A Critical Look at Cryptogovernance of the Real World: Challenges for Spatial Representation and Uncertainty on the Blockchain

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Abstract

Innovation in distributed ledger technologies–blockchains and smart contracts–has been lauded as a game-changer for environmental governance and transparency. Here we critically consider how problems related to spatial representation and uncertainty complicate the picture, focusing on two cases. The first regards the impact of uncertainty on the transfer of spatial assets, and the second regards its impact on smart contract code that relies on software oracles that report sensor measurements of the physical world. Cryptogovernance of the environment will require substantial research on both these fronts if it is to become a reality.

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1 Introduction

Distributed ledger technologies, such as blockchains, have generated tremendous interest of late, because of their ability to support peer-to-peer transactions of digital assets. The first and still most notable public blockchain is the distributed ledger of Bitcoin transactions [10]. Yet, the discussion of distributed ledgers needs to go beyond this particular example. Blockchain technology is based on a distributed consensus algorithm–such as proof of work–which ensures that the ledgers cannot be corrupted by bad actors. As a consequence, the transactions in such distributed ledgers are *trustless*, meaning that the system works to verify transactions between participants who might not trust or even know each other.

Chapron, in his Utopian vision of cryptogovernance [3], makes a number of strong claims about the benefits of distributed ledgers with respect to *"wins"* for ownership, traceability, incentives, and governance of the environment. Despite sharing enthusiasm for technological advancement, we take a more skeptical view toward benefits of distributed ledgers and environmental cryptogovernance. In this paper, we initiate the discussion of the potential pitfalls of automated smart contracts supported by distributed ledgers relating to the physical environment. Our spatial perspective can take at least two aspects – through *spatial assets* being the subject of transactions, or the *spatial context* (of one or multiple transaction parties) acting as the enabler of the transaction. We highlight why distributed ledgers cannot be decoupled from the particular characteristics of environmental and land assets, the limitations of the technology that is used to sense the environment, and societal needs and degree of digital literacy.

2 A Brief Introduction to Distributed Ledgers and Smart Contracts

The consensus algorithms underpinning transactions in blockchain are the foundation of the technology. They need to be highly robust so as not to be easily corruptible [7]. For example, in the case of Bitcoin, no one has yet successfully corrupted the public ledger of transactions. This removes the need for a third-party notary to mediate transactions and enables the distributed characteristic of the ledger. For a standard blockchain, the kinds of transactions supported are fixed to a particular type. For example, for Bitcoin the ledger records the transfer of Bitcoin currency from one account to another.

The innovation of *smart contracts* has expanded the potential of blockchains by introducing a method of encoding scripts or programmable code onto distributed ledgers [13, 2]. These scripts must execute only once certain conditions are met. Any arbitrarily complex combination of computable rules can be defined to test that certain conditions are met.

Once the conditions are met, the contract will automatically execute the transaction. The main limitation is that whatever is being transfered must be tokenizable in digital form. For assets that are easily digitized and tokenized, such as money, the potential of the technology is clear. For rules, regulations, and laws that can be formalized into unambiguous algorithms a smart contract can, in theory, fully automate complex chained management and transaction of assets, thus replacing the need for third-party actors or escrow to complete the process.

There has been of late an emergence of proposals to apply blockchain and smart contract technology to problems that require digital representations of the spatial attributes of real world objects, either to support the transaction of physical and environmental assets or to detect spatio-temporal events that trigger execution of smart contract code. Recently proposed spatial applications of blockchain technology include the internet of things [4], transport networks and smart cities [17, 11], land registration and administration [1], governance of the environment [3], and timber supply chain tracking [5].

When the transfer concerns only *digital representations* of physical assets (such as land parcels), however, a number complications arise. Unsurprisingly, questions around uncertainty in the spatial representation of the physical objects arise–a fact that has been long-studied in geographic information science [6, 12]. This is the first aspect of distributed ledgers discussed in this paper and one that – we believe – has not been considered critically enough.

Recall the conditions that have to be met for a contract to be executed. Some smart contract conditions can be assured through so-called *oracles*, linking the virtual world of the ledger to the physical world through sensors. This is the second aspect where space may comes into play. Consider spatial (co-)presence as a condition (a catalyzer) of a transaction to occur, ascertained by e.g., GPS sensing. Imagine that two parties *have to* physically meet at a certain location as a condition for a transfer to occur.

