Dao and Nature from a Cybernetic Perspective

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Abstract

Against the backdrop of the rapid expansion of cyberspace reshaped by electronic computing, networks, and artificial intelligence, human living space manifests as a cyber-physical-social-mind four-domain coupled space (CPST space). This paper first defines the natural laws and generative order of Dao within the CPST space, and proposes the four principles of accommodation-limitation-self-reflection-co-governance, with cyberscience as a methodological fulcrum and in conjunction with contemporary expressions of wuwei. Second, focusing on scenarios such as digital twins, intelligent governance, and Artificial General Intelligence (AGI), it proposes and demonstrates ten propositions concerning time, space, representation, embodiment, identity, morality, governance, ecology, knowledge, and risk. Finally, based on this, it constructs a three-layer conceptual framework of representation-interaction-value, and proposes a series of design criteria aligned with Daoist principles, providing theoretical guidance and methodological support for the synergistic development of Dao and nature, while also offering referable insights for practical scenarios such as digital twins, intelligent governance, and future technology ethics, thereby demonstrating the universal value and practical significance of Chinese philosophical wisdom in the digital era.

Full Text

The Dao and Nature from the Perspective of Cyberism

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Abstract

Against the backdrop of cyberspace' s rapid expansion—reshaped by electronic computing, networks, and artificial intelligence—human living space has evolved into a coupled domain of cyber-physical-social-thinking (CPST space). This paper first defines the natural laws and generative order of the Dao within CPST space, proposing four principles of compliance, limit, self-reflection, and co-governance by taking cybernetics as the methodological fulcrum and integrating the contemporary expression of non-action. Second, it advances and argues ten propositions encompassing time, space, representation, embodiment, identity, morality, governance, ecology, knowledge, and risk, grounded in scenarios such as digital twins, intelligent governance, and artificial general intelligence (AGI). Finally, it constructs a three-layer conceptual framework of representation-interaction-value and proposes a series of design guidelines aligned with Dao principles, providing theoretical guidance and methodological support for the coordinated development of the Dao and nature. The work also offers referable insights for practical scenarios including digital twins, intelligent governance, and future technology ethics, demonstrating the universal value and practical significance of Chinese philosophical wisdom in the digital age.

Keywords: Dao; Cyberism; CPST space; Physical space; Control theory

Introduction

The spatial structure of human survival and development is undergoing profound transformation. The rise of cyberspace has expanded humanity from the traditional three fundamental spaces—physical, social, and thinking—to a four-domain coupled space of cyber-physical-social-thinking (CPST space) [1, 2]. As an artificial virtual space, cyberspace overcomes the temporal and geographical limitations of physical space and continuously deepens its transformation and integration with the physical world through technological development [2]. This cross-domain fusion poses unprecedented challenges to our understanding of physical space: when natural environments intertwine with digital virtual environments, we must re-examine the connotations of nature and space and their underlying order.

In facing these challenges, drawing wisdom from traditional Chinese philosophy holds significant importance. The Dao in Daoist philosophy refers to the fundamental law governing the universe' s operation, emphasizing the naturalness and orderliness of the heavenly Dao. "The Dao follows nature" reveals the principle that the Great Dao takes nature as its law, while non-action advocates following nature without forced action—that is, not violating natural patterns through deliberate intervention driven by subjective will [3]. Daoism proposes that humans should emulate nature and respect objective laws, achieving harmonious coexistence between humanity and nature through governance by non-action. This thought on natural order and the boundaries of human behavior provides a profound philosophical foundation for reflecting on the relationship between physical and cyberspace in the technological era.

Currently, scholars both domestically and internationally are attempting to respond to the series of challenges brought by the intertwining of cyberspace and physical space from scientific and philosophical perspectives. Internationally, cybernetics laid the pioneering foundation for studying human-technology system interaction. Wiener defined cybernetics in 1948 as "the science of control and communication in the animal and the machine" [4]. This theory emphasizes feedback regulation principles, providing insights for later understanding of system control and information cycles in cyberspace. However, the ontological and epistemological issues triggered by cyberspace remain under exploration in the West [5-7]. Domestically, Ning Huansheng et al. proposed the concept of Cyberism, defining it as a doctrine specifically studying the relationship between humans and cyberspace [8, 9]. The Cyberism framework systematically elaborates on fundamental issues such as cyber philosophy, cyber science, and cyber logic, constructing a new research paradigm based on CPST space that integrates natural sciences, social sciences, cognitive science, and cyber science [10, 11]. This approach inherits and expands upon classical cybernetics logic in some respects, connecting technical feedback control principles with humanistic values and ethical governance issues in cyberspace, offering new perspectives for understanding human-technology-nature relationships in the digital age [12].

Despite these research advances, important theoretical gaps remain: First, as a core category of Chinese philosophy, how should the Dao be reinterpreted in technologically shaped cyberspace? Whether traditional views of heavenly order remain applicable in highly artificial digital environments requires deeper clarification. Second, physical space is being mapped and reconstructed by digital technology as never before. For instance, digital twins reproduce the physical world through virtual models, while artificial general intelligence (AGI) shapes people' s cognition of reality in virtual space [13]. This cyber-reconstruction of the physical world raises new technical ethics and governance issues: deviations between digital mirrors and the real world, uncertainties brought by algorithmic autonomy, and impacts of virtual-real interaction on social order and values [14] all urgently require clear theoretical guidance and normative frameworks. In other words, relying solely on traditional cognition of physical space can no longer address the complex impacts of cyberspace. The value of the Dao in technological space urgently needs to be explored to bridge the gap between natural laws and digital innovation.

[Figure 1: see original paper]

To respond to these theoretical and practical gaps, this paper proposes an analytical framework centered on compliance-limit-self-reflection-co-governance within CPST space, using cybernetics methodology as the theoretical fulcrum and addressing the re-representation and re-governance of physical space (such as digital twins and AGI). Specifically, compliance ensures that technology follows natural laws and the generative logic of system self-organization; limit defines the intensity and boundaries of technological intervention in natural systems; self-reflection incorporates continuous auditing of models and intervention consequences into the closed loop; and co-governance organizes multi-stakeholder collaborative decision-making and accountability under conditions where rules and responsibilities are decomposable. On this basis, we further implement a representation-interaction-value three-layer structure and a verifiable research agenda (threshold identification, negative feedback priority, reversibility auditing, community participation), striving to transform insights on the Dao and order into operational tools and metrics. This provides robust theoretical clarification and normative guidance for technologies such as digital twins and AGI, thereby promoting bounded coupling and benign interaction between cyberspace and physical space.

