

The user wants me to translate a Chinese academic text about “元宇宙赋能广州城市治理实现科学化现代化” (Metaverse enabling scientific and modernized urban governance in Guangzhou). Let me break down the requirements: 1. Preserve ALL LaTeX commands and placeholders exactly 2. Preserve ALL citation commands ([?],...

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Date: 2025-04-15T12:55:20+00:00

Abstract

The user wants me to translate a Chinese abstract to English. Let me break down the requirements:

1. **CRITICAL REQUIREMENTS:**
 - Preserve ALL LaTeX commands and placeholders exactly
 - Preserve ALL citation commands ([?], ??, (??), etc.) exactly
 - **PRESERVE ALL ...paragraph wrapper tags EXACTLY**
 - Maintain academic tone and formal scientific writing style
 - Use precise technical terminology - obey the glossary strictly
 - Preserve section structure and paragraph organization
 - Translate all content completely - do not omit any information
2. **OUTPUT RULES:**
 - Return ONLY the translated text (no explanations, no quotes, no headings)
 - Keep one output paragraph per input paragraph
 - Maintain exact count and IDs of ...tags
 - Do NOT add Markdown formatting unless present in source
 - Preserve original line breaks within the paragraph when meaningful
3. **FORMATTING GUIDELINES:**
 - Keep mathematical expressions in original LaTeX format
 - Preserve equation numbers and references
 - Maintain proper academic paragraph structure

- Use formal scientific language
4. **Glossary:**
- 机器学习 => machine learning
 - 深度学习 => deep learning

Now, looking at the input text:

(Abstract): 首先, 文中阐述了元宇宙和工业元宇宙的概念, 指出元宇宙推动了城市形态、社会组织形

Wait, I notice there's no `...wrapper` in this input. The user said "PRESERVE ALL `...paragraph wrapper tags EXACTLY`" but the input doesn't have any. Let me re-read the instructions.

The instructions say: "if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs". Since this input has 0 paragraph tags, I should output 0 paragraph tags. But that seems odd for an abstract. Let me check if the user expects me to add them or if this is just a general instruction that doesn't apply to this specific case.

Looking at the context, this appears to be a standalone abstract translation task. The user is giving me a sample to translate. The general instructions about tags are probably for future tasks where those tags will be present. For this specific input, since there are no tags, I should just translate the content as a single paragraph.

But wait, let me re-read the instructions more carefully. The user says "PRESERVE ALL `...paragraph wrapper tags EXACTLY` - these are structural markers that identify paragraphs and MUST remain untouched with their IDs". This suggests that if they are present, I must preserve them. If they are not present, I don't need to add them.

The input is a single paragraph abstract. I should translate it as a single paragraph without any tags.

Now, let me translate the content:

“首先, 文中阐述了元宇宙和工业元宇宙的概念, 指出元宇宙推动了城市形态、社会组织形态、工业生产形态等多个维度的变革与优化;”

First, the paper expounds on the concepts of the metaverse and the industrial metaverse, pointing out that the metaverse drives transformation and optimization

Full Text

Preamble

Metaverse Empowering Scientific and Modernized Urban Governance in Guangzhou

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Abstract

This article first elaborates on the concepts of the metaverse and industrial metaverse, highlighting how the metaverse drives transformation and optimization across multiple dimensions, including urban morphology, social organization, and industrial production. Second, it examines how the metaverse empowers urban governance in Guangzhou by enhancing urban management efficiency, strengthening emergency response capabilities, improving human-city interaction quality, and advancing smart city development. Third, the paper reports on Guangzhou's successful implementation and outcomes of key technologies—including blockchain, digital twin, generative AI, and drone-plus-AI systems—in urban governance and public service delivery. Finally, it clarifies that metaverse-related technologies will propel urban and social governance toward the integration of carbon-based and silicon-based civilizations, enabling humanity to leverage silicon-based technologies to expand living spaces and improve quality of life while allowing silicon-based civilization to draw inspiration from the culture and emotions of carbon-based life for more comprehensive development.

Keywords: artificial intelligence, blockchain, digital twin, urban governance

Introduction

The rapid development of digital technology continues to drive the economy and society toward greater digitalization, intelligence, scientization, and modernization. From enterprise digital transformation and digital government construction to digital cities and digital Earth, humanity's increasingly digitalized way of life has gradually formed a “digital version” of our existence—this is the metaverse. The metaverse's evolution has catalyzed transformation and optimization in urban and social governance, boosted social productivity, and revolutionized production modes, exerting profound influence on related industrial chains and value distribution models.

