. In this paper, we ask what if properties are owned by no one (machine agents), or everyone (cluster of agents)? In a blockchain network, ownership can be fractioned and disintegrated, for example the house could have the operational rights, while a human community around it has the decision rights, or the other way around. Another possible scenario depicts a truly community governed house, by giving them all related rights such as economical, operational, or managerial. Even more radically, the rights can belong to machines as a new type of owner on the blockchain. In this prevailing trend towards human-machine assemblages, we need not only to engineer the technology, but also the ownership that governs their relations and interactions.

Therefore, this paper explores engineered ownership as a new governance architecture on the blockchain. We identified that theories of property rights are, to a great extent, comparative with ownership. Ownership and property rights are different sides of the same coin, the former emphasizing the content of entitled articulation, and the later emphasizing the state of possession. Hence, we first introduce the notion of ownership and property rights and examine then blockchain's role in such a system. Furthermore, we explore the governance of property and existing theories of property rights with special attention to theories that attempt to formalize, systematize and modernize property rights theory. To conclude, we propose and discuss the principles, challenges, and future work for engineered ownership.

Blockchain technology and autonomous agents

The balance of privacy protection and security has long been a challenge for cypher systems. Prior to 1970, only symmetric key algorithms were used, meaning that both the coder and decoder have the same encrypted information passed by a secrete channel. Research of asymmetric key pairs enabled by one-way mathematical functions emerged in the 70s (Diffie and Hellman, 1976). In such a system, the public key information can be exposed and only the person with the pairing private key can decode the information. This invention eventually lead to the creation of a digital payment system in the late 80s. For the first time, anonymity could be ensured in a digital payment system by blind signatures (Chaum, 1983). Subsequently, a more advanced concept, smart cash, was introduced (Bos and Chaum, 1990).

Bitcoin (Nakamoto, 2008) solved for the first time the double spending problem in a secure, transparent, anonymous, and distributed way with the proof-of-work consensus algorithm. Agents can stay anonymous by identifying themselves on the blockchain with encrypted addresses. While this capability has initially received wild support from Crypherpunk's libertarian ideals (Jarvis, 2021), critics worry that it could be exploited by malicious criminals to conduct illegal transactions worldwide (Dyntu and Dykyi, 2018).

The development of Ethereum gave rise to the mainstream adoption of diverse applications on the blockchain, most notable, Non-fungible Tokens (NFT), Decentralized Finance (DeFi), and Decentralized Autonomous Organization (DAO). NFTs and DeFi harness the power of efficient and transparent value transfer on a P2P network with the use of smart contracts as a tool to encode complex operations. Even more advanced, the concept of a DAO implies that the encoded rules could govern relations among participants and act as the organization itself (Buterin, 2017). The ability to digitally govern human agents in a bottom-up manner is explored by scholars from fields such as Open Source Software (OSS) governance (Liu et al., 2021), the sharing economy (Pazaitis et al., 2017) and common pool resource management (Rozas et al., 2021).

Beyond the anonymity of human agents, for the first time, non-human agents such as code or machines can participate in a peer-to-peer network with the same encrypted account as its human peers. More so, the address can hold and control funds, token assets and operational logic. This embryonic of the anonymized human-machine network has been captured by many scholars. In the field of Internet of Things (IoT), scholars explored the possibility of blockchain to facilitate transparent records, communication and multi-step process automation between devices (Christidis and Devetsikiotis, 2016). Legal scholars such as Wright and De Filippi (2015) describe the probable legal overturn, when all physical devices are connected on ubiquitous internet and managed through blockchain, especially regarding property rights and contracts law. In addition, Artificial Intelligence (AI) and blockchain have become an increasingly convincing synthesis. Singh et al. (2020) argue blockchain has the potential to compensate for the existing challenges of AI, for instance, its centralized structure, or security and privacy. Another example is to combine swarm robots and AI to extend blockchain's capability of autonomous machines. The robotic swarm depicts a collective of robots coordinating tasks and performing advanced behavior that is similar to a natural swarm pattern. In such a system, blockchain could act as a governance system for autonomous robot agents and possibly improve the application of swarm robots in aspects related to security, decision making, behavior differentiation and business models (Castelló Ferrer, 2019).

