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Gayan Benedict

University of Technology Sydney, gayan.benedict@uts.edu.au

Clare Sullivan

Georgetown University, cls268@georgetown.edu

Asif Gill

UTS, asif.gill@uts.edu.au

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Governance Challenges of AI-enabled Decentralized Autonomous Organizations: Toward a Research Agenda

Short Paper

Gayan Benedict

University of Technology Sydney
Sydney, Australia
gayan.benedict@uts.edu.au

Asif Gill

University of Technology Sydney
Sydney, Australia
asif.gill@uts.edu.au

Clare Sullivan

Georgetown University
Washington DC, USA
cls268@georgetown.edu

Abstract

The emergence of novel applications using distributed ledger technologies (DLTs) has gathered pace since the introduction of Bitcoin and the subsequent release of the Ethereum platform for decentralized applications (dApps). Such decentrally governed DLT systems are accelerating the displacement of intermediaries in regulated contexts such as the financial system and challenging the efficacy of governance regimes that have conventionally levered governance controls on identifiable, accountable decision-makers. The governance challenges of DLT systems are exacerbated by the arrival of digital autonomous organizations (DAOs) that use on-ledger decision-making mechanisms to further displace or eliminate human decision-makers. When DAOs are augmented with artificial intelligence (AI), their potent combination of computational power and access to large on-platform data sets and resources, signals a significant disruption to conventional institutional, regulatory, and legal governance regimes. This paper discusses the governance challenges of AI-enabled DAOs and presents a research agenda to address these challenges.

Keywords: Governance, Distributed Ledger Technology, Bitcoin, Regulation

Introduction

The emergence of distributed ledger technologies (DLTs) and their derivatives has accelerated over the past decade. Introduced by Bitcoin in response to the Global Financial Crisis, thousands of variations of DLT now fulfil the prediction of a ‘Cambrian explosion’ of DLT designs (Ehrsam 2017, p. 2). DLT systems, particularly permissionless variants such as Bitcoin that present no substantive barriers to participation, facilitate trust between parties by using cryptography and incentives to displace society’s reliance on intermediaries and authorities (Beck 2018). In the years since Bitcoin’s release, the Ethereum platform’s launch transformed DLTs into ecosystems of decentralized applications (DApps). DApps add executable code by implementing smart contracts that execute logic when specific conditions are met. Spurred by this innovation, many DLT-based solutions have emerged, including decentralized finance enabling peer-to-peer financing (DeFi) and non-fungible tokens (NFTs) that assure the uniqueness of digital assets.

In recent years, decentralized autonomous organizations (DAOs) have emerged as a new class of DLT systems. DAOs are autonomous dApps that leverage DLT-based decision-making mechanisms to oversee their governance and operations (Buterin 2013). For DAOs, some of these decisions are automated through the execution of smart contract logic, while others are made through voting by governance rights holders (Kondova and Barba 2019). A significant characteristic of DAOs is their operation on resource-rich DLT platforms like Ethereum. Such platforms give DAOs access to on-ledger digital assets such as fungible crypto-currencies and NFTs that can be earned, held and divested by participants.

As DAOs proliferate, the arrival of a new class of DAOs incorporating self-directing artificial intelligence (AI) is emerging. AI has been described as the application of attributes of human intelligence by machines (McCarthy 2007). Modern AI implementations use programmed code and are improved with machine learning algorithms that generate knowledge from large volumes of data. AI-enabled DAOs incorporate AI into their operation or governance. Over the past several years, examples of DAOs incorporating AI to supplant the role of conventional human decision-makers have emerged. As DAOs incorporate AI, it has been posited that their capabilities will accelerate as they gain access to sizeable on-platform data sets and their functionality extended through the acquisition and use of on-platform resources (McConaghy 2016).