The Decision of the Central Committee of the Communist Party of China on Further Deepening Reform Comprehensively to Advance Chinese Modernization, adopted at the Third Plenary Session of the 20th CPC Central Committee in July 2024, states: “Deepen reforms of urban construction, operation, and governance systems, and accelerate the transformation of urban development modes. Promote the formation of a new system for smart and efficient governance of mega- and super-sized cities.” As a frontier city in China's digital economy, Guangzhou is actively exploring the integration of metaverse technologies with urban governance. By leveraging digital intelligence technologies such as artificial intelligence (AI), big data, cloud computing, blockchain, Internet of Things (IoT), digital twins, and immersive interactive technologies (virtual reality/augmented reality/mixed reality/extended reality, VR/AR/MR/XR),

Guangzhou is vigorously promoting digital government and digital city construction. These efforts drive multi-dimensional reforms in operation and governance systems, urban morphology, and industrial production and service models, constructing an intelligent, scientific, and efficient new urban governance system that has achieved remarkable results.

1. Metaverse Driving Multi-Dimensional Transformation of Urban and Industrial Forms

1.1 Concept of the Metaverse

The metaverse represents a new social form that achieves the symbiotic coexistence of the physical world and its mirrored digital counterpart through the clustered application of digital technologies. “The essence of the metaverse is to create a twin mapping of the physical world in the digital realm, enabling interactive integration between the two. Through clustered applications of next-generation information technologies such as IoT, VR/AR, big data analytics, AI, and blockchain, the metaverse simulates, analyzes, and predicts physical world operations in the digital space, driving physical world operations with optimal outcomes” [1]. From a technical perspective, the metaverse integrates digital technologies that support immersive sensory experiences and large-scale concurrent user access through 5G or 6G low-latency networks and cloud-edge-end collaborative computing, enhancing user immersion and accessibility while facilitating transparent execution of system rules. This creates a new social form of virtual-physical symbiosis that not only satisfies spiritual needs but also substantially improves labor productivity.

Metaverse development can be broadly divided into three stages: Metaverse 1.0 (digital native), Metaverse 2.0 (digital twin), and Metaverse 3.0 (virtual-physical symbiosis), each with distinct connotations. Zheng Weimin, an academician of the Chinese Academy of Engineering and professor at Tsinghua University’s Department of Computer Science and Technology, observes: “The metaverse encompasses not only 5G, AI, blockchain, cloud computing, and big data in the digital economy but also forward-looking deployments in VR, AR, brain-computer interfaces, IoT, and other technologies” [2]. The metaverse drives transformation across multiple dimensions, including urban morphology, enterprise organizational forms, and industrial production patterns. In urban contexts, it enhances management efficiency, strengthens emergency response capabilities, and improves human-city interaction quality through AR/VR technologies, thereby advancing smart city construction. “Enterprises can achieve more efficient communication and collaboration through the metaverse, promoting the globalization of labor supply and consequently transforming organizational forms and management models” [3]. In office environments, the metaverse drives top-down renewal of industrial chains, including hardware and software updates and service model innovation. In industry, it tightens connections across upstream and downstream industrial chains, enables more efficient management collaboration,

and reshapes industrial chains and value distribution models. By constructing virtual training environments, it facilitates more intuitive and vivid learning and mastery of new quality productive forces-related knowledge and skills, improving learning and training effectiveness.

1.2 Industrial Metaverse: A New Industrial Civilization System

The industrial metaverse serves as an industry integration platform encompassing entire industrial chains, business models, participation methods, and innovation ecosystems. It functions as a universal operating system supporting industrial production, e-commerce, social networking, game engines, virtual economies, and ICT infrastructure—the “Garden of Eden” of the new industrial civilization [4]. This definition comprises three layers of meaning:

At the industrial level, the industrial metaverse provides a brand-new, expansive stage that accommodates and supports integration within the same industry’s upstream, midstream, and downstream sectors, as well as cross-industry integration. It supports various business models, borderless enterprises with universal participation, and innovations by individuals and organizations. This support is not merely policy-level “permission” but technical-level “interconnection.” Different enterprises can seamlessly connect and efficiently interact in real time under unified data, technical, and coding standards.

At the technical level, the industrial metaverse integrates different technical forms—such as social networking, gaming, industrial production, and consumer internet—onto a unified digital technology infrastructure. This enables effective integration and comprehensive assembly of various new technologies, multiplying their capabilities and value by hundreds or thousands of times. Technological fusion drives industrial integration and cross-industry connectivity.

At the civilization level, this new “universe” of the industrial metaverse must actively cultivate excellent and uplifting culture to ensure humanity’s sustainable development.