With blockchain and DAOs, both human and machine agents can elegantly cluster into a swarm with obscure and dynamic borders, while maintaining a collective identity. The autonomous nature of DAO resembles the early cybernetic imagination of an autonomous organization. Nabben (2021) illustrated a future of an imaginative human-machine symbiosis, where DAOs are governed by artificially intelligent algorithms. McConaghy (2018) delineates a world where machines own their own network and act similar to nature, purely being and mutually benefiting humans who engage with them. He termed this concept "Nature2.0" (McConaghy, 2018). Following the vision of Nature2.0, no1s1 links self-ownership with a physical space to apply the concept in the built environment (Hunhevicz et al., 2021).

On the one hand, technology has advanced rapidly such that the cyber world is morphing into the real-world triggering all human senses; and on the other hand, the traditional values and virtues had not been reflected and transferred into the new cyber world (Fairfield, 2015). To facilitate bridging between the future scenarios and current limitations requires a close examination of the fundamental principles of value and property.

Ownership and Property rights

The definitions of ownership and property rights

Historically, ownership has been at the center of the ideology debate. Plato (375AD) and Aristotle (330AD) dispute over the value of collective ownership and private ownership. Plato stresses that common property would promote common interest and pursuit, resulting in the social division; Aristotle argues that private ownership promotes virtues such as prudence and responsibility. Thereafter, ownership becomes one bracket to separate political ideology. Following the line of Aristotle, a capitalism ideology holds that intrinsic moral rights lie in private property. The linking of personal liberty with ownership provided an ideological basis for the liberation of slavery. By contrast, under the background of industrialization, a communist ideology regards extensive private property rights as the enemy for reaching common wealth (GREY, 1980).

As a fiercely debated concept, ownership is beset with definitional difficulties. According to Grey (1980), the reason is twofold. First, there is inherent ambiguity within the phrase. Ownership does not describe the degree, scope, the mode of owning, nor the condition of the object of property. For example, private ownership is drastically different from collective ownership. Second, the increasing complexity of today's economic structures has caused the disintegration between property and institutions. For instance, one can own a share of a company without being able to have a voice in its governance. To summarize, the above reasons caused a large spectrum of understanding gap among individuals. There is a lack of a clearly comprehended, unitary concept of property (GREY, 1980).

To confront the complexity in the phrase of ownership, legal scholars decomposed the articulations of owning into different rights. The bundle of rights theory is one of the dominant theories and the standard entering point when seeking to understand the nature of property (Penner, 1996). The bundle of rights theory argues that ownership should be understood as a variety of rights instead of a single right (Honore, 1961). Prior property theory regards property as the governance between a person and a thing (Blackstone, 1830). Owning physical objects is the focal point of dispute. The bundle of right theory shifted the emphasis of property from the thingness to interdependent relationships. Ownership is no longer between the owner and an object, but as a series of correlative rights against other non-owners. For example, the owning rights of a car include the duty of other people not interfering, damaging or benefiting from it.

However, the linearity of the bundle of rights is redundant in an information cost perspective (Smith, 2012). Because it is impossible to delineate all the probable scenarios covering all the relational rights, it is not scalable. For example, a person understands to not trespass a private property without the need of knowing who owns the property. In this case, the ownership detail of the property does not need to be exposed to others, but only the information that this property is a privately owned property. Thus, a delineation of all rights would be inefficient and increase information cost. Smith then integrates the idea of information cost into property and further promote modularization of the packages of property rights (Smith, 2012). This theory is especially helpful in incorporating modern information system architecture design into traditional property law. There is a growing incompatibility between traditional property theory and modern technology progresses (Libling, 1973; Johnsont, 2007). Additionally, intangible properties have been facing many obstacles integrating with traditional viewpoints. In the next section, we explore how blockchain technology can bridge the above disparity in property theory, taking the discussion of property forward.

