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Traceability

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Abstract: Traceability is an increasingly prominent research topic in decentralised technosocial systems in fields as diverse as health, sustainability, finance, and supply chain management. At the same time, traceability connotes different meanings and potentialities within each of these fields. This Glossary article homes in on "traceability" as a concept that is deceptively simple but fundamentally crucial in blockchain technologies. First, the entry provides an overview of the historical background of traceability within digital technologies. The entry then outlines the most critical dimensions of the concept by relating the term to questions about accountability, explainability, and speculation. Finally, emergent methodological and theoretical insights concerning traceability as a paradoxical concept in distributed technologies are highlighted.

This article belongs to the **Glossary of decentralised technosocial systems**, a special section of *Internet Policy Review*.

Definition

Traceability is the ability to identify and trace something or someone.

Introduction

The Oxford English Dictionary (OED) defines “traceable” as something that is “capable of being traced”. In the analogue world, various methods have been devised to ensure that objects and subjects are capable of being traced—things like seals and censuses and certificates and spreadsheets. Over the past few decades, digitalisation has allowed traceability efforts to intensify, expanding the scale and scope of things that are not only capable of being traced, but also leave traces seemingly everywhere, often inadvertently (Thylstrup, 2019, 2022). As Philip Agre outlines in his classic text “Surveillance and capture: two models of privacy”, the development of technologies of traceability were in particular intensified by the emergence of standardised and globalised supply chain systems in the mid to late 20th century (Agre, 1994). Today, the growing ease of tracking and growing volumes of left-behind traces make the promise of perfect traceability seem increasingly achievable.

Blockchain technologies, in particular, have come to signify this possibility as a means of clarity within otherwise black-boxed infrastructures (Bertino et al., 2019; Kritikos, 2020). They have also, however, given rise to a new politics of traceability that is both imbricated in deeper power structures but also shaped by the new technological affordances of digital distributed ledger systems.

Histories of traceability

The contemporary definition of traceability, according to the *Oxford English Dictionary,* has been shaped by diverse contexts, ranging from geography (1793) and natural theology (1802) to archaeology (1854) and physiology (1874). In addition, the OED cites a late 19th-century law journal, which argued that “The doctrine of following trust money depends on traceability,” a meaning that is echoed in the common law definition of traceability (tracing) as the right to assert claims against one’s property (Scott, 1965).

It is no coincidence that traceability occurs within the context of capital and control. Control derives etymologically from the French *contre-roule*, a duplicate of another document kept to crosscheck. The origins of the word control thus link to verification, later branching into broader meanings of management and surveillance in the 17th century (Chamayou, 2015). Therefore, traceability has historically been a critical factor in economies of scarcity and colonialism. It enables verification of ancestry and origins (Fourcade, 2012), as well as management techniques that create new information flows and control.

Ledgers are central traceability technologies, functioning as *contre-roules* designed to enable *verification* and *management*. The rendering of enslaved Africans as ledger entries, for instance, not only ensured control in the form of rights to locate and reclaim them in the case of escape but also gave rise to modern management practices (Browne, 2015; Rosenthal, 2018). Moreover, and sometimes relatedly, it gave rise to value speculation, for instance, in insurance claims (Baucom, 2005; Keeling, 2019).

Traceability in the age of blockchain

In his work on the infrastructures of traceability in the digital age Professor of accounting Michael Power foregrounds three different "faces or ontologies" of traceability: ideational (traceability as regulatory ideal), material (traceability as technological infrastructure), and processual (traceability as organisational connectedness and distributed agency) (Power, 2019). *Ideationally*, traceability is a programmatic value related to the facilitation of regulation and accountability. In this regard, traceability means the ideal of accurately tracing people and things. *Materially*, traceability takes the form of diverse technologies (analogue and digital), including ledgers, passports, and blockchains. And *processually*, traceability is the continual establishment of connectedness across a multitude of organisations. Each of these ontologies, a word Power uses almost synonymously with "characteristics", is exceedingly relevant in the context of blockchain technologies: the growing interest in blockchains is connected, at least in part, to the radical promises of democratisation and decentralisation that blockchain proponents constantly expound; for several emerging traceability schemes, blockchain is the traceability infrastructure; finally, these schemes connect actors across organisational forms (producers, regulators, etc.) and levels (from individuals to institutions). Furthermore, each of these three ontologies further highlights the inherently political nature of traceability technologies, which, as Calvão and Archer (2021) show in the context of mineral supply chains, have "the potential to actively reshape socio-spatial scales and create new digital territorialities with impacts on livelihoods, control and intermediation, and social inclusion."