The future vision of the industrial metaverse is that employees can work anytime, anywhere, from home or while traveling, by commanding their avatars (digital doppelgängers) to complete tasks in the virtual-physical symbiotic metaverse. As AI capabilities advance, avatars can handle most routine work, while employees themselves focus more on free creation. Work organization takes the form of social platform-based workgroups; meetings are held in virtual conference rooms; marketing activities occur on social or gaming platforms; inter-enterprise collaboration involves system interface calls guided by business agreements, with all contracts and financial transactions completed under smart contracts on blockchain platforms. Physical product production is essentially designed digitally in the metaverse and output to the physical world through 3D printing. Operations of real-world equipment are also largely conducted by metaverse residents through IoT connections, potentially eliminating most blue-collar jobs in the future.

In this new industrial civilization system, avatars, digital employees, and NPCs (non-player characters) will constitute the main body of the “working class,” while all humans will become “artists” rich in creative spirit and appreciation. Human work will be to depict the newest and most beautiful “pictures,” which digital employees will then bring to reality.

1.3 Key Technical Elements of the Metaverse

1. **Digital Twin:** Refers to a complete mapping from the physical world to the virtual world. It must achieve not only formal resemblance but also “form and spirit,” with virtual-physical interaction. Most importantly, it must enable real-time linkage and interoperability between digital twin entities.
2. **Internet of Things (IoT) Technology:** Includes IoT and other connectivity technologies such as 5G, 6G, and industrial WiFi, enabling interconnection of all things, human-object interconnection, and connectivity between the industrial metaverse and reality.
3. **Game Engine:** Provides a foundation for the virtual world, mimicking the natural environment of the real world and giving the metaverse a virtual space. It creates rendering capabilities for the virtual world, making it more realistically mirror the physical world, provides various tool conditions for free player creation, and constructs incentive mechanisms that encourage creation.
4. **Cloud Computing Power:** Computing power is the most basic condition for the metaverse’s existence. The operation of the virtual world and industrial equipment requires strong computing power support to ensure lag-free, low-latency, and persistent stability.
5. **Artificial Intelligence (AI):** AI is the fundamental technology of the current metaverse, supporting the construction of avatars and NPCs, and is also a key technology for future development. It provides autonomous learning and self-improvement capabilities for intelligent beings like avatars and offers industrial production mechanism modeling and operation optimization capabilities, which are crucial for the metaverse’s growth.
6. **Virtual and Augmented Reality (VR/AR):** VR, AR, MR, XR, and other immersive interactive technologies provide computing environments for players, employees, and participants to interact with and access the metaverse anytime, ensuring realism and presence. Future development directions will involve comprehensive access to human senses—vision, hearing, touch, smell, etc.—while providing more flexible and efficient interactive operation methods.
7. **Economic System:** In the metaverse, it is necessary to build decentralized or multi-centered economic systems based on blockchain and NFT

(Non-Fungible Token, a data object that can record and process multi-dimensional, complex attributes on the blockchain). This involves constructing protection mechanisms for digital assets and property rights, providing the metaverse' s own virtual currency, creating economic systems, transaction methods, lending rules, smart contracts, etc., and forming exchange relationships between virtual and real currencies. Blockchain is a decentralized distributed ledger using block-chain storage that is tamper-proof and secure, combining distributed storage, peer-to-peer transmission, consensus mechanisms, and cryptography to record transactions and information through continuously growing data block chains, ensuring data security and transparency.

8. **Social System:** In the metaverse, avatars, NPCs, and other intelligent beings and objects constitute the metaverse' s social system. This includes individuals, organizations, and enterprises with different identities, as well as potential regulators and governments. Basic ethics and behavioral norms are required to ensure stable social operation. Sustained development will eventually form its own unique civilization system.

The metaverse will undoubtedly bring entirely new architectures, business forms, operation modes, and existence modes to the economy and society. These novel changes will inevitably impact and transform societal value systems and human survival modes. Metaverse residents (avatars, digital employees, NPCs, etc.) will extensively replace human labor, bringing true freedom and liberation to humanity. As Marx stated: "The realm of freedom actually begins only where labor which is determined by necessity and mundane considerations ceases; thus, in the very nature of things, it lies beyond the sphere of actual material production" [4]. The metaverse will lead humanity to the realm of freedom through virtual-physical symbiosis beyond material production.

1.4 Metaverse Empowering Urban Governance and Promoting Carbon-Silicon Civilization Integration

In urban governance, AI, virtual-physical interaction, cloud computing, blockchain, digital twins, IoT, and mobile communications technologies enhance digital-intelligent governance levels.

1. **Carbon-Based and Silicon-Based Civilizations:** Carbon-based civilization refers to civilization created and sustained by life forms based on carbon elements—humanity. Its core lies in human wisdom, emotion, creativity, and social structures and cultural systems. Since ancient times, carbon-based civilization has accumulated rich knowledge and experience through continuous exploration, learning, and innovation, driving social progress and development [5]. Silicon-based civilization refers to civilization represented by the technology world based on silicon elements. Silicon is the key element of semiconductor materials and the cornerstone of modern electronic and computer technology. With the rapid development of

computer technology, silicon-based civilization has formed a vast technical system including AI, big data, cloud computing, and IoT [5].