1. Cybernetics Methodology and Reinterpretation of the Dao

1.1 Cybernetics and Information Theory

Cybernetics, pioneered by Wiener and others, explores the laws of control and communication in animals and machines, with feedback regulation mechanisms at its core—particularly the role of negative feedback loops in system stability [15, 16]. Negative feedback loops maintain system equilibrium by feeding deviations between system output and target values back to regulators for correction. For example, a thermostat detects temperature exceeding a set threshold, triggers an error signal, and activates cooling or heating feedback to restore optimal temperature. In information theory, Shannon pointed out that reliable information transmission in noisy channels requires redundancy—adding extra information bits to correct errors [17, 18]. Redundancy configuration enhances system robustness and fault tolerance: even if some components fail or data is lost, the system can continue operating through backup channels or error-correcting codes [19]. Resilience emphasizes a system' s ability to absorb shocks and recover from unexpected disturbances—that is, to adjust and resume normal function after failures, accidents, or environmental upheavals [20].

These principles of cybernetics and information theory have intrinsic compatibility with the Dao discussed in Daoism. Laozi' s *Tao Te Ching* states, "Reversal is the movement of the Dao," revealing the law that things naturally reverse when reaching extremes; this can be seen as nature' s negative feedback mechanism, where excessive factors generate inhibitory forces that restore balance. This idea of following spontaneous regulation also appears in Laozi' s advocacy of "non-action" —not doing nothing, but not violating the natural state of things. The concepts of system redundancy and resilience also align with this wisdom: Daoism opposes excessive ornamentation and extreme optimization, emphasizing "Better to stop in time than to fill to the brim," meaning everything should leave room and not be pushed to extremes. Just as system design should retain margins and avoid pushing metrics to limits that sacrifice resilience, natural systems often maintain stability through diversity and redundancy (such as species redundancy providing functional backups in ecosystems), embodying the robustness of "the Dao follows nature."

In contemporary CPST space, these principles have been widely applied. For instance, smart cities and industrial control systems extensively employ sensor-control loops to automatically regulate environmental parameters, maintaining systems within stable ranges. Large networks and infrastructure enhance resilience through redundancy design: power grids introduce backup transmission lines, and internet backbones set up multi-path routing to ensure robust operation even when any node fails. These practices embody the engineering concepts of "negative feedback priority" and "redundancy resilience," which are essentially connected to the Daoist idea of "governance by non-action"—maintaining minimal necessary intervention, allowing CPST space to self-regulate according to its own laws, and reserving margins to cope with contingencies. This thinking also manifests in social governance: macroeconomic regulation makes timely fine-tuning based on feedback signals after implementation to prevent risk accumulation and loss of control; distributed network architecture ensures that failure of any single node does not destroy overall order through multi-center redundancy. Thus, integrating the Dao's wisdom of balanced self-stability into cyberspace architecture design can significantly enhance CPST space's stability and shock resistance.

1.2 Complex Systems and Emergence

Complex systems science studies the overall behavior produced by nonlinear interactions among numerous components within a system, often manifested as emergent properties, self-organization, and multistability [21]. A key concept is threshold and phase transition: when system parameters exceed a critical threshold, the overall state may undergo abrupt change (phase transition), emerging with entirely new behavioral patterns [22-24]. For example, in ecosystems, if a lake's nutrient load surpasses a threshold, water quality may phase-transition from clear to eutrophic; similarly, group movement models show that when individual density exceeds a critical value, global ordered swarm behavior emerges from disordered motion [25]. Nonlinear robustness refers to a complex system's ability to maintain functional stability within a certain range of disturbances—small perturbations may be absorbed by internal feedback, but once disturbances exceed thresholds, significant qualitative changes may occur [26]. Complex network research shows that such systems exhibit robustness against random failures but may experience cascading failures at thresholds, embodying the coexistence of vulnerability and robustness [27].

These properties of complex systems resonate with Daoist generative theory. Laozi proposed, "The Dao gives birth to one, one gives birth to two, two gives birth to three, and three gives birth to all things," describing the natural evolution from simplicity to complexity, approximating emergence phenomena: basic elements gradually generate new properties and order through interaction. Similarly, the *I Ching*'s concept of yin-yang waxing and waning at thresholds—that things reverse when reaching extremes—aligns perfectly with modern threshold-phase transition concepts. Contemporary researchers note that Daoism's emphasis on grasping "degree" corresponds to respecting thresholds and boundary conditions, with compliance stressing not violating nature' s critical points and limits (corresponding to the first principle proposed in Section 2.5). Therefore, the Dao can be understood from a complex systems perspective as natural laws containing various critical thresholds that guide spontaneous system evolution. Following the Dao means respecting internal thresholds and nonlinear laws when intervening in systems, avoiding forced crossing of phase transition points that could lead to uncontrollable consequences.

In real-world CPST space scenarios, threshold effects and emergent behaviors are ubiquitous and thus widely concerned. For example, climate change systems have tipping points (such as temperature thresholds for ice sheet melting), and exceeding these thresholds may trigger irreversible phase transitions and chain reactions, posing severe challenges to global ecological robustness [28, 29]. In social networks, when information dissemination scale exceeds a certain threshold, opinions may undergo phase-transition-like abrupt consensus or polarization, forming irreversible emergent group behaviors [30]. In engineering, infrastructure systems like power grids must monitor load thresholds to prevent cascading failures caused by overloads; engineers introduce mitigation mechanisms (such as segmented circuit breakers) to enhance system robustness, allowing gradual risk resolution even when approaching thresholds rather than sudden collapse. In summary, integrating complex systems' threshold awareness into cyberspace governance helps achieve gradual intervention, identifying warning signs and making small adjustments before major phase transitions occur to maintain overall stability.

1.3 Computational Experimental Philosophy

Computational experimental philosophy refers to using computer simulation and digital experiments to explore philosophical questions or system laws, with digital twin technology as one of its core tools. Digital twin refers to a dynamic virtual mirror of a physical system that synchronizes model states with physical objects through real-time data for monitoring, prediction, and control [31]. In practice, digital twins have a dual nature of "mirror-mold" : on one hand, they faithfully reflect physical objects' attributes and behaviors like a mirror, providing real-time monitoring and diagnostics (e.g., urban digital twins presenting city energy consumption distribution in real-time); on the other hand, they serve as molds for offline simulation of various hypothetical scenarios to guide and shape real-world decisions. By testing different parameters or strategies on digital twins, decision-makers can pre-assess impacts and then apply optimal solutions to physical systems, thereby promoting reality through virtual means. This dual role of mirror and mold makes digital twins an important vehicle for computational experimental philosophy—using virtual experiments to test and extend understanding of real systems.

