Perspective

The TAO of Blockchain Intelligence for Intelligent Web 3.0

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WE are in an exciting new intelligent era where various Web 3.0 systems emerge and flourish. [1]–[3]. In this new epoch, the collaboration of data and knowledge, humans and machines, actual and virtual worlds is undergoing an unprecedented diversification and community-driven transformation, unveiling an open future full of boundless possibilities. However, the value of dispersed data extends far beyond passive storage and application. Instead, it has become an incentive and driving force that connects different workers in different worlds, forming a more powerful network of knowledge. No longer monopolized by a select few organizations or companies, the community-driven data sharing and exchange enable every individual to participate and contribute [4]–[6]. The diversification, sharing and integration of data create numerous avenues for learning, exploration, and innovation.

However, merely possessing data is not enough to propel us into the new realm of Web 3.0. The continuous progress and innovation in intelligent technologies are the key to taking this era to new heights. Artificial intelligence (AI), machine learning, natural language processing, and other intelligent technologies have integrated into various aspects of our societies, showcasing astonishing capabilities in data processing, information interpretation, and knowledge inference [7]–[9]. With the support of blockchain intelligence [10], realized through the combination of AI and blockchain technologies, the Web 3.0 era reveals unprecedented vitality [11], [12]. Decentralized and distributed collaboration in the trustless environment allows individuals to pool their wisdom, share insights, and collectively create a more insightful knowledge ecosystem. These sparks of wisdom not only drive advancements in technology, economy, and society but also lead us into a new era of intelligence.

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The Role of DAO for Intelligent Web 3.0

Decentralized autonomous organizations and operations (DAO) play a transformative role in blockchain intelligence and the intelligent Web 3.0 driven by it. They embody the principles of decentralization, autonomy, and collective decision-making, which are crucial to realize blockchain intelligence [13], [14]. These innovative entities disrupt traditional hierarchical structures and empower individuals to participate in governance, collaboration, and resource allocation. It is undeniable that the DAO will continue to be at the forefront of innovation, paving the way for a more inclusive, democratic and decentralized world. By leveraging the power of data sharing, knowledge collaboration and intelligent technologies, together with the decentralized governance principles, we can usher in an era of unprecedented cooperation and progress, where individuals actively shape their collective future [15], [16].

Operating on blockchain technology, DAOs utilize smart contracts to enable transparent, secure, and immutable decision-making processes [17]–[19]. As such, they eliminate the need for intermediaries, ensuring the trustworthy collaboration in the trustless environment. Besides, by allowing a broad audience to join and contribute to the organization, DAOs unlock the potential for diverse perspectives and ideas to flourish. This inclusiveness enriches the pool of knowledge and ensures that decisions are made with the collective wisdom of the entire community, rather than being confined to a select few. Moreover, DAOs promote a sense of ownership and accountability among their members. Their transparency fueled by blockchains not only enhances trust but also motivates members to act in the best interest of the organization, as their contributions directly affect the collective success. Furthermore, the flexibility and adaptability of DAOs make them ideal for the dynamic landscape of Web 3.0. Traditional organizations often struggle to keep up with rapid technological advancements and changing market demands. In contrast, DAOs can swiftly adjust their strategies, upgrade their protocols, and incorporate new ideas through community proposals and voting mechanisms. This agility allows them to stay responsive to emerging challenges and opportunities.

However, DAOs also reveal the following shadows in practice, stemming from deficiencies that hinder their full realization of the inherent essence of justice, which is deeply rooted in their core principles of decentralization and autonomy [20], [21].

1) The new monopoly caused by decentralization: de-

spite advocating for decentralized and democratic governance, DAOs may encounter challenges in achieving ideal governance in practice, stemming from technical limitations and inadequate participation. Some DAOs might be influenced by a few active members or individuals/organizations holding significant amounts of tokens, leading to power centralization and biased decision-making.

2) The resource trap arising from token economy: an excessive reliance on token economy often leads to the neglect of essential technological and operational development within DAOs. Many DAOs become overly focused on the token economy, with the primary goal being the appreciation of native tokens. This token-centric approach may inadvertently prioritize the interests of token holders over the overall objectives and long-term sustainability of the organization. Decisions that maximize token value in the near term might not align with the broader mission and vision of a DAO, potentially causing misalignment and discord among community members.

3) The unreliability in value systems: in the process of building an economic system, many DAOs rely on capturing the value of governance rather than transactions. However, due to limitations in frequency and scalability, governance alone cannot serve as the core value source for DAOs. Additionally, for some scenario-based transactional value, DAOs' economic models may exhibit periodic fluctuations, leading to value instability and unpredictability. Consequently, DAOs struggle to consistently generate sufficient value, resulting in a precarious and unreliable economy.