2. **AI Revolution: Facilitating Carbon-Silicon Integration:** First, at the technical level, the silicon-based civilization's technical system provides powerful support for carbon-based civilization, enabling significant progress in scientific research, healthcare, education, and entertainment. Second, at the lifestyle level, the popularization of smart homes, autonomous vehicles, and smart healthcare makes life more convenient and comfortable, representing deep integration between silicon-based technology systems and carbon-based life needs. Third, at the thinking mode level, the AI revolution brings transformative changes in thinking patterns. Machines are no longer merely tools or assistants but become partners and collaborators in life and work. Simultaneously, AI technology stimulates human creativity and imagination, driving innovation in technology, arts, and culture.

2. Metaverse Empowering Urban Governance and Enhancing Guangzhou's Digital-Intelligent Governance Level

As a frontier city in China's digital economy, Guangzhou is actively exploring the integration of metaverse technologies with urban governance, enhancing digital-intelligent governance levels through AI, virtual-physical interaction, blockchain, and digital twins.

2.1 Policy Support and Industrial Layout

Guangzhou's districts have introduced relevant specialized policies. In October 2022, Nansha District released the *Nine Measures for Promoting Metaverse Ecosystem Development in Guangzhou Nansha New Area (Free Trade Zone)* (Sui Nan Kai Guan Ban Gui [2022] No. 8), providing support in technology R&D, industrial agglomeration, application scenarios, and talent introduction, with maximum funding of 200 million RMB for major metaverse research platforms. Nansha District has also planned a metaverse industry agglomeration area, attracting enterprises to establish headquarters and R&D centers with rent-free premises and financial subsidies to build a complete industrial ecosystem.

In April 2022, Huangpu District issued the *Measures for Promoting Metaverse Innovation Development in Guangzhou Huangpu District and Guangzhou Development District*, focusing on digital twins, human-computer interaction, and AR/VR/MR/XR, offering up to 10 million RMB in rewards for projects overcoming key technologies. Huangpu District has built a "Metaverse Industry Innovation Base," attracting enterprises to virtual office spaces and providing policy consultation and industrial chain connection services.

In April 2022, Tianhe District established a metaverse think tank, specialized committee, and joint investment fund, launching metaverse industrial park pi-

lots. The first batch of pilot parks provided over 100,000 square meters of industrial space, driving rapid development of related industries.

2.2 Metaverse Empowering Urban Governance to Accelerate Guangzhou's Digital-Intelligent Modernization

2.2.1 Digital Twin City: Comprehensive Dynamic Governance

Guangzhou established the “Suizhiguan” urban operation management hub in 2021, combining metaverse technologies to build high-precision digital twin models that integrate real-time data from transportation, environmental protection, and emergency management, enabling dynamic simulation of all urban elements. For example, through IoT sensors and drone data collection, the system simulates flood disaster scenarios in virtual space to optimize drainage scheduling in advance. In 2022, Nansha District piloted a “Metaverse City Information Model (CIM)” for three-dimensional visualization and analysis of buildings, pipelines, and population density to assist land planning and infrastructure decision-making. Yuexiu District uses metaverse technologies for three-dimensional modeling and virtual simulation in urban planning, providing intuitive and accurate decision-making foundations, while using AI and big data for real-time traffic monitoring and intelligent dispatching to effectively alleviate congestion.

2.2.2 Virtual Government Affairs Hall: Immersive Public Services

In metaverse government affairs, VR/AR technologies create online government halls where citizens conduct business using digital avatars. For instance, Tianhe District piloted “Metaverse Tax Services,” allowing users to consult and submit documents in virtual scenes with AI assistants automatically reviewing forms. In old city renovation projects, residents preview renovation plans and vote through metaverse platforms, enhancing decision-making transparency.

2.2.3 Smart Transportation Governance: Virtual-Physical Collaborative Optimization

In traffic simulation implementation, Guangzhou uses metaverse engines to simulate traffic flow and test the effects of traffic restriction policies and signal timing schemes. For example, the Pazhou area predicts congestion points during exhibition periods through virtual road networks and dynamically adjusts bus routes. In autonomous driving testing, the city constructs extreme weather and accident scenarios in the metaverse to accelerate algorithm training, supporting the construction of intelligent connected vehicle test zones.

2.2.4 Emergency Management and Public Safety

For disaster prevention drills, fire and medical departments simulate emergencies like fires and pandemics in the metaverse to conduct cross-departmental collaborative exercises. In 2023, Guangzhou Metro jointly completed a “Metaverse Flood Control Exercise” with the Emergency Management Bureau to optimize emergency plans.