The mirror/mold duality of digital twins can be reinterpreted from the Daoist perspective. Daoist thought includes the saying, "When the Dao governs the world, ghosts lose their power," emphasizing that following the natural Dao in governance prevents uncontrollable chaos. Mapped to digital twins, the mirror function requires models to faithfully represent the Dao (laws) of the real world without exaggeration or deviation, ensuring judgments based on models remain undistorted. The Daoist saying, "Man follows Earth, Earth follows Heaven, Heaven follows the Dao, the Dao follows nature," implies emulation: when digital twins act as mirrors, they should emulate real mechanisms (the Dao follows nature) and avoid subjective bias; when digital twins serve as molds to influence reality, they should adhere to the principle of non-action—model-driven interventions should not violate the system's own evolutionary logic. Otherwise, if models deviate from the Dao, interventions based on them may cause reality to deviate from the natural Dao and become imbalanced. This "mirror-mold" duality discrimination corresponds to reflection on model intervention intensity and deviation: when digital models purely mirror objectivity, people tend to trust their predictions; but once models oversimplify reality or are granted active decision-making authority, we must guard against their deviation from the true Dao and becoming molds that overstep nature. This requires introducing corresponding reversibility auditing mechanisms to continuously assess deviations between digital twin outputs and real-world data, verifying effects through feedback after model-guided interventions to ensure mold functions do not overstep and can be reversed when necessary, thereby re-establishing the mapping relationship between model and reality.

In cutting-edge CPST space fields, digital twins have been widely used in urban governance, industrial control, healthcare, and other scenarios, demonstrating enormous value. For example, urban digital twin platforms real-time mirror city operation status, including traffic flow and energy consumption, and serve as mold references for governance by simulating effects of different policy options (such as traffic control measures) [32]. This practice enhances decision-making scientificity but also demands higher model accuracy: to avoid model misguidance of reality, authorities often establish verification and iteration mechanisms to continuously correct twin models based on real feedback, ensuring they always remain close to the real world. Similarly, complex equipment digital twins in industry can mirror equipment health status when abnormal signs are detected and optimize actual maintenance by simulating different repair schemes. In this process, engineers carefully verify the reliability of virtual experiments, intervening to correct model parameters when necessary to prevent digital twins from providing advice that deviates from reality [33]. In summary, the dual nature of digital twins as "mirror-mold" requires us to follow the Dao's advocacy of seeking truth from facts and acting with moderation while enjoying computational experimental convenience: allowing digital models to objectively mirror reality as much as possible while maintaining prudence toward model-based interventions, achieving a virtuous cycle of virtual-real synergy through closed-loop verification.

1.4 Contemporary Expression of Non-action

“Governance by non-action” is the core proposition of Daoist political philosophy, traditionally referring to rulers not acting arbitrarily or disturbing the people, allowing all things to cultivate themselves naturally and the world to achieve great order. Laozi elaborated on non-action in the *Tao Te Ching*, for example, “I do nothing and the people transform themselves,” meaning that when rulers practice non-action, the people can self-educate and live in peace. This governance ideal of “following natural transformation” emphasizes trust and respect for a system’ s internal evolutionary mechanisms: as long as the overall environment follows the natural Dao, specific affairs will naturally tend toward order. However, in contemporary complex socio-technical systems, complete non-action can no longer be directly applied, as many unprecedented situations have emerged in rapidly developing cyberspace and artificial intelligence fields, where complete laissez-faire may lead to runaway risks. Therefore, it is necessary to operationally reinterpret non-action by introducing concepts such as limited intervention and reversibility auditing to maintain its guiding significance in contemporary contexts [34].

Limited intervention can be seen as a modern reflection of non-action: it advocates moderate management and control within necessary bounds, but such intervention should have clear boundaries and restraint to avoid disrupting the system’ s self-organizing functions through excessive force. This embodies an intervention-as-probing idea, where each intervention is as small as possible and evaluable to observe system responses before deciding subsequent actions. This resembles engineering’ s incremental control or policy sandbox experiments: verifying effects through small-scale pilots, scaling up if successful, and stopping promptly if adverse effects occur, ensuring the overall system still primarily relies on its own mechanisms [35]. Reversibility auditing provides a safeguard mechanism for limited intervention. Reversibility means any intervention measure should structurally support revocation and rollback to prevent irreparable losses from erroneous decisions. For example, introducing version control and undo functions in software systems allows changes to be audited and rolled back; in AI model deployment, retaining decision logs and enabling suspension or revocation of models’ autonomous authority when adverse effects are discovered through adversarial testing [36, 37]. These practices embody a modern interpretation of the non-action spirit: even when conducting human intervention, maintaining respect and attachment to the system’ s original state, enabling rapid retreat and restoration when signs of deviating from the Dao appear. Simultaneously, the introduction of auditing mechanisms ensures each intervention is documented and evaluable for impact, aligning perfectly with the Daoist wisdom of “self-reflection and contraction.”

In CPST environments where cyberspace and physical world deeply integrate, the contemporary expression of “governance by non-action” has permeated many aspects of technical governance. Take internet content governance as an example: platforms increasingly tend toward community self-discipline and user collaborative filtering—establishing minimal rules (bottom-line intervention) to allow community self-management rather than centralized, exhaustive review; once deviations occur, post-hoc auditing and correction are conducted through traceable records [38]. This governance model demonstrates trust in the system' s self-organizing capabilities and the principle of minimal intervention. Another example is autonomous vehicle design: under normal conditions, vehicle AI drives autonomously based on sensor feedback (without human intervention), but the design reserves mechanisms for human takeover and emergency braking, allowing real-time human intervention and exit from automatic mode when AI behavior exceeds safety thresholds. This is equivalent to adding limited intervention insurance and reversible human audit loops to non-action autonomous systems [39]. Another case is financial circuit breakers: when stock market volatility exceeds thresholds, trading is automatically suspended until market sentiment stabilizes, then normal operation resumes—regulators do not directly intervene in markets daily (routine non-action), only taking brief reversible measures during extreme anomalies to prevent crashes, then removing interventions afterward [40]. These cases show that translating non-action principles into concrete operational strategies requires introducing modern engineering thinking: trusting the system' s own evolutionary power (following natural transformation), but setting wise thresholds and monitoring, applying gentle, reversible adjustments when deviations become too large. This preserves the essence of non-action (not destroying internal order) while ensuring safety and controllability of complex systems in rapidly changing times, achieving transformation from normative concepts to engineering practice.