A review of academic literature identified limited research studies addressing the emergence and challenges of AI-enabled DAOs. To address this research gap, we are adopting a participatory action design research (ADR) approach to incorporate multivocal literature analysis and DLT governance expertise to design a governance framework for AI-enabled DAOs. Multivocal literature reviews explore a broader range of data sources and are useful in emerging research contexts with limited academic research and a significant pace of innovation (Ogawa and Malen 1991). The broadened literature review informed a process of research problematization to identify a novel research question in the intersectional fields of AI and DLT research. Problematizing effectively develops novel questions in intersectional research by identifying conflicting assumptions underpinning synthesized research domains (Locke and Golden-Biddle 1997). In the intersecting AI and DAO research domains, AI-enabled DAOs challenge a fundamental assumption underpinning conventional governance contexts – namely, that governance outcomes are achieved by leveraging controls on identifiable accountable human and institutional decision-makers. As DAOs incorporate AI that supplants identifiable accountable decision-makers, we are faced with the question of ‘how should AI-enabled DAOs be governed?’

To inform the response to this question, this paper is organized into five sections. Firstly, it discusses the research background and approach we are adopting in this study. Secondly, it explores DAOs as a rising class of DLT applications. Thirdly, it explores the emergence of AI-enabled DAOs at the juncture of AI and DLT governance domains. Fourthly, it explores the challenges that AI-enabled DAOs present to conventional IT, regulatory and legal governance regimes. Finally, it proposes a research agenda for this emerging interdisciplinary research domain.

Research Background and Approach

This in-progress research is part of a joint academia and government study of the governance challenges of AI-enabled DAOs. The study adopts a participatory ADR method to incorporate participants in designing a research problem and artefact to identify the governance challenges and recommend responses to AI-enabled DAOs. A key benefit of the participatory ADR approach is its suitability for research problems with

limited extant research and literature through the incorporation of expert participants (Haj-Bolouri et al. 2015). The participatory ADR research approach is being supplemented by literature and theory-generating research techniques to increase the theoretical contribution of the research artefact (Beck et al. 2013).

This paper presents the outcomes of the initial multivocal literature review and future research agenda. While information systems researchers have gained insights into the governance of DLT systems (Beck et al. 2018), the regulatory implications of decentralized DLT governance (Benedict and Gill 2021), and the regulatory challenges of AI systems (Sullivan 2018), we were unable to find any significant body of research on the governance of AI-enabled DAOs in detailed searches of the AIS Basket of 8 and Google Scholar. In emergent research fields such as DLT, where practical implementations often precede academic research, multivocal literature extending beyond well-recognized academic data sources has been deemed an appropriate source of data (Ogawa and Malen 1991). In the context of AI-enabled DAOs, a multivocal literature review entails the examination of broader literature sources, such as industry-based DAO discussion papers, in addition to extant research in DLT and AI. As is common in design research, the early development of theory, such as the governance challenges identified in this paper, is abductive in nature (Gregor et al. 2020).

Having reviewed a broad base of diverse multivocal research on the emerging field of AI-enabled DAO governance, the study develops a synthesized coherence across the research domains of AI and DAO governance. Creating synthesized coherence is a technique used to draw connections between non-intersectional research fields to identify emerging or otherwise underdeveloped research fields (Locke and Golden-Biddle 1997). Using this technique, we identified a novel research question by identifying a problematic assumption underpinning the synthesized AI and DLT governance research domains: the identifiability of accountable human or institutional decision-makers upon which governance controls are levered. Many conventional governance controls rely on such identifiable accountable decision-makers and risk technological displacement by AI. In future research stages, inter-disciplinary experts from IT, regulatory and legal governance domains will be leveraged to co-design a research artefact to explore the challenges presented by this AI displacement and inform responses to the governance challenges discussed in this paper.

Decentralized Autonomous Organizations

The absence of trust among unknown parties has been historically addressed through the assurance of overall systemic integrity by central authorities and intermediaries (Scott 1998). As these central parties themselves have been recently regarded with mistrust, their role in ensuring systemic trust has been displaced by cryptography and incentives that assure the operational integrity of DLT systems (Beck et al. 2018). Using these mechanisms, DLT systems distribute data across multiple locations and stores without relying on a trusted centralized canonical register or ledger.

The first DAO appeared in May 2016 on the Ethereum DLT platform. ‘TheDAO’ was designed to crowd-fund investment ideas proposed and voted on by community participants. Within days of its launch, however, a flaw within TheDAO’s smart contract code was identified and exploited by hackers. As no governance mechanism within its design accommodated such a scenario, it was not prevented or remediable using TheDAO’s internal governance framework. To thwart the completion of the hack, Ethereum’s core developers agreed to ‘fork’ the Ethereum platform to create an alternative consensus version of Ethereum’s blockchain history where TheDAO’s hack had never occurred.