Property rights and ownership as a system

In this section, we closely look at three theories that systematically characterize property rights and further evaluate the effect that property has in a larger social context.

The elements of property (Carruthers and Ariovich, 2004)

As discussed in the previous section, property consists of relational rules between owners and non-owners. It cannot be assessed outside of a greater social context. Therefore, as much as property right law is a political or economic issue, it is also a social issue. Nevertheless, it is rarely studied by sociologists (Carruthers and Ariovich, 2004). Carruthers & Ariovich (2004) concur with the argument of the bundle of rights that property right involves a triadic relationship, rather than dyadic only between people and things. In the triadic relationship scheme, property rights vary according to the nature of the right, the owner or the group the rights are vested in, and the objective value of the owned asset. The authors developed five dimensions to define property based on an earlier definition by Reeve (1986).

The five dimensions are *objects of property, articulation of use, subject of property, enforcement of rights* and *transfer of rights* (see Figure 2). While the transfer and enforcement of rights are self-explanatory, the object of property describes what can be owned and the subject is who can own the object. The articulation of use represents all the rights that involve how the objects can be used.

The object of property varies according to culture, law, politics, economy and technology. It hinged on the process of commodification and decommodification. An increasing number of intangible things such as business models is a major part of the modern property debate. As for who may own, no society grants equal and full ownership rights to all natural persons. While ownership of a single person suffers from inequity based on biased categories, ownership of fictive groups, corporations or institutions gain perpetual accumulation of wealth without inheritance issue. Similarly, the articulation of property use is also mostly restricted depending on the nature of property and it changing over time. Some restraints are enforced formally, others informally. The enforceability connects property with politics and state-level government and shifts towards the international level due to globalization.

Carruthers & Ariovich (2004) have taken property outside the common legal context, and abstract the basic elements of property. This evidently demonstrates that the concept of property is highly dynamic. All five elements of property interconnect and have mutual effects. Culture, economics, politics and technologies change property and vice versa.

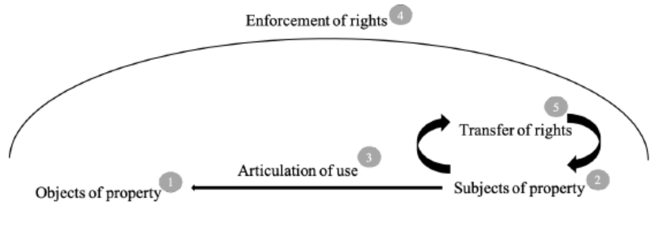

Figure 1: The property rights graph (Nagel and Kranz, 2021).

The qualities of rights (Scott, 1989)

Scott (1989) builds the theoretical foundation of common resource property using the "characteristic" approach. His theory suggests evaluating the effects of the right regime against six axes (see Figure 2):

Land	Operational		Collective-decision		
Right	Access	Withdraw	Management	Exclusion	Alienation
Authorized user	x	x			
Claimant	x	x	x		
Proprietor	x	x	x	x	
Owner	x	x	x	x	x

Table 1: Adopted bundle of rights table (Schlager & Ostrom, 1992)

flexibility, exclusivity, quality of title, duration, divisibility and transferability. Additionally, a difference in degree for each dimension result in different property systems.

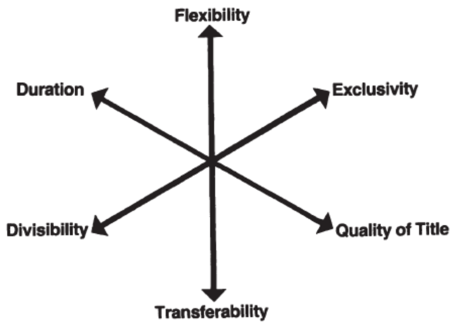

Figure 2: The six axes of property rights (Scott, 1989)

Fishery is one of most popular common pool resource scenarios. With this example, two common fishing systems, license and quota, are compared in detail. Scott (1989) discovered that each quality of rights yields different social effects. For instance, on the one hand exclusivity can encourage self-enforcement of control and long-run investments. On the other hand, extensive exclusivity might result in collusion. Individuals who hold rights that are durable, exclusive and transferable, share more sense of responsibility in the scheme of collective ownership.

