

## Perspective

# Digital CEOs in Digital Enterprises: Automating, Augmenting, and Parallel in Metaverse/CPSS/TAOs

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**B**IG models or foundation models are rapidly emerging as a key force in advancing intelligent societies [1]–[3]. Their significance stems not only from their exceptional ability to process complex data and simulate advanced cognitive functions, but also from their potential to drive innovation across various industries. When it comes to their value creation, the commercial application is undoubtedly an effective approach, with enterprise management serving as an ideal scenario. As we gaze into the future, it is increasingly evident that these large models will not only transform the operational facets of businesses but also revolutionize the strategic decision-making processes at their core. The introduction of large models into enterprise management marks a new era where data-driven insights and machine intelligence become integral to corporate governance.

Central to this wave of change is the role and responsibilities of the Chief Executive Officer (CEO). CEOs, traditionally seen as the harbingers of human intuition and experience in business strategies [4]–[6], are now at the crossroads of a paradigm shift towards a digital-centric business environment, which necessitates a new breed of leadership: digital CEOs [7], [8]. They will work in metaverse or cyber-physical-social systems (CPSS) to significantly transform traditional work methodologies, not by rendering people jobless but by making work processes more efficient [9], [10].

As shown in Fig. 1, they are poised to undergo a trans-

formative journey marked by three distinct developmental stages: automating CEOs, augmenting CEOs, and parallel CEOs [11]. In the stage of automated CEOs, digital CEOs are simply AI-driven tools and systems that can streamline and automate routine and administrative tasks, so as to free human CEOs from mundane tasks. In the stage of augmenting CEOs, digital CEOs go further to be digital assistants that provide advanced insights and analytics, enabling human CEOs to make more informed and strategic decisions and expanding their capabilities beyond traditional limits. In the stage of parallel CEOs, digital CEOs work in parallel to human CEOs rather than just supporting or being subservient to human decision-making. Parallel CEOs breaks away from traditional management hierarchies, introducing a new mode of human-machine collaboration where digital and human CEOs jointly form the virtual-real interactive loop for decision-making and strategic planning. These three stages outline a trajectory where the role of CEOs evolves in tandem with advancements in intelligent technologies, reflecting a profound shift in the nature of leadership and management in modern enterprises. Currently, although the prospect of digital CEOs assuming nearly all responsibilities related to managing tasks and people remains within the realm of future possibilities, the potential of AI technologies and tools to augment or assist in high-level decision-making is already evident [12].

The presence of digital CEOs further heralds a broader transformation into digital enterprises. These enterprises are not merely organizations that use digital tools, but rather embody a fundamental shift in how businesses operate, strategize, and interact with their customers and environments. These digital enterprises evolve to fully leverage the cutting-edge technologies such as blockchain, smart contracts, and decentralized autonomous organizations and operations (DAOs) [13]–[15] or TRUE autonomous organizations and operations (TAOs) [16]–[18] and so on, to fundamentally change the organizational structure and operational mode to achieve intelligence and smartness. Under leadership of digital CEOs and the collaborative efforts of digital workers, digital enterprises transform from automated entities to intelligent organizations, and ultimately, to wise enterprises that are not just technology-driven, but technology-empowered.

## Automating CEOs

In the context of strategy formulation, team leadership,

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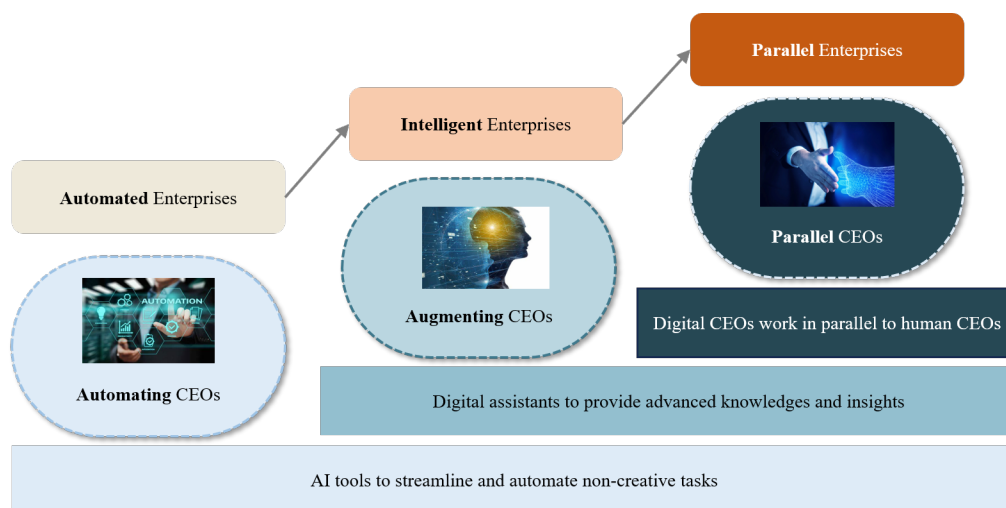