4) The failure of democracy due to decision-making barriers: despite adopting democratic decision-making mechanisms, DAOs often encounter a lack of active participation from decision-makers due to factors such as decision-making costs, professional knowledge requirements, and the sense of futility in voting. As a result, the true potential of democracy is not fully realized.

5) The vulnerability in technical systems: Although blockchain technology itself is deemed highly secure and decentralized, the smart contracts governing DAOs might still be vulnerable to loopholes and attacks. It significantly shakes members' confidence in collective governance.

From DAO to TAO

As early as 2018, Fei-Yue Wang and his team have recognized these issues and proposed the concepts of "TRUE" and "DAO" in the context of blockchain intelligence, where "TRUE" stands for Trustable, Reliable, Usable, and Efficient/Effective, and "DAO" refers to Distributed & Decentralized (D), Autonomous & Automated (A), Ordered & Organized (O) [22]. They emphasize the importance of blockchain technology for truly make trust and attention be commodities that can be produced massively and circulated on a large scale, thus provide a high level of trustworthiness for information and transactions. However, achieving genuine trust also requires ensuring system reliability, user interests, and efficient operation. In 2019, they further elucidated the essence of the DAO and pointed out that it is not just a technological and organizational form, but also a governance concept characterized by decentralization, democratization, and community-driven

principles [13]. In 2021, they emphasized that DAOs should focus on not only organizations but also operations. While DAOs have been primarily associated with their decentralized organizational structure, it is essential to recognize that their effectiveness and success also heavily depend on efficient and well-designed operations [23]. In 2022, they discussed the fundamental requirements for DAOs, emphasizing the need to meet the demands of "D" and "A" in both the organizational and operational perspectives [24]. They also advocated the introduction of intelligent technologies and algorithms into DAOs, enabling sophisticated data analysis, prediction, and decision-making [14]. Furthermore, the concept of TAO, namely TRUE autonomous organizations and operations, was proposed to address the challenges encountered by DAOs in the realm of blockchain intelligence [21]. TAOs shift the focus from emphasizing the decentralized attribute of DAOs to highlighting their fundamental essence of being "TRUE". They represent the holistic and balanced consideration to the development of intelligent Web 3.0. They not only underscore the importance of maintaining trust in the decentralized landscape but also prioritize intelligence and sustainability in the pursuit of DAO excellence.

The core features of the TAO include the equity distribution, non-token-centricity, diverse value systems and artificial intelligence (AI) integration, as shown in Fig. 1. The equity distribution not only means decentralization of power and benefits but also emphasizes the separation of ownership, decision-making power, and profit rights. This forms the foundation for a fair, transparent, and democratic governance model of TAOs. Non-token-centricity refers to the fact that decision-making power is not solely determined by token holders and incentives are not dominated by tokens. Besides, TAOs adopt a multi-dimensional participation mechanism, considering factors such as reputation, contribution, and technical abilities to ensure a more balanced value system. Unlike traditional DAOs, which often prioritize capturing value through transactions and token holdings, TAOs recognize the importance of incorporating various forms of value. In TAOs' diverse value systems, contribution, expertise, reputation, and individual needs all play crucial roles in decision-making and resource allocation. By valuing and integrating these multifaceted aspects, TAOs create a more inclusive and equitable environment, where participants are recognized for their unique contributions and expertise. AI integration means intelligent technologies are extensively used for decision-making, resource allocation, and operations in TAOs. It empowers TAOs' participants with better information, more efficient processes, and predictive capabilities, ultimately leading to increased engagement and effectiveness in achieving the common goals. The combination of AI and democratic principles lays the foundation for a dynamic and inclusive TAO ecosystem for realizing blockchain intelligence, further contributing to the advancement of the Intelligent Web 3.0.

DAOs and TAOs share interconnected principles while exhibiting distinct characteristics. As follows, we will conduct a comparative analysis of DAO and TAOs from the perspectives of the complex systems theory, social contract theory, and decision theory.
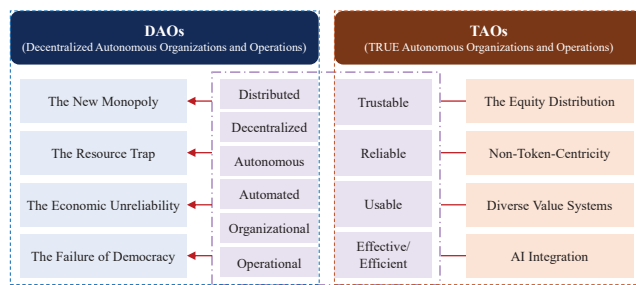
Fig. 1. Key features of DAO and TAO