Scott (1989) demonstrates that it is important to view individual rights as the nuclei of larger collectives. Furthermore, proper joint management not only make regulation of property efficient, but also has the potential to promote greater virtue and ensure sustainable maintenance of the property. The dynamic characteristics of property regimes significantly influence the social outcomes.

The nested relations (Schlager and Ostrom, 1992)

Through a series of extensive field analyses on indigenous groups, Elinor Ostrom defended the commons against the popular theory of "tragedy of commons" (Hardin, 1968). Parallel to the fishery example in the last section, Schlager and Ostrom (1992) examined property rights in a common resource-based scenario. They then further identified the confusion in scientific study and policy analysis when the term "common-property resource" is used together with different types of ownership. A conceptual schema (see Table 1) was developed to clarify and array the property right in a common resource.

While this schema includes many aspects of property rights, the main focus is on the level of property rights in relation to the owner's participatory level. There are five rights related to common resource that are further grouped into two categories. The operational level rights include the rights for access and withdraw products. The collective-choice rights are the decision layer of operational rights, including the rights to regulate the use of resources (management), determine who has access (exclusion), and the right to sell or lease the other collective (alienation). The enforceability is classified into de facto and de jure. The former is self-enforced and latter is given lawful recognition by formal instruments. While de jure rights ensure more security, de facto rights are valuable through internalizing cost in solving conflicts, matching rules closely with the local conditions and reduces the incentives to overinvest. Ownership does not guarantee the survival of a resource, and resource abuse occurs when there is a high discount rate.

Schlager and Ostrom (1992) draw a picture of complex nested relationships. Hierarchical relationships are divided through holding different rights, while horizontal relationships between members hold the same rights. The rights and duty of a person influences individual incentives, actions and finally the organizational outcome. The property rights regime is inherent complex and has no existing system that seems to produce net benefits in all situations. It revealed that the ownership regimes are spatial-temporal systems.

Towards engineered ownership

When Blockchain meets property rights

Through computational labor and artificial scarcity, blockchain uniquely unleashed technologies' capability to directly create digital monetary value. The online digital asset hitherto becomes unique, rival and scarce. It is perhaps not surprising that bitcoin is referred to by many as digital gold (Gkillas and Longin, 2019). Beyond the value in the inherent scarcity nature of cryptocurrency, through the distributed network and the private-public key pair design, blockchain technology also allows for safe storage of the currency by the end-users and efficiently transfer directly between peers. Furthermore, records of the above transactions and processes are transparently visible to everyone on chain. Blockchain technology not only alters our perception of value and assets, but also transforms the method and increases the speed of asset transfers (Graglia and Mellon, 2018).

The close coupling with value, assets and economy departs blockchain technology from the conventional perception of technology - as merely a tool to improve efficiency. It can also shape human behavior by implementing coded rules with economic incentives. These coded rules are the formalization of relationships, where agreements meet (Szabo, 1996). In our current society, such a system written as law, has been imposed by the government. Nagel and Kranz (2021) conducted a systematic literature review of 35 articles that cover the topics of blockchain and property. They discovered that blockchain technology can streamline property registration, digitize property using non-fungible tokens, speed up the transaction of property and make the system more transparent. Moreover, by encoding governance logic, blockchain technology can be the property institution itself. Ishmaev (2017) compared Bitcoin with Penner's (1997) theory of property and Hegel's (1991) system of property rights. Blockchain technology as an alternative property institution could eliminate centralization, promote knowledge commons and alter traditional property relations (Ishmaev, 2017).

Property essentially is a cluster of rules governing the articulation of certain resources or material of value. Blockchain technology has the potential to unify traditional property theories with modern developments. For example, cryptocurrency reformed the understanding of money. Traditionally, the value within money was deemed intrinsic; now money can be coded as long as it is socially agreed to have value. This change of perception is also brought to the concept of property. Property is no longer the law of things, but rather is information. When talking about property, we are not talking about the soil and stones in the land but the imaginary boundaries we are entitled to own (Fairfield, 2015). Correspondingly, blockchain promises significant improvements in information efficiency, certainty and security compared to traditional methods of property management.