It is noteworthy that up until now, nearly all of these proposed applications of smart contracts are still at the conceptual stage. As a result, supporters have been able to largely gloss over detailed discussion of spatial representation and uncertainty. A few start-up companies are currently working on proof-of-location systems, but these remain at the early stages[1]. In this paper we focus on two cases in order to probe further into these issues. In

[1] Cf. `https://www.foam.space`, `https://platin.io`.

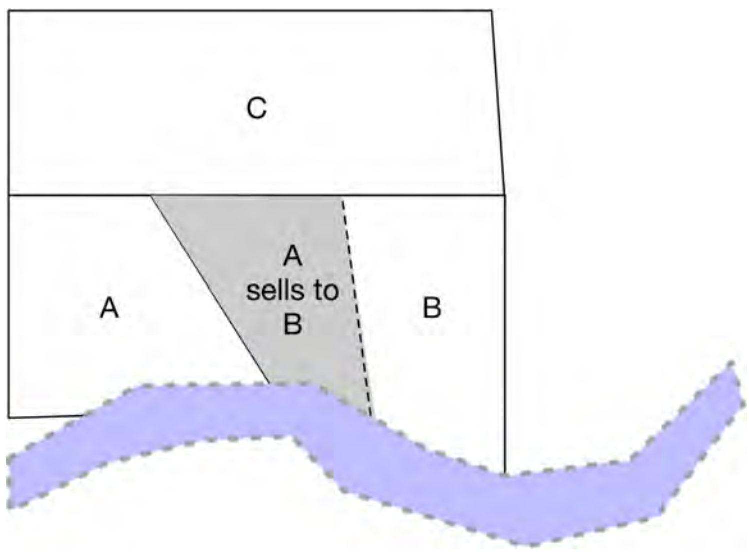

Figure 1 An illustration of the scenario described in the text of Farmer A selling land to Farmer B.

the first case, we critique claims made about the use of blockchains and smart contracts to programmatically enact environmental policy and land transfers (Section 4). In the second case, we explore the idea of blockchain oracles and the role that spatial representation and uncertainty plays in how they might operate (Section 5).

3 Land transaction scenario

Let's imagine *Farmer A* who is willing to sell a piece of his paddock to *Farmer B* using a distributed ledger, sensing technology and an automated legal framework. The farmers meet to agree on the boundary of the piece of land transferred from A to B and to be merged with B's current land (Fig. 1). They walk along the boundary, identify and measure the position of the new corners (metes) of their shared boundary with a GPS on their smartphones. The title to this land is then automatically transferred to B using a smart contract. Funds are transferred electronically from B to A, and a state land tax is automatically levied, in proportion to the areas of land transferred.

The following complications arise:

1. **Ownership problem.** The neighbor C of A and B questions the position of one of the metes, claiming it infringes on his land and shifts the current boundary.
2. **Traceability problem.** The areas of A's and B's lands do not add up after land transfer, due to measurement uncertainty and consequently the digital representation of the physical asset. The taxable land area of both (actually, all three farmers) has changed, and moreover, A and B now *digitally encroach* on the protected buffer zone around the waterway on their southern boundary.
3. **Error propagation.** The uncertain numeric representation of the new boundary triggers an automated response from the titling database, and stops the legal transfer due to the computational, automated interpretation of the legal code and regulations.
4. **Incentives problem.** In the absence of a trusted third party, it may be problematic to assure that the transfer occurred under mutual agreement, without coercion. This is particularly true for subdivisible assets (such as land), where a new identity and demarcation must be established. A chartered surveyor or similar professional currently assures this function.

5. **Digital divide** An advanced technology that relies on the promise of decentralized, ad-hoc information repositories requires an extensive investment of trust from the users. The lack of a physical artifact issued by a central authority and endowed by legitimacy may undermine this trust, in particular in societies affected by the digital divide [8] and with low digital literacy. Paradoxically, these may be the ones that would profit most from the decentralized system removed from governmental control.
6. **Governance problem.** The ability to ensure common good and protection for areas of special value must be preserved. Limiting what authorities must do may be an appealing argument in some situations, but the question is whether reform, rather than replacement, is not more desirable. The tragedy of the commons may well ensue in situations where the majority of people in a certain area have individual interests (e.g., logging) that are in conflict with a common good.

4 Is environmental cryptogovernance desirable?

The above scenario describes a common set of issues that land surveyors and public notaries help to resolve routinely. Currently, the land transfer system in most countries relies on a centralized authority, certified workforce of highly regulated surveyors, and a certain leeway in the interpretation of the digital representation of the physical asset.