The *ideational* dimension of traceability in blockchain technologies embody the possibility of regulation and accountability through the affordances of their technological apparatus. In light of an ever-more globalised and complex world, distributed ledgers embody a regulatory ideal of knowing the origins and paths of people and things insofar as they promise accuracy and immutability. That is, distributed ledgers are claimed to capture in an accurate and tamper-proof way historical records of transactions, which then allow regulation and accountability through inquiries into them. This programmatic ideal of accurately tracing people and things is mirrored in various contexts of blockchain technology application from supply chain provenance (Kim & Laskowski, 2018) through accountability in governmental affairs (Aztori, 2017) to secure data sharing (Shrestha et al., 2020). There is also, however, a tension between blockchain-enabled traceability as a regulatory ideal and demands for data justice, privacy and anonymity. In this context, for instance, groups such as the Center for Democracy and Technology (Kamara et al., 2021) and scholars at the Stanford Internet Observatory (Pfefferkorn, 2021) have expressed concerns about the implications of traceability for the future of privacy and anonymity. Scholars have in this context also pointed to the ambivalence haunting decentralised systems, because they are now both understood in terms of their evasion of regulation (Walker, 2021) and achievement of privacy (Bodó et al., 2021) as well as facilitating the very same through traceability. Thus, the ideational ontology of traceability in distributed ledger technologies is paradoxically implicated in a tension between the potential for regulation and accountability, and a commitment to their evasion.

Materially, the technological architecture of blockchain is emblematic of the material face of traceability. This stems mainly from the material affordances of digital distributed ledgers which constitute a specific type of database maintained on a distributed network, whose participants, therefore, have a shared, identical, and ideally tamper-proof record of transactions (Davidson et al., 2016). Most crucially, and because of this, they differ from traditional ledgers in that they prevent the need for a central trusted third party (Maurer, 2016). On a fundamental level, the word "blockchain" itself encapsulates the particular materiality of traceability: "blocks" capture detailed data that is then linked to each other in a historically linear and traceable "chain". In this vein, Power (2019) stipulates: "Blockchain is, therefore, the dream of, the metaphor for, a perfect, uniquely referential, precise traceability infrastructure" Scholars have also, however, pointed out that this imaginary of blockchain is sometimes far removed from the reality of blockchain technology in use (Power, 2019; Calvão & Archer, 2021). While blockchain technologies may reify the computational imaginaries of linear time, now down to the "femtosecond" as Geoffrey Bowker observes (Bowker, 2021), they also operate as a chain of translation. As Marieke de Goede (2018) notes, such chains always involve a "dynamic process of continuous circulation, referral, and contestation" producing not only a politics of logistics but also of modification. Thus the imaginary of blockchains as producing a neatly iterated trace that can be followed from one point in time to another point in time obscures the self-referential relationships and feedback loops that such traceability initiatives invariably generate and the iterative information ecologies they are part of (Amoore, 2019).

Moreover, blockchain technologies, which rely on inordinate inputs of physical resources (energy and water, in particular) and produce increasingly vast amounts of (Cooper 2021), exemplify the material contradictions of traceability. Nevertheless, the promise of traceability in the context of blockchain technologies is premised on specific technical characteristics of distributed ledgers, even if claims about those characteristics do not match the reality of actually-existing blockchains. Importantly, distributed ledgers differ from traditional ledgers in that they prevent the need for a central trusted third party (Maurer, 2016). In doing so, distributed ledger technology allows the consensus-building process in socio-economic matters to be shifted away from governments and big corporations, with whom these competencies traditionally rested, leading Davidson et al. (2016) to theorise blockchains as a kind of institutional innovation. Moreover, the purportedly "trust-free" nature of distributed systems facilitated the emergence of self-executing *smart contracts*, enabling the verification of transactions without human interference (Maurer, 2016). Although a growing body of critical scholarship has rejected many of these claims about the immutable, decentralised, and trust-free nature of blockchains, these narratives persist in popular discourse and are fundamental to the promise of blockchain-enabled traceability schemes.