However, we depart with Fairfield's view on describing blockchain as merely a neutral property technology. Of course, the knowledge and information in technology are neutral, bytes of zeros and ones reads the same to everyone; atoms in the stone do not try to throw themselves into a glass. Nevertheless, the definition of technology is a practical application of knowledge, and the action of applying involves motivation and purpose that is not neutral. It is not long ago, we discovered that data analytical technologies were notoriously used in profiling users to influence presidential elections (Berghel, 2018).

The inherent design of the blockchain architecture determines the value allocation, as well as decision-making processes. Thus, we need to be informed when adopting and applying it. For example, permissioned and permissionless blockchains yield a drastic difference in access rights. The former controls access within certain group of individual and the latter grants accesses to all. It is apparent that being able to make faster and more transparent transaction, or assist registration of ledger is useful, however, the governance aspects of blockchain are arguably just as important as the technology itself if not more so. In the next chapter, we further examine the governance of property on the blockchain in order to understand better the various dimensions of engineered ownership.

Departure from existing blockchain governance frameworks

The governance capability of blockchain has been studied by various scholars (Liu et al., 2021; Beck et al., 2018; Pelt et al., 2021). The concept of engineered ownership shares similar features with existing blockchain governance frameworks. These frameworks have a similar agent-based view and discuss agent's rights, incentives and accountability. However, based on the above foundations of property rights, we propose that the concept of engineered ownership uniquely emphasizes the five aspects that are either non-existing or little discussed in other frameworks.

- *Non-human Participation:* Fundamentally, this work is motivated by the imagination of a future of human-machine symbiosis. It emphasizes the ownership of autonomous machine agents (no one) or a DAO formed by a cluster of autonomous agents (everyone). This aspect is often neglected or lightly mentioned in all existing frameworks.
- *Relational:* Through the review of property theories, it is apparent that ownership is relational to others in the network. The full ownership of a certain resource excludes others from it. The existing frameworks emphasis on the delineation of agent properties with little emphasis on the relation between them.
- *Interplay:* Certain ownership rights show closer relationship than others. For common pool resources, access rights and withdraw rights are often bundled together. Holding withdraw rights independently from access rights is meaningless. The different elements of certain rights are also correlated with each other. The enforceability of the right influence the intrinsic value of rights.
- *Complexity:* Ownership is not only a right but also a duty and an accountability. A small change in one aspect of the ownership could trigger very different actions and outcomes. The ownership regime is inherently complex having nested structures. It requires independent study. In other frameworks, the complexity is commonly reduced to a single decision right.
- *Cyber-physical Integration:* The concept of engineered ownership emphasizes the integration of cyber-physical systems, while other frameworks seek only to govern the digital

community. This feature also increases additional complexity.

Moving forward: challenges and plausible solutions

The five aspects of ownership engineering presented above also highlight the various difficulties moving forward. The challenges are twofold. On the one hand, there are intrinsic conceptual complexities in the matter of ownership. On the other hand, there are technical complexities in the architecture of blockchain especially attempting to bridge the cyber world with the real physical world.

Challenges in ownership

Ownership is hierarchical, nested and interplayed. It varies based on culture, law, politics, economy and technology (Carruthers and Ariovich, 2004). There are different levels of ownership resulting in different levels of participation (Schlager and Ostrom, 1992). Permeance, transferability and divisibility of ownership changes the engagement pattern of participants (Scott, 1989). A stable ownership regime could also encounter new conflicts induced by external events. The de jure right enforcement involves politics and government intervention. De facto enforcement can be embedded into the local custom or enforced through individual contracts (Schlager and Ostrom, 1992).