Fig. 1. Three development stages of digital CEOs and digital enterprises.

and critical decision-making, the CEO emerges as a pivotal role [19], [20], which typically encompasses a spectrum of functions including but not limited to high-level innovative thinking, interpersonal interactions, and complex judgment and decision-making [21], [22]. However, within the ambit of their daily responsibilities, there exists a range of tasks that are non-creative, repetitive, or rule-based. For instance, CEOs may spend extensive hours, or even days, in the comprehensive examination and analysis of a multitude of company reports. This encompasses an array of information sources such as financial reports, market analysis data, operational indicators, human resources statistics, and customer satisfaction surveys. The process involves contrasting historical data, identifying trend shifts, unearthing potential issues, and forecasting future trajectories to make strategic decisions that profoundly influence the enterprise. These tasks are both time-intensive and demand meticulous attention and focus, undoubtedly consuming a significant portion of the CEO's energies. Furthermore, in the face of voluminous data, manual processing is susceptible to omissions or misinterpretations.

In such scenarios, digital CEOs can be instrumental, and serve as intelligent tools by nature. With the help of digital CEOs, a portion of these non-creative tasks can be assisted or even supplanted. AI-driven data analysis systems embedded in digital humans are capable of real-time capture and integration of a variety of report data from both internal and external sources of the enterprise [23]. Through machine learning and deep learning algorithms, these systems perform deep mining and intelligent interpretation of the data, swiftly producing visual reports. They automatically pinpoint critical information such as main business progressions, team efficiency, and potential risks like anomalies. Additionally, the digital CEOs can utilize historical data and machine learning models to predict future trends, offering precise and timely decision support to the CEO [24]. This significantly reduces the timeframe from data acquisition to insight generation, enabling the CEO to allocate more time and resources to more innovative and strategic matters, including optimizing busi-

ness models, developing long-term strategies, and maintaining key relationship networks, thereby effectively enhancing the operational efficiency and competitive edge of the enterprise. Concurrently, it also minimizes errors due to human factors, ensuring the accuracy and reliability of decision bases. This, in turn, reduces the probability of decision-making errors by the CEO and enhances their decision-making efficiency.

### *Augmenting CEOs*

If automating CEOs primarily focus on liberating human CEOs from tedious, non-creative tasks like data analysis, then augmenting CEOs are designed to provide human CEOs with a wealth of specialized knowledge. In this stage, digital CEOs are regarded as indispensable digital assistants or think tank of experts for CEOs, particularly adept at processing complex data to generate knowledge, thereby significantly reinforcing and supporting the strategic thinking and innovative capacity of CEOs [25]. For instance, in formulating key strategic development directions for an enterprises, digital CEOs can efficiently integrate diverse, voluminous, and heterogeneous data from internal operations and external markets, and rapidly distill them into precise knowledge tailored for specific management scenarios.

By amalgamating expert knowledge bases and practical experiences across different industries and domains, digital CEOs are capable of training professional-grade big models that span multiple disciplines and industries [26]. These big models further support the construction of AI agents with their low cost, reduced cognitive blind spots, and rapid response to dynamic environments, become a formidable intellectual support for CEOs in making strategic and innovative decisions [27]. They utilize these professional knowledge systems to perform deep and efficient interpretation and analysis of extensive complex data from multiple professional perspectives, offering CEO multi-dimensional and multi-layered strategic insights and recommendations. This not only assists CEO in swiftly grasping the current operational status of their enterprises but also in discerning trends in market development, shifts in

competitive landscapes, and the evolution of customer needs, thereby enabling more precise and forward-looking strategic decision-making proactively rather than reactively.

### Parallel CEOs

With the bold vision of digital CEOs work like human CEOs and parallel to them in the metaverse or CPSS, intelligent technologies are required to advances to a point where they encapsulate not just the analytical and decision-making capabilities of human leaders, but also the nuances of leadership that involve emotional intelligence, strategic foresight, and human empathy [28]. The former is being realized by AI technologies represented by large multi-modal models (LMM), while the latter still requires more in-depth exploration.

Digital CEOs transcend intelligent machines or agents powered by LMM, and no longer represent any specific individual. Instead, they could be a digital human, an intelligent program, or an information machine. Alternatively, they might encompass a group of digital humans, programs, or machines, each assuming different functions. They are intricately designed to mirror human nuances, ensuring that they not only perform tasks but also think and interact in a human-like manner. Digital CEOs could be powered by sophisticated AI that extends beyond data processing and pattern recognition, and possess advanced cognitive abilities, enabling them to understand and interpret complex market dynamics, corporate politics, and human emotions. Besides, they could continuously evolve, learning from not only data but also knowledge and experiences much like a human CEO, but at an exponentially faster rate. In addition, digital CEOs could potentially manage global operations seamlessly, working without the human limitations physical endurance and mental energy. This could lead to increased efficiency and productivity, as decisions and responses to market changes could be made instantaneously [29]. However, digital CEOs may also raise significant ethical moral concerns [30]. The ability of a AI-powered program or machine to fully replicate the human qualities that often define the best leaders, such as empathy, moral judgment, and the capacity to inspire and motivate people, remains a complex and unresolved challenge.