For security prevention and control, AR glasses connected to public security systems enable police officers to retrieve suspect virtual portraits and location trajectories in real time, enhancing patrol efficiency.

2.2.5 Empowering Culture, Tourism, and Economy Yuexiu District launched the “Yuexiu Maritime Silk Road Fantasy VR Space *Guangfu Dream Records*,” restoring the Poshan Ferry ancient site and blending ancient and modern Guangzhou for immersive cultural experiences. The district’s Guangfu Temple Fair integrates metaverse technologies for online-offline interaction, enriching public participation. Offline events also feature metaverse live streaming and virtual photo opportunities, providing more diversified interactive experiences for on-site audiences.

Liwan District’s Yongqingfang Metaverse Project restores the Xiguan historical neighborhood, allowing tourists to experience cultural scenes through virtual-physical overlay, driving consumption. Nansha District has built a city image display window at Baiyun Airport Terminal 2 and provides integrated “customs clearance + culture and tourism” services at the Pazhou Hong Kong-Macao Ferry Terminal, enhancing tourism public service quality.

2.2.6 Strengthening Infrastructure Construction and Security First, the city strengthens digital infrastructure construction by rationally deploying 5G base stations and data centers to improve network speed and data processing capacity, providing a solid foundation for metaverse applications. Second, it ensures data security and privacy protection by establishing robust mechanisms to safeguard user information and promote healthy, sustainable metaverse development. In blockchain rights confirmation, Guangzhou Data Exchange explores digital asset transactions in the metaverse, using blockchain technology to ensure traceable data circulation. In privacy computing, citizen data is desensitized in virtual scenes to balance governance efficiency with personal information security. The city also develops local standards for metaverse governance, clarifying behavioral norms in virtual spaces (such as digital avatar identity authentication).

Guangzhou plans to build “20+ benchmark metaverse application scenarios” by 2025, focusing on livelihood services and industrial upgrading. By breaking physical boundaries through the metaverse, Guangzhou is constructing a new governance paradigm of “virtual-physical symbiosis,” with its experience potentially serving as a reference for the Guangdong-Hong Kong-Macao Greater Bay Area urban agglomeration. In summary, Guangzhou actively explores metaverse applications in urban governance through policy support, industrial layout, scenario applications, and infrastructure construction.

3. Blockchain “Connecting” Livelihood Services: Applications in Multiple Government Service Areas

Blockchain has extensively permeated various fields, providing guarantees for life and work in Guangzhou. Since participating in the national blockchain innovation application (comprehensive) pilot in December 2021, Guangzhou’s Municipal Cyberspace Administration, together with 15 construction units and with strong municipal Party committee and government support, has adhered to “standardized, secure, and orderly” development. The city has strengthened the construction of a unified blockchain trusted service network infrastructure. In the end-of-term assessment of the national blockchain innovation application pilot jointly issued by the Central Cyberspace Administration and 16 ministries and commissions in 2024, Guangzhou’s pilot work was rated as excellent.

3.1 Blockchain Supporting Multiple Government Service Areas

Guangzhou continues to expand application scenarios, comprehensively promoting blockchain technology to empower government, enterprise, and citizen production and life. The blockchain trusted authentication service platform provides citizens and enterprises with integrated, networked identity authentication, electronic seals, and electronic signature services. Currently, these functions have been promoted in government services such as business registration, online signing of existing housing transactions, scientific research project contract signing, and electricity and water supply. The unified government blockchain basic platform has provided blockchain application support for medical institution test result sharing, personal equity transfer tax collection, employment security fund collection for disabled persons, and credit inquiry.

“Now household registration transfer can be handled across districts and operated on mobile phones—no need to visit the site!” In recent years, many citizens have discovered that whether it’s opening or paying water and electricity accounts, or buying and selling houses, everything can be done with a tap of a finger. These transformations result from Guangzhou government’s continuous digital transformation and service process optimization, underpinned by blockchain technology providing a solid technical foundation for the digital transformation of government services.

In 2021, Guangzhou launched the nation’s first blockchain-supported “Trust Guangzhou” digital platform. As an important public service infrastructure, it integrates digital certificate services and trusted authentication capabilities from advanced domestic and international electronic certification service providers, building a favorable network trusted authentication ecological environment and Guangzhou trust ecosystem. This provides standardized trusted service capability support for various resource-using units in Guangzhou.

3.2 Building “Trust Guangzhou” to Truly Benefit the People

In the metaverse, strangers can establish trust mechanisms based on digital technology and complete work based on digital trust. According to the Guangzhou Blockchain Industry Association, “Through legally effective identity authentication, electronic documents, and electronic certification, we ensure the full digitalization of government and commercial activities, with full process traceability, solving the problem of authenticity and trustworthiness of online data and electronic materials in the digital economy environment.”