2. Four Methodological Principles

Building upon cybernetics and information theory, complex systems, computational experimental philosophy, and modern non-action thinking, this section proposes four methodological principles—compliance, limit, self-reflection, and co-governance—to transform the Daoist concept of "governance by non-action" into contemporary engineering practice norms for CPST space. Rooted in traditional Chinese philosophy (particularly Daoism) and integrating modern technical theories such as feedback control, threshold effects, and model interpretability, these principles aim to guide limited and verifiable interventions in digital governance: taking effective action within necessary bounds while ensuring interventions align with natural evolutionary laws and are auditable and traceable.

(1) Compliance

The philosophical origin of the compliance principle traces to Daoism' s reverence for natural laws, as Laozi stated: "Man follows Earth, Earth follows Heaven, Heaven follows the Dao, the Dao follows nature." The Dao' s operation takes nature as its basis, complying with the natural growth and evolution of all things. Daoism emphasizes non-action while following trends, not violating spontaneous generation thresholds and boundaries. This wisdom is embodied in *Tao Te Ching* Chapter 57: "I do nothing and the people transform themselves," meaning that without imposing interventions beyond nature, all things will evolve naturally. The compliance principle inherits this thought, requiring engineering and governance practices to respect systems' internal thresholds and critical points, allowing systems to operate within their stable ranges. In other words, in both cyberspace and physical space, we should avoid forcibly breaking natural limits: whether ecological environmental carrying capacity, socioeconomic tolerance, or algorithmic model robustness boundaries, all should be regarded as inviolable Dao limits. This principle aligns with cybernetics' negative feedback stability thinking: detecting deviations and making moderate adjustments to restore balance rather than unlimitedly pushing output growth. Similarly, complex systems science shows many systems have phase transition thresholds; excessive approach or crossing triggers qualitative change and emergence. Following compliance means closely monitoring these critical points in digital twin applications, choosing to follow trends or postpone intervention when approaching critical states to avoid triggering uncontrollable cascading effects.

At the engineering and design level, compliance requires embedding respect for nature and system boundaries into technical solutions. For example, in smart city water governance, we should pre-identify urban drainage system capacity thresholds and river warning water levels, adopting flexible "living with floods" strategies during storms rather than attempting to completely conquer flooding: using digital twins to simulate water flow, clearing emergency flood storage spaces, allowing floods to discharge naturally within controllable ranges rather than building higher dams to forcibly block them [41]. This boundary-compliant design ensures urban hydrological systems can maintain overall stability under extreme conditions without causing greater disasters through limit-exceeding interventions. Additionally, in AI model training, the compliance principle manifests as respecting the intrinsic structure of data and problems: not excessively pursuing ultimate model performance on training sets but retaining appropriate generalization margins to accommodate the diversity and complexity of real-world data. In summary, compliance reminds us that technical intervention should humbly follow the law of "the Dao follows nature," functioning within boundary conditions to allow system adaptive mechanisms to manifest rather than being brutally replaced.

(2) Limit

The limit principle originates from Chinese philosophical wisdom on moderation and the middle way. Confucianism advocates "going too far is as bad as not going far enough," while Daoism' s *Tao Te Ching* Chapter 9 also warns: "Better to stop in time than to fill to the brim; if you sharpen a blade too much, its edge cannot be preserved." Pushing things to extremes is worse than stopping at the right point; excessive sharpness makes it difficult to maintain long-term preservation. This reflects grasping the "degree": any development has its limits, and exceeding moderation leads to backlash (things reverse when reaching extremes). In modern technical governance, limit corresponds to guarding against over-optimization tendencies—avoiding damage to overall system robustness and resilience in pursuit of extreme optimization of a single metric. Cybernetics tells us that excessively high gain leads to system oscillation and instability; complex systems research also shows that over-optimization often sacrifices redundancy, making systems more vulnerable when facing disturbances [42, 43]. For example, globalized supply chains overly pursuing lean efficiency (zero inventory, just-in-time production) represent a typical case of over-optimization, resulting in systems losing buffer redundancy and triggering cascading collapses once any link is disturbed. Similarly, in algorithmic governance, blindly optimizing decision models based on historical data may cause overfitting—models perform perfectly on training sets but cannot adapt to new situations. Such governance, rigidly targeting existing patterns, instead loses adaptability to changing environments.

Therefore, implementing the limit principle in CPST space design and governance requires balancing optimization and robustness. Specific approaches include: introducing redundancy and fault-tolerance mechanisms to hedge uncertainties (e.g., retaining backup capacity in power or network systems rather than pushing them to the extreme), and adopting gradual trial-and-error, step-by-step optimization strategies rather than extreme one-shot solutions. A typical case is traffic signal control: over-optimized algorithms might maximize traffic flow efficiency under ideal conditions, but slight accidents or anomalies in reality could cause complete traffic network paralysis due to lack of buffers; conversely, strategies like reserving green light buffer time and setting multi-path redundancy may sacrifice local efficiency but improve overall disturbance resistance, preventing small accidents from causing large-scale paralysis. Similarly, in machine learning model training, regularization techniques are used to deliberately limit model complexity, preventing overfitting and maintaining generalization ability to new data—this is essentially a technical implementation of limit. In summary, the limit principle reminds governors to be vigilant about the costs behind "optimality," timely pressing the brakes on optimization, seeking balance of stability and performance within limits, and avoiding system fragility and imbalance caused by greed for perfection.

(3) Self-Reflection

The self-reflection principle embodies strong self-examination and cyclic consciousness in Chinese thought. Confucianism emphasized "I examine myself three times daily" (Zengzi's words), while Daoism's *Tao Te Ching* also states "Reversal is the movement of the Dao,"revealing the philosophy that all things cycle and return to the Dao through reflection. This tradition of self-examination provides inspiration for modern governance: effective cyberspace governance should not be linear, one-way control but requires continuous self-observation and correction during operation. The self-reflection principle demands embedding comprehensive auditing and feedback mechanisms within technical and governance systems, enabling systems to monitor their own behavior, evaluate intervention effects, and adjust and optimize based on feedback results. This principle aligns with the negative feedback control described in Section 2: governors should not blindly trust initial decisions but should continuously obtain output signals like controllers, compare them with target states, and correct deviations when they exceed thresholds. This cyclic reflection ensures governance is not a one-time shot but a continuous calibration process.