### From Digital CEOs to Digital Enterprises

The impact of digital CEOs goes far beyond individual leadership, but embodies the integration of advanced technologies and strategic foresight in the business landscape. This heralds the emergence of digital enterprises, which are organizations fundamentally reshaped by the principles of digital innovation and intelligence. Digital enterprises guided by digital CEOs and propelled by digital workers using a variety of digital tools under the decentralized organizational structures and equity frameworks. As shown in fig. 2, they are established based on blockchain intelligence as well as their derivative technologies [31], to redefine the organizational and operational model of future enterprises, offering unprecedented levels of transparency, security, and efficiency [32].

In essence, digital enterprises embody an advanced, intelligent instrument for the future businesses, serving as an intelligent operating system that equips business owners with the

necessary tools for effective enterprise management. With the help of digital enterprises, the future business can operate in an autonomous mode (AM), requiring mainly digital workers and robotic workers. In this framework, the need for large, physical office spaces and extensive human resources is significantly reduced, as many functions are automated and handled by digital workers. This is paving the way for the miniaturization and micro-sizing of future businesses.

Moreover, it is crucial to integrate human-machine consensus mechanisms to ensure human intervention in non-standard situations. While digital enterprises predominantly operate in an automated or autonomous mode, incorporating such mechanisms ensures that they are still grounded in human insight and discretion. This is particularly important in handling complex, unforeseen, or ethically ambiguous situations where human intuition and ethical reasoning are paramount. The human-machine consensus provides a failsafe, ensuring that decisions made by automated systems can be reviewed, modified, or overridden by human operators when necessary. Under this consensus framework, when encountering unpredictable and long-tail issues that digital workers cannot handle, parallel mode (PM) will be activated by providing remote access of human experts. If an issue persists even after PM deployment, expert mode (EM) should be called to dispatch human experts or emergency teams to the site [33]–[35]. The future enterprises will operate by shifting among these three modes as circumstances dictate, with AM being the predominant one.

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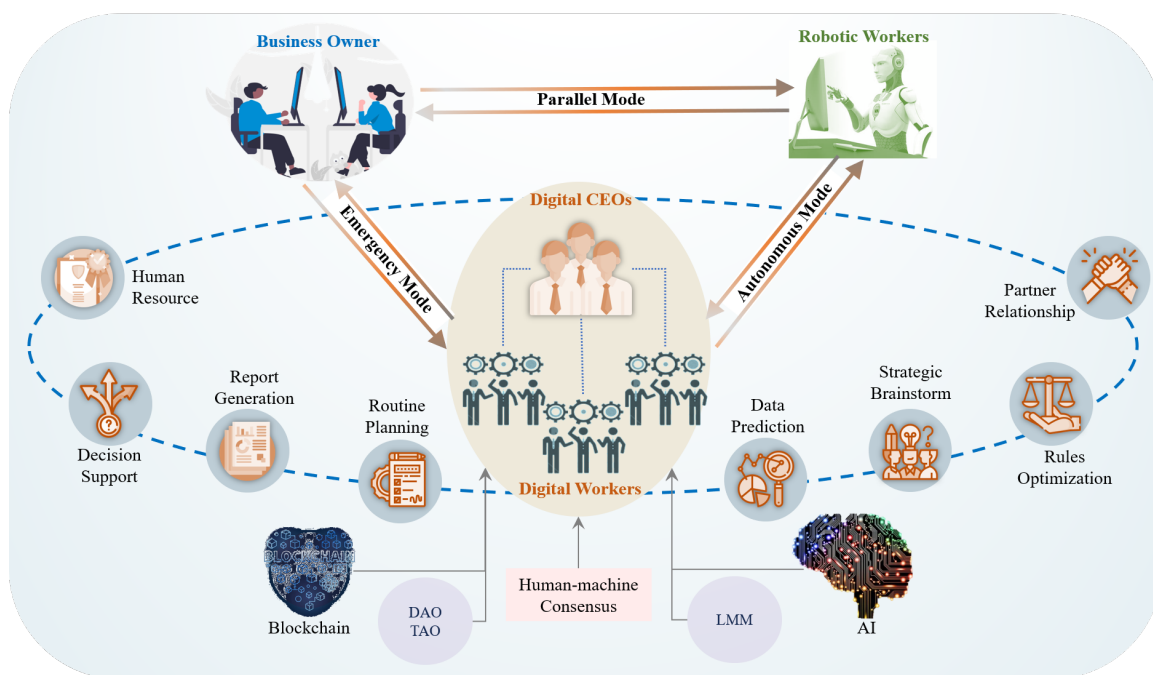


Fig. 2. The operational mode of digital enterprises.

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