3.2.1 Making “Medical Test Mutual Recognition” Truly Benefit the People Guangzhou actively promotes “blockchain + medical test result mutual recognition services.” Previously, visiting different hospitals required obtaining test reports, sometimes necessitating repeated examinations. Now, “medical test mutual recognition” reduces costs in money and time for Guangzhou citizens. In the past, technical issues prevented information sharing, forcing patients to repeat tests when switching hospitals. Fundamentally solving this problem required breaking technical barriers to smooth the path of medical test mutual recognition and improve industry efficiency.

To address inter-hospital mutual recognition and trust issues, Guangzhou uses the government blockchain platform to store medical test results on-chain. After verification operations, each test report receives a blockchain authentication identifier, ensuring data authenticity and immutability. This effectively achieves cross-hospital test result mutual recognition, reducing patients’ financial burden while improving medical service quality and efficiency. By the end of 2023, the “blockchain + medical test result mutual recognition service” had connected 199 medical institutions in Guangzhou, with 508 million items stored on-chain [6].

3.2.2 Achieving Trusted Enterprise “One-Chain Access” Previously, offline seal stamping processes were cumbersome, generally taking three days. If form errors were discovered, repeated operations could take a week. For enterprises handling “file intermediary service agency filing” business, relevant information is automatically obtained, and after facial recognition, seals can be applied. The entire process takes less than 10 minutes, and processed materials are automatically stored on-chain for traceability.

The Guangzhou Chain-based Enterprise Service Platform uses enterprise chain code technology to provide “one enterprise, one code, one account” services and enterprise chain space. By integrating enterprise basic information and credit information with blockchain accounts using “blockchain + QR code,” it creates enterprise chain codes that enable digital trusted identity and seal mutual recognition. This provides precise services combining “enterprise credit and enterprise profiling,” achieving full lifecycle services integrating enterprise chain space and chain services.

Currently, Guangzhou has opened blockchain spaces with enterprise chain codes

for over 3,700 enterprises, enabling the “one-network handling, one-chain access” blockchain service and reducing time and space costs for enterprises handling government services.

3.2.3 Blockchain + Public Resource Transactions Guangzhou has built a public resource transaction blockchain platform, enabling cross-regional “mobile handling, anytime handling” of public resource transactions. In reducing costs and increasing efficiency for enterprises, the platform has issued 5,045 electronic guarantees, reducing capital occupation by approximately 800 million RMB. Domestically pioneering enterprise chain code applications, it has provided chain-based services to over 120,000 enterprises and 100,000 individual users, and offered free electronic seals, electronic contracts, and chain safes to more than 2,400 enterprises, saving over 100 million RMB in operating costs.

Based on the “Trust Guangzhou” digital platform, Guangzhou’s trusted authentication service platform has completed trusted authentication integration with Hong Kong Post’s electronic certification authority, enabling access to Guangdong-Hong Kong mutually recognized certificates issued by Hong Kong Post. Hong Kong residents can use cross-border certificates to sign electronic documents when starting businesses. The platform also connects with the Feisign contract platform to enable blockchain cross-border contract signing services between mainland and Hong Kong residents and enterprises. Through Hong Kong Post’s electronic certification authority connected to blockchain, verified Hong Kong resident identity authentication information is registered on-chain. Based on blockchain characteristics, mainland business applications can use cross-border certificate information and identity information on-chain to verify Hong Kong residents’ identities and electronic signatures. Currently, this service has provided identity verification and on-chain services for over 120 Hong Kong residents, signing more than 460 cross-border contracts. Approximately 1,000 cross-border authentication information items have been stored on-chain.

Since the blockchain-supported “Trust Guangzhou” digital platform launched in 2021, Guangzhou’s trusted authentication service platform has connected to over 30 categories and 2,000 government service items, with more than 170 categories and 60 million data items stored on-chain [6].

3.3 Further Industrial Cluster Development: Guangzhou’s Blockchain Enterprises Reach 500

According to the *Response of Guangzhou Municipal Bureau of Industry and Information Technology to Proposal No. 20242497 of the 16th People’s Congress, 4th Session* dated May 9, 2024, Guangzhou’s blockchain enterprises have reached 500, with 157 enterprises and 185 projects registered with the national cyberspace administration’s blockchain information service filing. The blockchain and related industries have achieved a production value of several billion RMB.

Guangzhou' s pilot work was rated as excellent in the national blockchain innovation application pilot end-term assessment [7].

3.3.1 Seizing the High Ground in Blockchain Development

Guangzhou has introduced multiple key support measures for blockchain and other key software development sub-fields in terms of enhancing independent innovation capabilities, increasing enterprise cultivation and attraction, and fostering industrial ecosystems. For four consecutive years, blockchain has been included in Guangzhou' s high-quality development fund software and information service industry special support directions, supporting blockchain software demonstration platforms such as Fangxin Technology, Yuntong Lianda, and Civil Aviation Information. Huangpu District was the first in China to introduce blockchain-specific policies, with municipal and district-level finance cumulatively supporting blockchain enterprises and projects with over 100 million RMB.