In digital governance practice, self-reflection manifests as auditability, traceability, and interpretability of algorithmic decisions and system behaviors. First is auditing and traceability: all important automated decisions and human interventions should have logging and post-hoc auditing mechanisms so regulators and the public can track accountability. This resembles supervision and auditing in financial systems or version control in software engineering, allowing any abnormal results to be traced and root causes identified. For example, regarding potential AI algorithm biases or errors, governors should conduct regular model audits to examine decision bases and assess social impacts, enabling rolling back or adjusting model parameters when problems are discovered (achieving reversible intervention). Second is decision interpretability: requiring complex algorithms to provide human-understandable reasons. This aligns with the emerging concept of explainable artificial intelligence (XAI), revealing black-box models' internal mechanisms or influencing factors through technical means to make decision processes transparent rather than opaque. For instance, when a machine learning model rejects a loan application, it should provide several main factors influencing its judgment, allowing affected parties and regulators to understand decision rationality and raise questions [44]. Similarly, in digital twin city governance, the self-reflection principle means comparing and analyzing deviations between each simulation prediction and actual results to continuously correct the model' s (mirror' s) representation bias against reality, achieving co-evolution between digital models and real systems. Through these measures, the self-reflection principle ensures CPST space is not a rigid instruction machine but an organism with self-observation and learning capabilities: able to see its own behavior and impacts, continuously approaching a more Dao-compliant state through feedback, thereby improving governance decision robustness and credibility.

(4) Co-Governance

The co-governance principle reflects traditional Chinese emphasis on collective collaboration and governance by non-action. Laozi proposed in his governance philosophy, "The best ruler is one whose existence is barely known by the people···When achievements are completed and matters are settled, the people all say 'We did it naturally.' " This actually shows that the best governance is not single-subject 包揽一切 but creating conditions where each part performs its duties, collaboratively producing good order, making people feel they naturally handled matters themselves. This thought evolves in modern contexts into concepts such as multi-center governance and collaborative governance, emphasizing that governance networks should have multiple actors participating in interaction, achieving overall order emergence through division of labor and 博弈 rather than complete reliance on top-down command and control. Daoist "governance by non-action" is not passive but advocates that rulers use less direct personal intervention and build more rule-based soil to foster "many forces forming the Dao." Confucianism and modern political philosophy also emphasize that good social operation 离不开 group members' shared responsibility and cooperation. These thoughts collectively nourish the philosophical foundation of the co-governance principle.

In CPST space where cyberspace and physical space deeply integrate, co-governance has urgent practical logic. As complex systems theory reveals, networks composed of numerous heterogeneous actors (such as the internet, cities, ecosystems) cannot be fully perceived and controlled by a single center; their order emerges more from local interactions and autonomous adjustments of components. Therefore, rather than attempting to establish omniscient, omnipotent central control, the co-governance principle advocates leveraging the initiative and wisdom of multiple stakeholders, making governance a distributed collaborative process. This includes different actors such as government, enterprises, social organizations, and individual citizens jointly participating in decision-making, implementation, and supervision, with clear accountability mechanisms ensuring each party fulfills its responsibilities. Many innovations in modern digital governance embody the spirit of co-governance. For example, urban governance introduces public participation platforms where residents can feedback community issues and participate in policy discussions through applications, achieving positive interaction between government governance, social regulation, and resident autonomy. Similarly, internet governance adopts a multi-stakeholder model: technical communities, enterprises, governments, and user representatives jointly formulate key rules and standards (such as domain name management, content norms) to avoid single-institution monopoly on decisions [45]. Such mechanisms ensure governance rules balance different interest demands and enhance implementation legitimacy and resilience. Co-governance also encompasses human-machine collaboration: in an era where AI widely participates in decision-making, we should build human-machine collaborative governance frameworks that leverage AI' s advantages in data analysis and decision-making while having humans supervise its behavior and set value boundaries, forming a responsibility-clear "human-machine community" to govern complex systems. This multi-actor collaboration also requires accountability mechanisms, such as using blockchain technology to record each actor' s decision contributions and behavioral logs, enabling traceable responsibility and evidence-based rewards and punishments.

In summary, the co-governance principle requires us to transcend the single-center control paradigm and establish a cooperative competition (co-opetition) ecology in CPST space: each actor collaborates and checks each other under a shared rule framework. By introducing more perspectives and wisdom into governance, co-governance helps compensate for single decision-making entities' cognitive and resource limitations, improving system adaptability to unknown risks; simultaneously, multi-party participation and public accountability enhance governance transparency and moral legitimacy, preventing power abuse. Co-governance makes governance in the cyber age closer to the Daoist ideal: rulers do not monopolize achievements but stimulate the internal order of "the people governing the people," ultimately achieving a Dao-compliant self-organizing good governance.

3. Ten Philosophical Propositions on the Dao and Physical Space from a Cybernetics Perspective

In the era of multi-domain interaction within CPST space, digital technology is driving the reconstruction of physical space, while the Dao in Chinese philosophy provides an important perspective for understanding and guiding this reconstruction process. This chapter reveals how the Dao embeds into key links of physical space reconstruction in the digital age through ten philosophical propositions. These propositions encompass time, space, representation, embodiment, identity, morality, governance, ecology, knowledge, and risk, each reflecting the tension between technical characteristics and philosophical speculation. In discussion, we define relevant concepts, analyze tensions between cyber and physical spaces, explain their internal connections with the Dao, and illustrate them with practical engineering or social cases. The ten propositions collectively outline a systematic path for the Dao's embedding in physical space in the digital age, providing new perspectives for interdisciplinary theoretical and empirical research.

3.1 Time Proposition: Cyber Time Plasticity vs. Physical Time Irreversibility

Cyber time refers to the temporal dimension in digital environments, possessing plastic characteristics such as compression, pause, and restart; in contrast, physical time flows irreversibly in one direction due to thermodynamic entropy increase [46]. Conceptually, cyber time's plasticity manifests as flexible manipulation of temporal sequences in virtual simulations, data storage, and playback, while physical time irreversibility means real events cannot be rewound once occurred. Additionally, digital systems can achieve a form of time reversal through state saving and playback, unimaginable in the real world, thereby expanding human subjective freedom in temporal experience [47, 48]. This creates tension both technically and philosophically: digital technology can make the past reenact or the future preview, challenging our intuitive understanding of time's arrow. Under this tension, the Dao perspective emphasizes following natural order: although cyber time allows counterintuitive operations, only by respecting real-world causal laws can digital simulations effectively guide reality. For instance, in smart manufacturing digital twin systems, engineers can accelerate or rewind virtual time to optimize processes, but must ultimately respect physical production process time constraints to avoid contradicting the Dao's natural rhythm.