Since the launch of TheDAO, a surfeit of DAO variants has emerged that address the original weakness in the concept’s initial design. A key characteristic of such DAOs is that they run in a decentralized, autonomous manner on DLT platforms (Kondova and Barba 2019). In DAOs, smart contract execution is used to assure trustless environments and make operational or governance decisions by executing ‘on-ledger’ smart contracts rather than conventional ‘off-ledger’ mechanisms such as the decisions of organizational executives or boards (DuPont 2017). By purportedly enabling highly scalable transparent on-ledger governance, some have claimed DAOs represent an evolution of governance, addressing the problem of conventional governance being invested in a few that make decisions in their own interests (Merkle 2016). However, recent industry analysis of the growing numbers of DAOs indicates that many still typically concentrate decision-making authority among relatively few human decision-makers (Chainalysis

2022). As this reality of not-so-decentralized DAO governance gains attention, pressure from market participants is likely to call for further evolution of DAO governance mechanisms to increase their integrity.

The Emergence of AI-enabled DAOs

The field of AI research has developed in parallel to that of modern computational research. McCarthy (2007, p. 2) defines intelligence as “the computational part of the ability to achieve goals in the world”. While the field of AI research has seen a wide range of definitions of artificial intelligence, commonly accepted definitions define AI without reference to humans and instead as systems that perceive their environment and take actions to maximize their chances of success, where such success is determined by the attainment of a specified purpose (Norvig and Russel 2002). Machine learning, a subfield of AI, studies computer algorithms that automatically improve through experience and using data (Jordan and Mitchell 2015). When augmented with machine learning, AI systems can increase their intelligence without human intervention (Silver et al. 2021).

Concerns of DAO governance being concentrated among relatively few decision-makers are now being met by calls for greater democratization of decision-making authority (Chainalysis 2022) or the removal of human authority altogether (Montes and Goertzel 2019). AI-enabled DAOs such as SingularityDAO have been recently released, which use AI to make decisions such as asset management investment choices, regardless of market trend and without active human intervention. It has been posited that such AI augmentation enables DAOs to autonomously make decisions that could conceivably extend to adjusting their core objectives and smart contract frameworks (McConaghy 2016). One outcome of such autonomous AI-enabled DAO governance decision-making is displacing conventional human or institutional governance decision-making mechanisms such as boards, executive management, or human-centred ‘conventional’ DAO voting.

For some, the convergence of AI and DLT is an inevitable outcome of continuing innovation in both fields. For advocates of this convergence view, the relative strengths of AI and DLT contribute to solving each other’s relative weaknesses. Dietzmann et al. (2020) note that DLT has experienced security, scalability, and efficiency problems, while AI has been criticized for its lack of trustworthiness, explainability, and privacy. According to this reasoning, criticisms of the centralization observed in corporate AI implementations contrast with blockchain’s inherently distributed design, AI’s opacity of internal decision-making processes contrasts with DLT’s inherent on-ledger transparency, and AI’s algorithms make educated probabilistic estimations in contrast to the deterministically driven logic of DLT smart contracts. AI can address DLT’s weaknesses by using machine learning to improve the security, scalability, and personalization of DLT systems. Conversely, DLT can mitigate AI’s weaknesses by providing the data and computational resources key to improving its power while addressing criticisms levelled at its transparency, explainability, and trustworthiness (Dinh and Thai 2018). By providing AI with access to the significant cryptocurrency and data resources available on DLT platforms, and DAOs with the autonomous decision-making capabilities of AI, AI-enabled DAOs could be a compelling match. The inevitability of such convergence is not, however, without dissent. The trajectory of AI maturation, particularly with machine learning, requires large volumes of data and computational power, both of which are typically available in a few concentrated institutions and government agencies. Such conditions for AI development arguably conflict with the inherently decentralized nature of DLT-based systems (Vergne 2020).