Guangzhou continues to promote industrial carrier construction, supporting Huangpu District as an important development pole for Guangzhou' s blockchain industry. It has been built into Guangdong' s first China Software Famous Park with blockchain characteristics, recognizing 154 blockchain enterprises with an estimated blockchain and related industry output value of 5 billion RMB. It has formed an industrial pattern focusing on blockchain technology R&D, application services, platform operations, and financial innovation. "Among them, Huangpu Chain Valley alone has introduced 57 blockchain enterprises, with 24 recognized as blockchain enterprises, 6 completing national cyberspace administration filing, and 3 recognized as Guangdong-Hong Kong-Macao Greater Bay Area blockchain rising enterprises" [7].

3.3.2 Using Blockchain to Assist Business Environment Reform

Guangzhou' s blockchain international trade platform has enabled 7.8 billion RMB in trade business on-chain. Guangzhou Development Zone pioneered the domestic "Tax Chain" blockchain invoice platform and "Policy Credibility Chain" government application. Hangxin Chain promotes blockchain technology implementation in civil aviation business, achieving record storage and data traceability functions. Guangzhou Internet Court launched the "Wangtong Falian" blockchain platform, using consortium chain form to connect nine units including Guangzhou Intermediate People' s Court and data from over 30 internet platforms like "BAT" (Baidu, Alibaba, Tencent), building a digital governance ecosystem.

In the blockchain field, Guangdong Radio and Television Group established Guangdong' s Virtual Digital and Blockchain Technology Engineering Research Center in 2017, the province' s first certified blockchain technology research center. The group uses blockchain to empower traditional industrial upgrading, creating a credible, collaborative, and secure blockchain industrial infrastructure. It has launched Yuntong Shulian, an enterprise-level blockchain technology plat-

form for finance, government, copyright, and other application scenarios, incubating applications in cross-border digital trade, multi-city rail transit clearing, and supply chain finance [8]. Next, Guangzhou will focus on empowering the real economy, developing application scenarios, and enhancing innovation capabilities according to the requirements of the national blockchain development pilot zone and comprehensive pilot, promoting new momentum in blockchain technology innovation and industrial development.

4. Digital Twins Empowering Intelligent, Refined, and Scientific Urban Management

The Decision of the Third Plenary Session of the 20th CPC Central Committee states: “Strengthen the cybersecurity system and establish an AI safety supervision system.” The application of AI, digital twins, and other technologies in Guangzhou’s urban governance has significantly enhanced urban management intelligence and operational efficiency.

4.1 Building the Urban Operation Management Hub— “Suizhiguan”

First, the city constructs a digital twin city foundation, creating a digital twin of Guangzhou corresponding to the real city through digital means, covering urban environment, buildings, roads, population, and other elements to achieve holographic projection and real-time monitoring of urban operation status. Second, it achieves multi-domain data fusion analysis, integrating data from economy, healthcare, urban management, transportation, ecology, and livelihood to establish a “one-map overview, one-network co-governance” operation mode, providing comprehensive and accurate information support for Guangzhou’s urban governance. Third, it enhances urban operation monitoring and emergency response capabilities, with functions including operation monitoring, prediction and early warning, collaborative linkage, decision support, and command scheduling, enabling real-time grasp of urban operation status, timely warning and response to emergencies, and improving urban safety and emergency response efficiency.

4.2 Accelerating Construction of Digital Twin Industrial Parks

As an entry point for future smart city construction, digital twin city industrial parks follow Guangzhou’s overall approach of “government-led, platform-supported, scenario-driven, and industry-cultivated.” The city provides comprehensive incentives for settled enterprises from industrial, financial, and talent perspectives to enhance Guangzhou’s digital twin industrial capacity and market competitiveness.

4.3 Building the Guangzhou Tower Scenic Area Intelligent Management Platform

The Guangzhou Tower Scenic Area Intelligent Management Platform creates a high-precision digital twin foundation, recreating a digital twin city of the

Guangzhou Tower scenic area. “From landmark buildings like Guangzhou Tower, Media Port, and Haixin Bridge to small urban facility components like manhole covers, fire hydrants, and lamp posts, comprehensive 1:1 3D digital restoration enables interaction between 3D virtual scenes and real urban elements” [9]. First, high-precision digital twin modeling: 1:1 3D digital restoration of the Guangzhou Tower scenic area and surrounding facilities builds high-precision digital twin models enabling virtual-real interaction. Second, real-time monitoring and intelligent early warning: real-time data on 人流, passenger flow, video surveillance, traffic conditions, and weather are accessed to establish early warning mechanisms for real-time scenic area operation monitoring. Third, enhancing scenic area management and service levels: video intelligent analysis technology automatically identifies uncivilized behaviors for rapid handling; passenger flow profiling optimizes public service space and facility layout to improve visitor experience. “After platform completion, event discovery and automatic analysis and early warning capabilities have been greatly enhanced. Simultaneously, by shifting from physical patrols to real-time roaming patrols on the platform, management efficiency and social service capacity in the area have been effectively improved, significantly alleviating social governance pressure around the Guangzhou Tower area” [9].