Distributed ledger technologies also bear the imprint of traceability's processual trait. Crucially, the processual establishment of connectedness links discrete organisational entities into an interconnected, dynamic infrastructure. This is a prerequisite for inquiries into the traces of objects moving through time and space (Power, 2019). For instance, this is a relevant undertaking in supply chains that span organisational boundaries, where blockchain-based traceability platforms have been proposed as a solution (Da Cruz & Cruz, 2020). The highly scattered and crime-ridden fisheries industry, for example, whose stakeholders include businesses, governments, and NGOs, is made governable through distributed ledgers by means of continual processes interlinking these stakeholders (WWF, 2018; Cruz & Da Cruz, 2020). Similarly, blockchain technologies are deemed suitable for the promotion of international cooperation (Reinsberg, 2021), and as fitting platforms for a well-functioning Internet of Things (Reyna et al., 2018). In doing so, distributed ledger technologies foster distributed modes of agency and shared responsibility among the implicated organisations. Such modes of governance through processual traceability, however, are themselves generative of novel demands and expectations whose fulfilment, failure, and surpassing imply a politics of traceability. Distributed ledger technologies emerged amid growing societal demands for traceability, providing a technical solution to a particular problem, even as their rapid adoption across different contexts and in different industries has generated new problems of untraceability. Processual traceability through distributed ledger technologies is thus a dynamic practice that links discrete organisational entities into interconnected structures, thereby enacting distributed modes of agency and shared responsibility, and indexing an evolving politics of traceability.

Traceability as accountability, explainability, and speculation

Having outlined some of the distinct but interconnected facets of traceability, we now turn to three recurring issues cutting across discourses on distributed ledger technologies: traceability as accountability, explainability, and speculation. Firstly, traceability is linked to concerns about accountability, the attainment of which through distributed ledgers is at once promised and questioned by emergent scholarly literature. Secondly, traceability through distributed ledgers relates to explainability insofar as the traces captured on them spark debates about the possibility of accurately explaining diverse spatio-temporal trails. Finally, traceability is also embroiled in speculative matters in the sense of giving rise to new forms of speculations of value.

Accountability

While traditional ledgers and audit regimes have historically offered traceability techniques of accountability to privileged groups in society (e.g., Baucom, 2005), blockchain-enabled traceability initiatives were and are often praised for their democratising and empowering potential by, for instance, enabling citizens of the developing countries to hold their governments accountable (Kshetri, 2017; Pilkington et al., 2017) or giving consumers access to accurate information about the origins of the products they buy. On a more general level, these hopes are linked to the projected empowering character of blockchain technologies (Tapscott & Tapscott, 2016). However, a growing critical literature has exposed the illusory nature of these optimistic claims (Roubini, 2018; De Filippi, 2019).

Emergent empirical and theoretical insights in the domain of supply chains serve to demonstrate this. For example, Calvão & Archer (2021) expose that the reality of blockchain use in mineral supply chains is characterised by a growing pervasiveness of private blockchains run by powerful corporate actors, which serves to further marginalise – rather than empower – artisanal miners and other communities at the so-called bottom of the pyramid. Similarly, Kshetri (2021) highlights that while blockchain-enabled traceability under the pretext of accountability has a promising outlook, it is at odds with reality. Because multinationals often design blockchains according to their preferences, they also reinforce existing power imbalances. Thus, blockchain-enabled traceability initiatives for accountability seem to primarily operate in the interests of powerful corporate actors. On one hand, this makes sense: blockchains store information about people and things, and as philosophers from Bacon to Foucault have shown, those who have access to information about people and things tend to have some degree of power over them. Like any other tool or technology, blockchains are inseparable from the social context in which they are used. What is new is the extent to which an overarching concern with traceability has motivated the adoption of blockchain technologies, and the extent to which other desirable outcomes (such as accountability, but also sustainability, democracy, human rights, and so on) increasingly presuppose an embrace of technologically-mediated traceability. This is distinct from the motivation behind other forms of record keeping, such as national or imperial censuses, which were primarily motivated by a desire to collect the accurate amount of taxes from an accountable population. Even if traceability was also an aspect of censusing, which helps governments track migration both internally and externally, traceability seems to have only recently become a dominant ideation.