Challenges in blockchain

There are two main difficulties when using blockchain as a tool to manage communities. The first problem lies within the complex and fast moving development of blockchain technology. For example, there remains many open questions around the scalability and the environmental impact of blockchain. Moreover, research on DAO community management is as well in its infancy. For example, there is debate if decision making should be on-chain or off-chain (Calcaterra, 2018; Reijers et al., 2021). On-chain voting is more secure while off-chain voting is economically efficient. New voting schemes, such as quadratic voting, have been proposed and present exciting promises in promoting equity (Wright Jr., 2019). Beyond technological problems, the high profitability of cryptocurrency is a two-sided sword. It provides economic incentives and at the same time attracts malicious behavior exploiting other users' resources.

The second difficulty occurs in integration of the physical and cyber world. Even though there exist many applications such as tokenization of physical assets, it often requires an entrusted third party to hold assets as the guarantee. This information gap between the physical and cyber world is referred to as the oracle problem (Al-Breiki et al., 2020). Autonomous machine engagement in the network suffers from the above problem.

Plausible Solutions

As discussed previously, blockchain technology could increase efficiency and reduce information costs in managing ownership (Fairfield, 2015; Ishmaev, 2017). Beyond pure information exchanges, blockchain is also a powerful governance tool to manage incentives and a complex cluster of autonomous agents in the social-technological context (John and Pam, 2018). Structurally, ownership complexity can be managed through modularization (Smith, 2012) and nested structures (or system of systems) (Espejo, 1990; Ostrom, 1990). Organizationally, mechanisms for effective monitoring and adaptation reduce the cost of conflict solving and increase resilience to external changes (Espejo, 1990; Ostrom, 1990). Moreover, due to the intrinsic complexity of ownership, adapting an engineered ownership system would require a degree of flexibility and freedom to adapt to the local culture and legal environment. This would require further investigation and will play an important role in system design.

Roadmap: blockchain-based engineered ownership

Moving forward, we identified three main steps required in order to achieve, validate, and apply a theory of engineered ownership:

Theory building in multidisciplinary context:

Engineering ownership bridges social and technological systems through the triadic relation among codable rules, individual incentives, and collective outcomes. The first step in building a new theory is not to take any existing system of a specific kind as given nor to create everything from scratch. In this paper, through reviewing the concept of property rights, we began to untangle the complexity of ownership in a greater social context. However, to achieve a holistic system design, not only legal and social aspects, but also other fields such as economic systems and complex system design need to be involved.

Quantification and System simulation:

Validating the engineering ownership system requires a large computational capacity to simulate the clustered autonomous agents' behaviors. For system validation, Model-based system engineering (MBSE) is one of the most prominent methods to support the analysis, verification and validation of engineered ownership systems. The dynamic of the system between the agents and net social outcome can be simulated through agent-based modelling. Large experiments with participation from global agents can be conducted through an engineered-ownership-system-based metaverse with digital communities.

Implementation

Real world applications of engineered ownership should be explored. In a nested system, these applications are multi-layer and multi-scale. A possible application is a decentralized and autonomous building and space, treating a single house as a unit of autonomous agent (Hunhevicz et al., 2021). On a greater scale, this idea can expand to decentralized autonomous infrastructure resulting in a human-machine symbiosis society.

Conclusion

In this paper, we investigate the concept of engineered ownership: a system of coded rules leveraging blockchain smart contracts that distribute rights, value and power among a hybrid community of autonomous human or machine agents. In this way, technological innovation becomes tightly coupled with economic incentives and social behavior. While the underlying technology is neutral, algorithmic bias does exist. In the application of blockchain, where ownership could be redefined and redistributed, a careful examination of the system design is required in order to prevent unintended consequences. Therefore, there is a need to investigate further the possibilities and challenges of engineered ownership.

A proper understanding of ownership is necessary to conceptualize engineered ownership. We turn to property and property rights in order to establish a better understanding of ownership. Property, like ownership, consists of a series of rules that define the rights, duties, and obligations of owners and non-owners. These rules distribute power, define boundaries, settle conflicts and increase resilience in a complex system. We suggest that available theories of properties and property rights can help to identify different possibilities to engineer ownership on the blockchain.