The arrival of DAOs, however, potentially addresses contentions in the mutual evolution of AI and DLT systems. McConaghy (2016) identifies three potential pathways for the emergence of AI-enabled DAOs; (1) the intentional design of AI into DAO smart contracts, (2) the accumulated ceding of DAO governance and decision-making control to delegated AI components, and (3) emergence of AI from a diversity of otherwise unintelligent agents whose collective interoperation creates the conditions for the unanticipated emergence of intelligence. More recently, the advent of new AI-enabled DAOs, such as SingularityDAO, has materialized. Such applied examples of AI-enabled DAOs incorporate AI to make decisions that have previously been the remit of humans. In the case of SingularityDAO, AI makes asset investment allocations without human intervention. As governance regimes seek to adjust to the emergence of AI-enabled DAOs,

The longer-term consequences of the synthesis of AI with DAOs are open to some conjecture. Montes and Goertzel (2019) note that AI DAOs operating on DLT platforms could engage in a diverse range of self-actualizing activities, including purchasing new capabilities, autonomously improving and coordinating

functions, developing emergent skills, and boosting computational power. It has somewhat controversially been contended that self-resourcing AI-enabled DAOs could extend beyond the capability of human-centric governance, resulting in outcomes unforeseen at inception (McConaghy 2016). More encouragingly, the evolution of advanced DLT-based intelligence has also been posited as a vital feature of any future society (Swan 2015). Arguably, AI-enabled DAOs present an intriguing development in the evolution of decentralized DLT systems. However, as with many intersectional innovations, their arrival is heralded by significant disruption and challenge to the status quo.

Governance Challenges

In organizational contexts, IT governance has conventionally been defined as the decision rights and accountabilities established to encourage specific behaviors (Weill and Ross 2004). The essence of such governance is that control and authority are vested in key decision makers and institutional bodies, and governance controls are levered on and through such entities to enforce the good governance of systems. Beck et al. (2018) extend this concept of organizational IT governance to distributed DLT systems, further emphasizing the importance of aligning stakeholder incentives. Such decentrally governed DLT systems enable scalability of governance that extends conventional governance frameworks beyond their reliance on central authorities and intermediaries (MacDonald et al. 2016). The AI-enablement of DAOs takes DLT decentralization a step further, displacing human decision-makers with AI technology. While benefits may flow from such AI-enablement, a diversity of literature identifies various challenges resulting from this development. We applied the process of identifying boundaries for theoretical IS constructs by Weber (2012) to classify four key governance challenges presented by AI-enabled DAOs: (1) the disruption of conventional organizational IT governance frameworks; (2) the lack of clear accountability and authority to resolve crises; (3) the disruption of legal frameworks that have historically relied on ex-post contractual enforcement; and (4) the outpacing the responsiveness of human-oriented governance.

Disruption of conventional organizational IT governance mechanisms

It has been argued that the emergence of on-ledger DAO governance represents an advance in the evolution of societal governance (Merkle 2016). Historically, corporate structures were introduced as a more efficient means of orchestrating societal resources to centrally led state-based oversight and management (Scott 1998). Corporate governance is conventionally achieved through board oversight over executive management, designed to ensure the firm's actions are aligned with the interest of shareholders (Shleifer and Vishny 1997). Historically, regulators applied regulatory governance on identifiably accountable bodies such as institutional intermediaries, executives and boards due to their ease of identification and leverage over broader regulated markets (Benkler 2016). However, these governance conventions are challenged when these intermediaries and central authorities are displaced by decentrally governed DLT systems (Benedict and Gill 2021).

DLT systems are often categorized as permissioned or unpermissioned, the distinction being whether access to and participation in a DLT system is restricted to a limited few or available to all (Beck et al. 2018). DLT-based DAOs were conceived to align with stakeholder interests through on-ledger mechanisms that implement governance and operational decision-making through executable smart contract code and the voting of governance rights holders (Buterin 2013). The implementation of restrictions in permissioned DLT-based DAOs is controlled by a limited few decision rights holders or discernible voters (Beedham 2018). Such permissioning mechanisms may afford governing bodies such as regulators some ability to lever controls on the humans or institutions accountable for the permissioning of participants. This may also be the case for unpermissioned DAO participants, where they can be identified through the holding of a DAO governance token (Kaal 2020). However, even though conventional DAOs involve human governance rights holders, parties engaging with such DAOs may still find difficulty assuring governance, mainly due to the opacity of the identity of governance rights holders (Rikken et al. 2019).