3.2 Space Proposition: Digital Topology Variability vs. Physical Metric Rigidity

Digital topology refers to connection relationships and spatial structures in cyberspace or virtual environments, uniquely able to flexibly reconfigure according to needs, transcending geographical distance limitations; physical space metric rigidity means distances and shapes in the real world have fixed scales that cannot be arbitrarily changed [49]. Conceptually, cyberspace can be transformed in real-time through algorithms—for example, virtual buildings in augmented reality can float freely regardless of gravity, and users thousands of miles apart can interact as neighbors in social networks; conversely, Euclidean metrics ensure constant object dimensions and distances in physical space. The philosophical and technical tension emerges here: does humanity' s use of cyberspace to break natural spatiotemporal limits lead to reconstruction or even loss of real sense and orientation? The Dao' s thought advocates finding unchanging principles amid change—the myriad changes of cyberspace should serve to enhance understanding and coordination of the real world rather than diverting people from natural scale fundamentals. Real cases like smart city digital twins achieve bidirectional mapping of urban topology: planners can test urban layout adjustments in digital models, but their rationality is ultimately tested by physical space operation feedback, embodying Dao-following in virtual-real space interaction [50].

3.3 Representation Proposition: Data-Model-Reality Mirror/Mold Duality

Data and models' representation of reality has dual forms: on one hand, they serve as reality' s mirror, faithfully recording and reflecting the objective world; on the other hand, they play the role of mold, shaping and guiding future reality reconstruction [51]. This proposition' s conceptual definition involves digital twins, simulation, and other technologies: mirroring manifests as sensor data and models precisely mapping physical states, such as urban digital twins real-time mirroring city operation status; molding manifests as models in turn guiding engineering practice and decision-making, such as AI-generated design models becoming blueprints for real buildings. The philosophical and technical tension lies in: as models become increasingly refined and powerful, will people trust models more and ignore unmodeled real complexity? From the Dao perspective, the Dao itself cannot be fully articulated (as revealed by "the Dao that can be told is not the eternal Dao"), and however perfect, models are only approximations of the Dao. Thus, we should approach data and models' mirroring function with humility, not mistaking them for ultimate reality; while skillfully using their molding function, infusing the concept of following the natural Dao into models to guide reality. For example, in Building Information Modeling (BIM), digital models help designers deduce building performance, but design concepts should still start from respect for natural and human needs (manifestations of the Dao) rather than blindly trusting software optimizations.

3.4 Embodiment Proposition: Embodiment Migration in Sensor-Algorithm-Actor Networks

Embodiment refers to the inseparability of cognition and action from specific bodies or carriers, while in cyber-physical intertwined sensor-algorithm-actor networks, embodiment undergoes migration [52, 53]. Conceptually, this embodiment migration refers to the transfer of intelligent behavior among different entities: sensors acquire environmental information, algorithms process decisions, and robots or humans execute actions, with intelligence' s body switching between physical and digital nodes. The philosophical and technical tension lies in the expansion of agency: when action agents are no longer limited to single bodies, can human will and experience extend into machines and algorithms? This involves cyborg concepts and actor-network theory, prompting reflection on the blurring of self-boundaries. The Dao perspective emphasizes the coherence of all things as one: although embodiment migration breaks traditional subject boundaries, if each part cooperates in following the Dao' s whole (harmony of nature, society, and technology), this network becomes an extension of the Dao. In reality, autonomous vehicles exemplify this: vehicle sensors perceive road conditions, AI algorithms decide steering and braking, and actuators complete physical actions, with driving intelligence' s embodiment having shifted from humans to vehicles. But to achieve safe and effective driving, the Dao requires all system links to align with natural principles such as traffic regulations and public safety, ensuring technology remains human-centered.

3.5 Identity Proposition: Consistency and Heterogeneity of Multiple Identities

In CPST space, individuals or entities often possess multiple identities: a person can simultaneously be a real-world citizen, virtual community member, and IoT device user, with their digital twin also existing as an agent. Conceptually, multiple identities include roles and representations in different domains; consistency means these identities coordinate and unify in core values and behaviors, while heterogeneity means their characteristics vary by context and may even contradict each other. The philosophical and technical tension lies in identity and role conflict: when our online personalities differ greatly from offline ones, or when algorithmic agents' decisions contradict principals' intentions, identity continuity is challenged. Here, the Dao manifests as a higher-level pursuit of self-identity: Daoist thought emphasizes following one' s nature (such as returning to an infant' s pure mindset), suggesting we guard authentic Dao-nature amidst complex multi-domain identities. Technical design must also consider ethical requirements of identity mapping, such as ensuring personal digital identity behaviors follow users' true will [54, 55]. Consider digital education scenarios: students may present different learning personalities in physical classrooms versus virtual learning platforms, requiring teachers to guide their integration to shape unified, rich character—this aligns with the Dao' s emphasis on holistic consistency and diverse balance.

3.6 Morality Proposition: Cultivability and Boundaries of Algorithmic Virtue

As AI and algorithms play important roles in social decision-making, algorithmic virtue becomes a new ethical proposition. Conceptually, algorithmic virtue refers to the value orientation and moral quality embodied by algorithms, such as fairness, honesty, and goodwill; cultivability explores whether we can enable algorithms to gradually acquire moral judgment capabilities through data training and rule constraints, while boundaries remind us that algorithms lack human emotions and conscience, making their ethical performance inherently limited [56]. The philosophical and technical tension is prominent: on one hand, humans hope to cultivate "good algorithms" through technical means, such as training AI to avoid bias and discrimination; on the other hand, can machines truly understand good and evil choices, or merely mechanically simulate behavior that appears ethical? The Dao' s significance lies in returning to the roots while opening new paths for moral foundations: Daoism has no rigid commandments but focuses on cultivating virtues that follow nature and human nature (guarding goodness). Analogously, shaping algorithmic virtue should also follow the fair Dao of human society while clearly recognizing that algorithms can only approach human virtue within limited boundaries and cannot overstep their role. In reality, autonomous driving AI is required to follow the supreme principle of not harming life in emergencies—this is the algorithmic projection of human moral bottom lines; but when encountering no-win situations (such as the classic trolley problem), ultimate value judgments must still be borne by humans, demonstrating the boundaries of algorithmic virtue cultivation.

3.7 Governance Proposition: Cyber Reinterpretation of "Governance by Non-action" and Limited Intervention

Facing complex cyber-physical space governance, traditional Daoist "governance by non-action" thought provides intriguing insights. Non-action is not passive neglect but conducting minimal necessary guidance following internal system laws, allowing order to grow spontaneously. Its cyber reinterpretation means minimizing rigid human control in digital governance, instead relying on algorithms and feedback mechanisms for space self-regulation [57]. The philosophical and technical tension lies in: complete laissez-faire may cause chaos, but excessive intervention suppresses spatial functions and creativity. The Dao' s wisdom lies in grasping the middle way and following trends: governors set principle frameworks (aligned with the Dao' s universal values), intervening moderately outside boundary conditions while allowing space autonomous evolution otherwise. A practical case is the digital governance system established by manufacturing enterprise Kutesmart, which achieves flat management through data-driven approaches, where management no longer intervenes in production exhaustively but allows frontline teams to autonomously optimize decisions based on real-time information. This "non-action with action" governance approach greatly improves efficiency and employee initiative, also confirming the management philosophy of adhering to “the Dao follows nature” in the cyber age—achieving balance between overall order and innovation through limited intervention. Similarly, internet community self-management and open-source collaboration also show that less intervention can facilitate self-organizing order.