Three theories of property are reviewed to offer a potential starting point for untangling the concept of ownership. Based on the generated insights, we proposed five aspects of engineered ownership that are not much explored by existing blockchain-governance frameworks. These are the non-human participation of machine agents, the relational nature of ownership to other agents in the network, the inherent interplay of rights, the complexity of ownership, and the cyber-physical integration that is possible beyond the mere governance of digital communities.

Based on the initial findings of this paper, we suggest that the existing theory and system of ownership could be advanced with and by blockchain technology. In alignment with other research, we support exploring further the use of blockchain not only as a technology tool to improve transaction efficiency and transparency, but also to initiate innovation on institutional, organizational and governance levels towards a new paradigm of engineered ownership.

There are a few important last remarks about this work. Even though we have mainly studied property rights, the duties and obligations associated with rights should not be ignored. In a system design, monitoring and necessary sanctions are critical to leverage malicious actions and impacts. Blockchain technology does not automatically result in good virtues such as freedom, liberty, social equity, and a mutually-beneficial symbiosis of humans and machines, but we could engineer a system towards such a vision.

References

Al-Breiki, H., Rehman, M.H., Salah, K., Svetinovic, D., 2020. Trustworthy Blockchain Oracles: Review, Comparison, and Open Research Challenges. IEEE Access.

Aristotle, A., 330AD. Politics. Max Bollinger, Place of publication not identified.

Beck, R., Müller-Bloch, C., King, J.L., 2018. Governance in the Blockchain Economy: A Framework and Research Agenda. J. Assoc. Inf. Syst. 1020–1034.

Berghel, H., 2018. Malice Domestic: The Cambridge Analytica Dystopia. Computer 51, 84–89.

Bos, J.N.E., Chaum, D., 1990. Smart cash: a practical electronic payment system. Centrum voor Wiskunde en Informatica.

Buterin, V., n.d. DAOs, DACs, DAs and More: An Incomplete Terminology Guide.

Calcaterra, C., 2018. On-Chain Governance of Decentralized Autonomous Organizations: Blockchain Organization Using Semada. SSRN Electron. J.

Carruthers, B.G., Ariovich, L., 2004. The Sociology of Property Rights. Annu. Rev. Sociol. 30, 23–46.

Castelló Ferrer, E., 2019. The Blockchain: A New Framework for Robotic Swarm Systems. In: Arai, K., Bhatia, R., Kapoor, S. (Eds.), Proceedings of the Future Technologies Conference (FTC) 2018, Advances in Intelligent Systems and Computing. Springer International Publishing, Cham, pp. 1037–1058.

Chaum, D., 1983. Blind Signatures For Untraceable Payment.

Christidis, K., Devetsikiotis, M., 2016. Blockchains and Smart Contracts for the Internet of Things. IEEE Access 4, 2292–2303.

Diffie, W., Hellman, M., 1976. New directions in cryptography. IEEE Trans. Inf. Theory 22, 644–654.

Dyntu, V., Dykyi, O., 2018. Cryptocurrency in the system of money laundrying. Balt. J. Econ. Stud. 4, 75–81.

Fairfield, J., 2015. Bitproperty. South. Calif. Law Rev.

Gkillas, K., Longin, F., 2019. Is Bitcoin the New Digital Gold? Evidence From Extreme Price Movements in Financial Markets (SSRN Scholarly Paper No. ID 3245571). Social Science Research Network, Rochester, NY.

Graglia, J.M., Mellon, C., 2018. Blockchain and Property in 2018: At the End of the Beginning. Innov. Technol. Gov. Glob. 12, 90–116.

GREY, T.C., 1980. The disintegration of property. Nomos 22, 69–85.

Hardin, G., 1968. The Tragedy of the Commons. Sci. New Ser. 162, 1243–1248.

Hegel, G.W.F., Nisbet, H.B., Wood, A.W., 1991. Hegel: Elements of the Philosophy of Right. High. Educ. Camb. Univ. Press.

Honore, A.M., 1961. “Ownership” in A.G. Guest (ed.) Oxford Essays in Jurisprudence, Oxford University Press.