AI-enabled DAOs appear even more problematic to governing bodies as beyond at best-limited criteria for participation, such as holding a governance token, the use of AI can altogether displace human decision-making and accountability. This could take the form of an AI-enabled DAO such as SingularityDAO, where AI algorithms make asset investment decisions without human intercession. In these circumstances, the degree of self-directing autonomy applied by AI could confound the ability of governance regimes to identify accountable parties and challenge the ability of parties to seek effective recourse from conventional

organizational or regulatory governance controls. An example of where the emergence of AI-enabled DAOs could significantly challenge the efficacy of regulatory governance regimes is the European General Data Protection Regulation (GDPR). Consumer data privacy regimes such as GDPR typically target penalties and sanctions at discernible legal entities such as identifiable economic organizations and human executives serving as data controllers (Hoofnagle et al. 2019). AI has been identified as a technology capable of re-personalizing, de-anonymizing and de-pseudonymizing personal data and, in the process circumventing the requirements of GDPR (Sullivan 2018). When AI is coupled with DAOs that have access to plentiful on-platform data and resources, such AI-enabled DAOs could possess the ability to bypass human-centred governance because of the increased opacity or lack of identifiable accountable decision-makers (McConaghy 2016). As AI-enabled DAOs emerge, the conventionally assumed reliance on human and institutionally accountable decision-makers is challenged, and the question of ‘*who* is accountable for an AI-enabled DAO?’ becomes problematic.

Lack of clear accountability and authority to resolve crises

The need for governance intervention in AI-enabled DAOs may be deemed warranted when a DAO, through its actions and decisions, causes losses to participants that would typically elicit a crisis response by governing bodies such as institutional boards or regulators. When the hack of TheDAO occurred, such conventional crisis interventions were not readily available to DAO participants. The only way to minimize substantial losses was for the infrastructural hard forking to the entire underlying Ethereum DLT platform (DuPont 2017). This reactive governance approach has been described as minimalistic and side-stepping the development of valuable norms capable of addressing future crises (Chiu and Lim 2021). The hack has been described as highlighting a weakness of decentralized governance in addressing unforeseen governance crises (Hassan and De Filippi 2021). Should a sufficient number of AI-enabled DAOs trigger material participant losses due to poor AI-enabled decisions, such as poor asset class investment decisions that materially affect broader investor confidence, adverse investor outcomes could challenge confidence in overall financial system stability, triggering systemic contagion and contribute to a financial crisis. The essence of this governance challenge revolves around the reliance of DAOs on decentralised decision-making mechanisms, which may fail to appoint accountable designated parties with the authority and powers to resolve DAO-based crises such as that experienced with the hack of TheDAO (De Filippi et al. 2020). The governance weakness is further complicated if AI-enabled DAOs present no formalized organization nor easily identifiable accountable parties. In an operational or governance DAO crisis, the lack of clearly identified parties responsible for crisis resolution (such as central banks for financial crises or boards for organizational crises) risks nullifying a key enabler for the ongoing stability and operation of governed systems.

Reduced efficacy of conventional legal frameworks

It has been argued that in contrast to conventional contractual governance, which places heavy reliance on ex-post contractual enforcement to ensure the ongoing alignment of contracted parties, the governance of DLT systems such as DAOs largely relies on the ex-ante enforcement of intent using programmatically enforceable smart contracts (Werbach 2018). According to this view, DLT-based governance relying on on-ledger governance mechanisms such as smart contracts supplants the need for participants to rely on legal frameworks to ensure compliance with agreements and instead relies on code to enforce agreed intent at the time of smart contract execution (Lumineau et al. 2021). DAOs stand to accelerate this move away from conventional legal recourse through contract enforcement by further obfuscating the identity of accountable governance decision-makers (WEF 2022). Significant focus is being directed to the implications of DAOs on conventional legal regimes, such as recent regulation being explored in the US state of Wyoming (Wyoming 2022). However, such early exploration often depends on the concept of ‘person’ and decision accountabilities attributable to corporeal beings, both challenged when AI is adopted.