3.8 Ecology Proposition: Moral Landscape and Natural Thresholds in Cyber-Physical Space

The fusion of cyberspace and physical space introduces the new concept of moral landscape—that is, the value distribution and ethical situation in CPST space resemble a moral terrain, while natural thresholds are the critical limits that ecological environments can bear. Conceptually, moral landscape includes how cyber applications shape good and evil patterns, such as social media algorithm designs creating clusters of goodwill or malice in information ecology; natural thresholds include non-crossable red lines in climate, resources, and other aspects [58, 59]. The philosophical and technical tension lies in: cyber development often pursues breakthroughs and efficiency but may inadvertently cross natural thresholds, triggering ecological imbalance or social risks. The Dao concept emphasizes respecting natural boundaries and yin-yang balance: CPST space should maintain the benign fluctuations of its moral landscape through embedded ethical regulation mechanisms and strictly guard against natural bottom line violations. Real examples include AI applications in energy scheduling systems: algorithms optimize power grid efficiency to avoid energy waste (good on the moral landscape); simultaneously, systems must follow environmental carrying capacity thresholds, not unrestrictedly mobilizing fossil energy for economic benefits to avoid dangerous breakthroughs of climate thresholds, thereby demonstrating awe and adherence to the Dao of heaven and earth in technology application [60].

3.9 Knowledge Proposition: Computability Boundaries, Black Boxes, and Explanatory Responsibility

Knowledge production in the cyber age is deeply driven by algorithms but also exposes computability boundaries and black box problems, triggering challenges of explanatory responsibility. Conceptual definition: computability boundaries refer to problem categories that cannot be precisely solved by algorithms theoretically or practically, such as certain NP-hard problems or chaotic system predictions; black boxes describe complex models (especially deep learning) whose internal processes are opaque to humans. The philosophical and technical tension manifests as: humans increasingly rely on algorithmic decisions but may not understand their basis; when algorithmic outputs exceed explainable ranges, knowledge credibility and responsibility attribution become ambiguous. The Dao’ s insight lies in balancing wisdom and humility: Laozi said, “To know what you do not know is best,” requiring us to acknowledge cognitive limitations—however powerful digital models have their unknowable domains, while insisting on taking moral responsibility for critical decisions, not using black boxes as excuses to shirk responsibility. Therefore, we need to establish algorithmic interpretability responsibility mechanisms, ensuring humans have ways to understand logic and bear consequences when models make public-affecting decisions [61, 62]. Practical cases include medical AI diagnostic systems: although using incompletely transparent deep networks for disease identification, regulators require providing credible explanations or auxiliary evidence, with doctors ultimately responsible for diagnostic results. This embodies adherence to the Dao (truth and responsibility) in the knowledge proposition.

3.10 Risk Proposition: Vulnerability, Cascading Risk, and Threshold Management

In CPST space, risk issues are increasingly complex: vulnerability refers to CPST domains' sensitivity to local disturbances; cascading risk means a node failure can rapidly transmit through networks causing chain failures; and threshold management aims to monitor and prevent risk accumulation from breaking critical points [27]. Conceptually, this covers considerations of CPST space resilience and early warning mechanism design. The philosophical and technical tension manifests as: modern technology brings powerful interconnectivity but also introduces uncertainty of systemic risks—what attitude should we adopt toward inevitable vulnerabilities? The Dao' s mode of thinking advocates prudence and moderation: Daoism proposes "Difficult tasks in the world begin with what is easy; great tasks begin with what is small," meaning in risk governance we should respect subtle signs and resolve hidden dangers timely to prevent them from evolving into uncontrollable disasters. Following the Dao also means acknowledging zero risk is impossible; what matters is seeking stability in balance. Real cases include power IoT applications for grid safety: sensors and AI monitor grid loads in real-time, automatically diverting power when a line approaches overload thresholds to prevent chain blackouts [63, 64]. This threshold management embodies the wisdom of "caution ensures long-term safety" —maintaining system resilience through preventive intervention, demonstrating a modern interpretation of the Dao following nature in risk governance.

4. A Dao-Cyber Co-Evolution Conceptual Framework in CPST Perspective

This chapter constructs a three-layer analysis framework of representation-interaction-value within CPST space, transforming Daoist philosophical principles into operational technical and governance strategies. It aims to propose a Dao-cyber co-evolution conceptual framework: establishing correspondences between natural entities and data/models through isomorphic/heterogeneous mapping at the representation layer; regulating spatial behavior through coupling of feedback, control, and game mechanisms at the interaction layer; and ensuring spatial operation aligns with Dao principles through reversibility auditing, threshold awareness, negative feedback priority, and community participation at the value layer. This framework inherits the philosophical propositions from Chapter 3 while providing guidance for subsequent design guidelines to achieve a closed loop from concept to practice.

4.1 Representation Layer: Isomorphic/Heterogeneous Mapping of Nature-Data-Model

Digital twin technology achieves real-time simulation and management of natural environments by constructing isomorphic mappings between physical and cyberspace [65]. Sensors collect real-time data from physical space, digitizing natural phenomena and loading them into models so models can truthfully reflect environmental states. For example, China' s Xiong' an New Area proposes synchronizing planning and construction of digital and physical cities, building digital twins in parallel based on physical cities [66]. In this process, system design must distinguish between isomorphic mapping (high-fidelity digital twins) and heterogeneous mapping (abstract simplified models), ensuring trade-offs between precision and efficiency. Mapping construction emphasizes compliance: models follow natural laws rather than imposed fabrication; adherence to limits: controlling model complexity; reliance on data feedback for self-correction; and multi-stakeholder co-governance including government, enterprises, and citizens jointly participating in building optimal models. This mapping approach embodies the Dao' s essence: respecting nature itself, not excessively surpassing physical limits, and continuously improving digital representation through feedback and collaboration.