Hunhevicz, J.J., Wang, H., Hess, L., Hall, D.M., 2021. no1s1 - a blockchain-based DAO prototype for autonomous space. In: Computing in Construction. Presented at the 2021 European Conference on Computing in Construction, University College Dublin, pp. 27–33.

Ishmaev, G., 2017. Blockchain Technology as an Institution of Property: Blockchain Technology as an Institution of Property. Metaphilosophy 48, 666–686.

Jarvis, C., 2021. Cypherpunk ideology: objectives, profiles, and influences (1992–1998). Internet Hist. 0, 1–27.

John, T., Pam, M., 2018. Complex Adaptive Blockchain Governance. MATEC Web Conf. 223, 01010.

Johnsont, D.R., 2007. REFLECTIONS ON THE BUNDLE OF RIGHTS. Vt. Law Rev. 32, 27.

Jr, D.W., 2019. Quadriatic voting and blockchain governance. UMKC Law Rev. 88, 23.

Libling, D.F., 1973. The concept of property: property in intangibles.

Liu, Y., Lu, Q., Paik, H.-Y., Zhu, L., 2021. Defining Blockchain Governance Principles: A Comprehensive Framework. ArXiv211013374 Cs.

McConaghy, T., 2018. Nature 2.0. The Cradle of Civilization Gets an upgrade.

Nabben, K., 2021. Imagining Human-Machine Futures: Blockchain-based “Decentralized Autonomous Organizations.” SSRN Electron. J.

Nagel, E., Kranz, J., 2021. Is “Chained” Property the Future? A Review and Synthesis of Literature on Blockchain Technology and Property Rights 16.

Nakamoto, S., 2008. Bitcoin: A Peer-to-Peer Electronic Cash System 9.

Pazaitis, A., De Filippi, P., Kostakis, V., 2017. Blockchain and value systems in the sharing economy: The illustrative case of Backfeed. Technol. Forecast. Soc. Change 125, 105–115.

Pelt, R. van, Jansen, S., Baars, D., Overbeek, S., 2021. Defining Blockchain Governance: A Framework for Analysis and Comparison. Inf. Syst. Manag. 38, 21–41.

Penner, J., 1997. The Idea of Property in Law. Oxford University Press, Oxford.

Penner, J.E., 1996. The “Bundle of rights” picture of property.

Plato, 375AD. Plato: Republic, Oxford World’s Classics: Plato: Republic. Oxford University Press.

Reeve, A., 1986. Property and Labour. In: Reeve, A. (Ed.), Property, Issues in Political Theory. Macmillan Education UK, London, pp. 112–151.

Reijers, W., Wuisman, I., Mannan, M., De Filippi, P., Wray, C., Rae-Looi, V., Cubillos Vélez, A., Orgad, L., 2021. Now the Code Runs Itself: On-Chain and Off-Chain Governance of Blockchain Technologies. Topoi 40, 821–831.

Rozas, D., Tenorio-Fornés, A., Díaz-Molina, S., Hassan, S., n.d. When Ostrom Meets Blockchain: Exploring the Potentials of Blockchain for Commons Governance. SAGE Open 14.

Schlager, E., Ostrom, E., 1992. Property-Rights Regimes and Natural Resources: A Conceptual Analysis. Land Econ. 68, 249.

Scott, A.D., 1989. Conceptual Origins of Rights Based Fishing. In: Neher, P.A., Arnason, R., Mollett, N. (Eds.), Rights Based Fishing, NATO ASI Series. Springer Netherlands, Dordrecht, pp. 11–38.

Singh, S.K., Rathore, S., Park, J.H., 2020. BlockIoTIntelligence: A Blockchain-enabled Intelligent IoT Architecture with Artificial Intelligence. Future Gener. Comput. Syst. 110, 721–743.

Smith, H.E., 2012. Property as the Law of Things (SSRN Scholarly Paper No. ID 2012815). Social Science Research Network, Rochester, NY.

Szabo, N., 1996. Smart Contracts: Building Blocks for Digital Markets.

Wright, A., De Filippi, P., 2015. Decentralized Blockchain Technology and the Rise of Lex Cryptographia. SSRN Electron.