We now review the consequences of a purely digital, decentralized ledger system for transferring sensitive physical assets with fiat vs bona-fide boundaries [12].

4.1 Distributed ledgers and contracts about land

A distributed ledger is a record-keeping system for transactions where a centralized registrar (authority) is not necessary, and the authority certifying the enduring nature of the transfer of ownership is assured by peers and a *consensus algorithm.*

For the transfer of a physical asset, the asset itself must be well identifiable (by a unique identifier) and distinguishable (from other assets). This may apply to transfer of diamonds or timber logs, but is more complex when it comes to land transfer, in particular when it comes to the ability to distinguish the extent of the asset. Administrative boundaries, as well as many parcel boundaries are social constructs, demarcated by agreement or authority (*fiat boundaries*). Yet, the number of legal cases and conflicts over fictitious lines demarcating property worldwide attests to the problems with the distinguishable property of these assets.

Many land assets and protected areas are bound by bona-fide boundaries, such as natural coastlines or rivers. Similarly, wetlands change in extent between the dry and wet season. These bona-fide boundaries may be highly indeterminate and a purely peer-based contract and title transfer system may result in increasing legal uncertainty with respect to land use rights and restrictions, or the inability to ensure protection of natural areas of national importance.

4.2 Crowdsourced sensing and spatial demarcation

The demarcation of boundaries, as well as the measurement of the location of the spatial context is always impacted by uncertainty [6]. This demarcation of the asset has often been left to protected professions (i.e., chartered surveyors, or notaries), thus controlling for adequate training and certifying that proper methodological approaches and equipment is used to demarcate the boundaries, and assuring the legal status of the professional as a trusted third party (further ascertaining that both parties are present and agreed about the identity and the demarcation of the asset to be transferred).

With recent improvements in consumer-grade sensing and their ubiquity (GPS sensors in smartphones), these professions have been touted obsolete despite concerns about low quality sensing [9]. Indeed, if no disagreement ensues, two parties could very well agree on their shared boundaries (Farmers A and B), and identify them by GPS coordinates. Yet, a third party may often be impacted by such decisions, if the topological correctness of the partition is to be assured (the boundary of C must follow those of A and B).

5 Blockchain oracles and spatial uncertainty

We now return to the second aspect of how space becomes an important consideration in smart contracts. Blockchain oracles are software or hardware services that are external to the blockchain and which are queried by smart contract code to test whether certain conditions in the real world have occurred [16]. This may include temperature sensors, rain gauges, proximity sensors, or GPS sensors. Consider a web service that provides access to real-time environmental sensor network measurements. This service may be monitored by smart contract code designed to regulate and impose fines to polluters. Another example would be an oracle that relies on sensors to verify the location of physical objects in space in order to verify the movement of goods or autonomous transport vehicles – a payment may be conditioned on certain goods reaching the client.

Issues regarding spatial uncertainty and representation remain largely unexamined in the initial discussions around blockchain oracles. Decentralized ledgers may still need to operate in an environment where certain conditions are mandated – such as both the buyer and the seller walking the boundary of the sold land parcel together, or at least meeting at the same location. How to assure that such conditions are met in a legally indisputable manner remains a concern, especially as the sensor information from consumer-grade devices could be easily questioned in legal proceedings. The need for blockchain oracles therefore will lead to a number of difficult research challenges to which the GIScience community – with its foundational work on spatial uncertainty and representation as well as environmental sensor networks and spatial change detection – can readily contribute [15].

6 Conclusion

We have chosen a land transfer scenario to illustrate that blockchain technology itself is not a *panacea* for problems of environmental governance, and will lead to unanticipated collateral effects. While distributed ledgers and smart contracts may create new possibilities for the management of digital assets, their applicability is also limited by aspects of environmental governance that deal with concepts that can not be simply tokenized and reduced to unambiguous digital representations. In addition to the spatial representation of land assets, biodiversity and non-point source pollution are two complex areas of environmental regulation which can not be interpreted through a simple automated set of rules with binary outcomes [14].

We therefore urge for strong caution and do not believe that *"time is ripe for 'cryptogovernance',"* [3] at least in the foreseeable future. In particular when it comes to the relationship of people with their living environment, their land ownership and the conservation of common-good natural assets, strong institutional frameworks, legal certainty and awareness of the fluid relationship between land and people are necessary. Research to develop a stronger understanding of the relationship between spatial representation and the workings of distributed ledger technologies is warranted, and a necessary prerequisite (among others) to any widespread adoption of environmental cryptogovernance.

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