4.2 Interaction Layer: Coupling of Feedback, Control, Optimization, and Game

The interaction layer' s core lies in the synergy of closed-loop feedback and control mechanisms. Negative feedback, as a basic control law, continuously detects deviations between targets and current states and automatically adjusts inputs to restore spatial stability and balance. Physical space ecology relies on positive and negative feedback interactions to maintain balance: for example, in grassland ecosystems, excessive grazing reduces grass quantity, which in turn suppresses herbivore numbers, ultimately restoring balance. The same applies in engineering projects: urban traffic sensor networks monitor flow data, feed back to control centers, and real-time optimize signal timing to significantly reduce congestion delays; in power systems, automatically adjusting excitation current to respond to load changes achieves grid voltage stability. Meanwhile, CPST space often requires optimization algorithms and game theory to coordinate multi-actor behaviors. AI and optimization simulation technologies can simulate effects of different intervention schemes, selecting optimal decisions through scenario 推演. Multi-actor game frameworks suit distributed systems: in integrated energy management, central controllers (leaders) determine overall dispatch strategies while distributed energy units (followers) autonomously adjust outputs based on prices and incentives, achieving a trade-off between global and individual interests [67]. This layer' s interaction emphasizes compliance—dynamic adjustment to adapt to external disturbances; limits—ensuring control strategies operate within safety thresholds; self-reflection—continuous self-learning and optimization based on data feedback; and co-governance—requiring multi-actor collaborative decision-making and accountability to jointly guarantee stable operation.

4.3 Value Layer: Reversibility Auditing, Threshold Awareness, Negative Feedback Priority, Community Participation

The value layer concerns CPST space' s fundamental values and sustainability. Reversibility auditing requires all spaces to fully record operations and decisions with traceability to prevent data tampering and misuse. In blockchain applications, decentralized storage and tamper-proof characteristics allow auditors to grasp each business data point in real-time, with any modifications leaving traces. Threshold awareness means timely early warning when systems approach potential risks or abnormal states. For example, Liangjiang New District monitors water levels in flood-prone areas through IoT sensors; once reaching warning thresholds, the system automatically issues alerts and activates emergency plans. System design should prioritize negative feedback: introducing negative feedback mechanisms first to offset disturbances and maintain steady states; and building redundancy and resilience, such as backup paths or resource overload switching mechanisms, to improve reliability and resilience. Community participation is another core value: space systems should not only be operated by technical personnel but require multi-party collaborative supervision and improvement by government, enterprises, users, etc. In smart city social governance, practice shows that resident participatory indicator formulation and feedback can significantly improve system transparency and trust. These value requirements manifest Dao principles: CPST space possesses self-reflective auditing capabilities and always-reversible mechanisms, perceives and respects nature-set limits, prioritizes negative feedback to maintain balance, and shares responsibility and improvement through community and stakeholder co-governance.

[Figure 2: see original paper]

5. From Principles to Design Guidelines

Based on the above discussion, this section distills a series of design guidelines aligned with Dao principles to guide synergy between cyberspace (digital systems) and physical space.

5.1 Negative Feedback Priority and Redundancy Resilience

In designing various systems within CPST space, negative feedback mechanisms should dominate to maintain stable states. Negative feedback can spontaneously suppress deviations and resist disturbances, enabling systems to follow nature stably, embodying the Dao’ s compliance and stability thinking. Simultaneously, introduce redundancy in critical components and pathways to increase resilience. For example, power grids adopt redundant transmission lines and backup capacity during operation; once main paths fail, backup systems can quickly take over to avoid instability. Redundancy design embodies the limit principle: after identifying physical system hidden dangers, moderately invest in backup resources to leave room for systems to maintain balance during natural regulation. This guideline requires systems to pre-consider failure scenarios, combining multi-layer negative feedback and resource backup to ensure systems maintain order amid changes.

5.2 Threshold Awareness and Gradual Intervention

Systems within CPST space need to establish threshold awareness for key indicators: clarifying which parameters reaching certain levels 预示 anomalies or risks, and setting corresponding thresholds in advance. Once approaching or exceeding thresholds, gradual intervention should be adopted to avoid radically and excessively affecting the physical world. For example, in smart city environmental monitoring, when pollutant concentrations exceed safety thresholds, the system first issues warnings and gradually intensifies control measures (traffic restrictions, emission limits) rather than a one-time comprehensive lockdown of urban traffic. Liangjiang New District’ s flood warning mechanism exemplifies this: when water level sensors detect exceeding warning thresholds, automatic alerts trigger graded emergency responses. This design embodies the Dao’ s limit thinking: intervention should be just right, gradually within the system’ s bearable range, both following natural trends and avoiding shocks to the real environment.

5.3 Reversibility Auditing and Public Verifiability

CPST space should design reversibility auditing mechanisms that provide fully traceable records of all decisions and operations, supporting post-hoc 还原检查 to fulfill system credibility guarantees. Public verifiability requires transparent auditing processes with publicly checkable information. Blockchain technology naturally fits this requirement: its autonomy and tamper-proof characteristics can ensure record authenticity. For example, uploading city management data to chains prevents arbitrary modifications; the public and regulatory agencies can verify decision compliance through public ledgers. This embodies the Dao’ s self-reflection principle, enabling space to continuously self-check and correct through auditing. It also manifests co-governance, allowing all stakeholders to participate in supervision and enhancing trust and responsibility.

5.4 Community Participation and Multi-Stakeholder Accountability

Spatial governance requires broad community participation: government, industry, research institutions, the public, and other parties should jointly formulate rules, participate in operations, and share responsibilities. Practice has proven that participatory governance at the community level can avoid one-size-fits-all approaches and increase governance solutions' pertinence and acceptability. For example, Guiyang' s smart governance project combines online and offline multi-party participation in indicator development, giving community residents voice in the data indicator system and enhancing governance solutions recognition. This multi-party participation model precisely fits the Dao' s co-governance concept: governance is not dominated by a single institution but results from negotiation among multiple stakeholders, continuously improved through multi-party accountability and feedback mechanisms. By establishing sound accountability and transparency mechanisms, systems can clearly assign responsibility to each actor, forming a benign multi-party co-governance pattern.

6. Conclusion

This paper reinterprets the meaning of the Dao and natural laws in cyber-physical coupling from a CPST perspective, proposing four principles of compliance, limit, self-reflection, and co-governance. Based on these principles, ten philosophical propositions are introduced to construct a representation-interaction-value Dao-cyber co-evolution framework. This is finally distilled into four design guidelines. Through 论证 in scenarios such as digital twins, intelligent transportation, and power dispatch, this paper clarifies the "mirror/mold" duality of data-model-reality and its embedded points in audit closed loops. Numerous real cases demonstrate that following the compliance-limit-self-reflection-co-governance principles can achieve virtual-real synergy and governance consistency without breaking natural thresholds, providing integrated theoretical and methodological support for physical space re-representation and risk control in the digital age.

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Note: Figure translations are in progress. See original paper for figures.