Explainability

A second issue associated with traceability in blockchain technologies revolves around questions of explainability. This is particularly true to the extent that decisions based on the analysis of data stored on blockchains have to be explained to affected stakeholders. Through an analysis of sustainability standards in the tea supply chain, Archer (2021) shows how the purported immutability of 'Big Data' stored on blockchains can be invoked to explain and therefore justify decisions that might otherwise seem unjust. Some sustainability standards stipulate that even household crops cannot be planted within a certain distance of rivers, a space known as a riparian zone, even though many smallholder farmers rely on this land for subsistence agriculture. When audits were paper-based, auditors could overlook these kinds of minor violations, but as audits become more frequent and even automated, and as the records these audits produce become digitised, that flexibility becomes nearly impossible, causing smallholder farmers to potentially lose their valuable sustainability certifications. In attempting to explain this harsh decision, standards developers and multinational companies both point to the objectivity of data and rules, obscuring the human aspects of certification (or, in this case, decertification) behind a rigid veneer of quasi-algorithmic governance. Underlying all this is a fairly straightforward explanation: in order for sustainability certifications to be of value, the products to which those certifications are affixed need to be traceable all the way back to a farm that complies with the standard in question. While blockchain enthusiasts typically foreground the immutability of data stored on blockchains (Tapscott & Tapscott, 2015), it is crucial to keep in mind that entities rendered as data in a blockchain are, like all data, never "raw" or neutral (Gitelman, 2013). Power (2019) reminds us that "technologies of trace creation like blockchain are always imperfect and incomplete realizations of the ideals that motivate them.".

Speculation

Thirdly, traceability through blockchain technology seems to have engendered new forms of speculations of value. Even the most prominent blockchain-undergirded cryptocurrency, Bitcoin, is used by most not as a medium of exchange but as a speculative asset (Baur et al., 2018). More recently, NFTs, which afford to uniquely identify the owner of a digital artefact, have attracted public attention and monopolised the discourse around blockchains. The staggering sums demanded for NFTs have led many to predict a speculative bubble (Ball, 2021).

The fact that a substantial share of both Bitcoin's and NFTs' utility seems to stem from their speculative potential further demonstrates that distributed ledgers constitute yet another, but not novel, form of traceability to govern economic relations in well-known ways. Bitcoin, in particular, despite its advertisement by figures like Elon Musk as a radically decentralised and democratic currency, has generated vast amounts of greenhouse gas emissions and has engendered resource conflicts between bitcoin miners and Indigenous communities, and is only valuable insofar as it is easily exchanged with the currencies like the US dollar and euro that Bitcoin advocates so callously deride. As Caliskan (2020) astutely observes, blockchain never truly disintermediates, but simply reintermediates, (re)inscribing unequal power relations even as it gives rise to newly empowered intermediary organisations.

Conclusion

Traceability is the ability to identify and trace something or someone. Optimistic narratives about the promise of blockchain-enabled traceability tend to be unfounded, obscuring a reality wherein traceability schemes are designed in a way that empowers those who collect, store, and control access to the increasingly vast quantities of data that constitute the digital traces of both people and products. From modern slavery (Nolan & Boersma, 2019) and unaccounted-for emissions to harmful AI systems (Kritikos, 2020) and online privacy, the framing of diverse social and environmental problems as a purely technical challenge of either too much or too little traceability presupposes purely technical solutions that are divorced, discursively at least, from the social contexts in which technologies like blockchains are developed and deployed. But technology never exists in a vacuum, and the politics of traceability are intimately and inextricably linked to the politics of technology.

Things leave traces as they move along a path through space and time from an origin to a destination. The extent to which these traces are interpretable as discrete objects and the extent to which those interpreted objects can be used to map the specific path of a specific thing from a specific origin to a specific destination is the traceability of that thing. From stone blocks to blockchains, from individuals to dividuals, from oral histories to smart contracts, technologies of traceability are certainly not a recent phenomenon. What is new, and what demands much more critical attention, is the increasing prominence of digitally-mediated traceability schemes as a proposed solution to problems ranging from financial wellbeing to climate change mitigation to food safety to border security. The ideational foundation of these schemes, the materiality of traceability technologies, and the processes involved in their development, adoption, and resistance are always already technopolitical; thus, whether one is interested in traceability as accountability, as a mode of explainability, or as speculation about value(s), the politics of traceability technologies like blockchain must remain front and centre.

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