AI-related legal complications are further exacerbated when decentrally deployed DAOs operate on a distributed infrastructure that traverses jurisdictional boundaries. The distribution of DAO operations across jurisdictions raises uncertainties about which specific laws a DAO and its constituents are required to obey (Kaal 2020). For legal frameworks that have taken centuries to develop and harmonize across jurisdictions, it is perhaps not surprising that their ability to accommodate technology-based governance innovations such as DAOs is not without significant challenge.

Outpacing the responsiveness of human-oriented governance

The explosion in DAOs, particularly those partaking in regulated contexts such as the financial system, presents challenges for regulators and governing bodies responsible for managing systemic risks and protecting the interest of market participants (ECB 2022). The relatively low cost of developing DLT systems like DAOs presents a challenge for regulators and institutional governance functions, which are often faced with the challenge of applying their limited technical expertise to fast-proliferating variations of DLT systems (Benedict and Gill 2021). A further confounding characteristic of AI-enabled DAOs is their ability to adjust their decision-making mechanisms and access large on-ledger data stores sufficient to improve machine learning capabilities faster than conventional governance bodies can scrutinize and sufficiently respond to (McConaghy 2016). Such unchecked AI-enabled DAO evolution on resource and data-rich DLT platforms could prove problematic for governing bodies and society. The Oxford theorist Nick Bostrom provides an alarming example of AI systems attaining general intelligence capability that could trigger AI supremacy over human governance (Bostrom 2003). In an outlier application of Bostrom's AI supremacy model, an AI-enabled DAO could evolve quickly and employ self-improving machine learning capability that outpaces the responsiveness of the humans who created the environment conducive to its emergence. Whether technology, governance design or regulation could impede this eventuality is to be seen. Such a DAO-based evolution of AI capability could present significant challenges for society unless effectively governed.

Future Research Agenda

The convergence of AI technology with DLT-based DAOs heralds new challenges for conventional governance regimes. These challenges devolve primarily from the technological basis of AI conflicting with the core organizational IT governance assumption of leveraging governance controls upon and through identifiable accountable decision-makers. This paper explored some of the challenges that result from the breakdown of this core assumption. Further research is required to understand these challenges and explore appropriate responses. This research requires interdisciplinary exploration of the legal contexts and more technologically oriented disciplines such as IT and DLT governance. Such research will address the invitation by Beck et al. (2018) to explore the decision-making, accountability and incentive dynamics of the fast-growing domain of decentralized DLT systems. Future research should explore the inherent characteristics of AI-enabled DAOs and seek to adapt governance frameworks for this new class of innovation. Such research would explore the decentralized nature of AI-enabled DAOs and seek to identify effective governance controls that accommodate the displacement of human decision-making in AI-enabled DAOs. These control responses would address the challenges presented by the reduced efficacy of governance regimes that conventionally rely on identifiable accountable decision-makers. Future research should explore the regulatory, institutional, and legal governance contexts most likely to be disrupted by the emergence of AI-enabled DAOs. Three research pathways are:

- 1) The regulatory risks introduced and impacted by AI-enabled DAOs and regulatory governance controls to effectively treat these risks.
- 2) The impact of AI-enabled DAOs on organizational IT governance frameworks.
- 3) The impact of AI-enabled DAOs on legal systems and adaptations to accommodate their synthesis.

Conclusion

The emergence of AI-enabled DAOs portends new classes of governance challenges for regulators, institutions and DLT participants. AI-enabled DAOs further increase the decision-making opacity of DAOs by displacing conventional human and institutional decision-makers. This human displacement challenges conventional governance frameworks that assume the availability of such identifiably accountable parties upon which to lever governance controls. The incorporation of AI to push DAOs beyond the reach of conventional governance is exacerbated by the ability of AI to evolve rapidly through continuously improving machine learning capability and traverse jurisdictional boundaries. The ultimate destination of AI-enabled DAO expansion on resource-rich DLT platforms is unnervingly unbounded. This paper identifies key governance challenges that warrant further research.

To address these challenges, we are continuing research to (1) understand how decentralized, autonomous characteristics of AI-enabled DAOs challenge conventional governance regimes and (2) identify appropriate control responses to ensure effective governance over this new class of DLT system. The study is now engaging research participants consisting of interdisciplinary institutional, regulatory and legal DLT experts to explore the challenges of AI-enabled DAOs and co-design a research artefact framework for their effective governance.

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