1) From the perspective of complex systems theory, both DAOs and TAOs are systems whose behaviors and characteristics emerge from the interactions and self-organization of individual entities within the system [25], [26]. However, they differ in several key aspects. First, DAOs are primarily composed of virtual identities, with each participant representing themselves and exert their functions. TAOs encompass biological humans, robotic humans, and digital humans, collaborating in decision-making using distinct modes tailored to specific situations [27], [28]. Second, interactions in DAOs primarily revolve between individuals around token holding and voting under certain governance framework. While, interactions in TAOs are more diverse, where robots and AI agents can interact, collaborate, and share information with human participants, jointly contributing to the decision-making and operations. Third, TAOs possess greater intelligence and adaptability than DAOs, due to the involvement of AI technologies, algorithms and agents. They promote TAOs to respond more flexibly to complex environmental changes, generate better decisions and make rapid adjustments, enhancing their adaptability.

2) From the perspective of social contract theory, both DAOs and TAOs draw from this theory in their decentralized governance approach [29], [30]. However, their key difference lies in their value systems, with DAOs currently relying primarily on token-centric mechanisms, while TAOs seek to create a more diverse and non-token-centric governance structure for increased inclusivity and participation.

Both DAOs and TAOs are rooted in the idea of decentralized governance, where decision-making and resource allocation involve the active participation of community members. Participants in both systems come together based on their shared interests and objectives, forming a collective commitment to the organization's principles and goals. However, the main difference lies in the nature of their value systems. DAOs primarily adopt a token-centric value system, where voting power and influence are tied to the amount of tokens held by individuals. Token holders have a greater say in decision-making and governance, leading to potential concentration of power among a few participants with significant token holdings. Instead, TAOs aspire to establish a non-token-centric value system, aiming to create a more inclusive and balanced decentralized economy (DeEco) system. While TAOs may still leverage token-based mechanisms, they also consider other dimensions of participation, such as reputation, contribution,

and expertise, to ensure a fairer and more democratic decision-making process. The goal is to avoid excessive centralization of power and promote broader engagement and influence among participants, including biological, robotic, and digital humans from both real and virtual worlds.

3) From the perspective of decision theory, while both DAOs and TAOs utilize collective decision-making methods [31], their implementation and emphasis on decision-making power differ significantly.

Notably, DAOs primarily adopt the classic voting theory [32] to generate decisions, where different voting methods and mechanisms are studied to determine the majority opinion or final decision within the community, such like simple majority, proportional representation, or quadratic voting. The objective is to reach a consensus on proposals or decisions based on the voting outcomes. DAOs' voting mechanisms can vary, leading to different degrees of representation and influence among participants based on their token holdings or voting power.

In contrast, TAOs also embrace voting theory but adopt a more nuanced approach to decision-making power. Instead of relying solely on token-based voting, TAOs consider contributions and needs as additional factors in determining individuals' influence on decisions. Participants with higher contributions or addressing essential needs within the community may have a proportionately greater say in the decision-making process. This mechanism aims to create a more equitable and inclusive system where decision-making power reflects the value and efforts contributed to the community.

Moreover, with AI integration, TAOs seek to enhance justice in the intelligently autonomous governance via various decision-making methods such as overlapping consensus, "veil of ignorance", social choice and so on. The overlapping consensus guarantees decisions are reached based on overlapping agreements among different groups, so as to promote fair representation and broad acceptance of decisions [33]. The "veil of ignorance" concept inspired by John Rawls' theory of justice ensures decision-makers make choices without knowing their specific role or status, promoting impartiality and fairness [34], [35]. Social choice methods, which consider individual preferences and prioritize collective welfare, are also used to achieve a more just and beneficial outcome for the community [36], [37].

Towards Future HANOI

In the context of intelligent Web 3.0, TAOs hold the potential to embrace the new philosophy of blockchain intelligence, which aims to transform our societies into "6S" paradigms with "6I" principles [38], [39]. These TAOs are envisioned to be safe in the physical world, secure in the cyberworld, sustainable in the ecological world, sensitive to individual needs, serve for all, and be smart in all aspects. This transformation would be facilitated by incorporating cognitive intelligence and parallel intelligence for intelligent science and technology, crypto intelligence and federated intelligence for intelligent operations and management, and social intelligence and ecological intelligence for smart development and sustainability.

By integrating the new philosophy and technologies of

intelligence, TAOs exemplify the potential for Web 3.0 to usher in a new era of interconnected, sustainable, and people-centric communities. By redefining the Tower of HANOI problem to include human, artificial, natural, and organizational intelligence [40], TAOs pave the way for a future where decentralized autonomous organizations evolve into thriving ecosystems that cater to the diverse needs of individuals, communities, and the environment. Through principles of TRUE and the integration of multidimensional intelligence, TAOs stand as beacons of progress, shaping the landscape of new intelligent era and leading us towards a more equitable, intelligent, and sustainable future.

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