4.4 Empowering Urban Lifeline Safety Management

First, real-time monitoring of infrastructure status: IoT and sensor technologies monitor the operation status of urban lifeline facilities like water supply, power supply, gas, and drainage in real time, obtaining key data such as pressure, flow, and temperature. Second, predicting and warning of potential risks: data analysis and simulation predict risks like pipeline leaks and equipment failures, providing early warnings to prevent accidents and ensure urban operation safety. Third, improving emergency response efficiency: in emergencies, the digital twin platform provides accurate facility information and emergency plans to assist rapid decision-making and resource dispatching, improving emergency handling efficiency.

4.5 Promoting Modernization of Grassroots Governance

First, constructing digital twin communities: Guangzhou builds digital twin models at the community level, integrating various community data resources to achieve digital and grid-based community governance. Second, enhancing community service and management levels: real-time grasp of community population, facilities, and environment information enables precise identification of resident needs and provision of personalized, convenient public services, optimizing community resource allocation and improving management efficiency. Third, promoting public participation in community governance: building community interaction platforms encourages residents to participate in community affairs and provide feedback, achieving co-construction, co-governance, and shared benefits.

5. DeepSeek Adapting to Guangzhou Government Affairs, Continuously Optimizing Livelihood Services

In January 2025, Guangzhou completed the nation's first domestic adaptation of DeepSeek (an open-source large AI model developed by Hangzhou Deepseek Artificial Intelligence Basic Technology Research Co., Ltd.) in the government affairs field. Currently, Guangzhou's government affairs field has comprehensively rolled out DeepSeek large model access, taking the lead in promoting DeepSeek technology's deep application and innovative practice in popular government affairs fields like livelihood services and urban governance.

Government system access to large models like DeepSeek requires computing power as a foundation. As early as September last year, Guangzhou proactively deployed intelligent computing power in the government affairs zone. A key technical support party for large model deployment in Guangzhou's government affairs field is the Digital Guangzhou Innovation Laboratory, which is currently exploring new prospects for deep integration of AI and public governance.

5.1 12345 Hotline Work Orders “Accurately Distributed, Quickly Handled”

Guangzhou's 12345 government service hotline receives an average of 50,000 calls daily. Callers' questions are diverse, and operators must quickly grasp core demands within one to two minutes to complete acceptance and consultation responses. Now, with DeepSeek's support, this process is much more convenient. Operators can quickly sort out call demands with DeepSeek's intelligent voice conversion assistance. DeepSeek can also analyze hotline data, accurately extract core points of demand work orders, and annotate and categorize data. In citizen demand handling analysis scenarios, Guangzhou 12345 hotline can use DeepSeek to conduct reasoning analysis on large amounts of data including demand content, completion opinions, and follow-up situations, proposing optimization suggestions for work order handling to provide scientific references for relevant departments and help efficiently solve livelihood issues.

In early 2023, Guangzhou 12345 hotline began building an intelligent seat system, integrating Automatic Speech Recognition (ASR), intelligent knowledge bases, and large language models to construct a human-machine collaborative smart hotline new model, reducing citizens' average waiting time by 43% and achieving 97% work order dispatch accuracy [10]. Unlike enterprise needs, government services concern people's livelihood and well-being, with broad service targets and diverse demands, making the “customization” advantages of open-source models more prominent. Simply put, model open-sourcing is like making a toolbox public—the key lies in how to use these tools to solve practical problems. In government affairs, relevant departments can conduct secondary development of DeepSeek-based models according to actual needs, iterate quickly, and continuously optimize livelihood services.

5.2 Promoting Smart Government Scenario Implementation

Since DeepSeek was fully launched on Guangzhou's government extranet in January 2025, municipal government units have actively promoted smart government scenario implementation. In Guangzhou's government extranet zone, the Digital Guangzhou Innovation Laboratory has established connections with 17 government units to conduct DeepSeek-enabled AI application cooperation.

For example, Guangzhou Intermediate People's Court recently officially launched the "Court DeepSeek Application Experience Center," marking the successful landing of Guangzhou's first DeepSeek integrated machine private deployment project in the government affairs field. It can provide real-time legal consultation answers and assist in generating standardized documents through file upload functions, providing precise and efficient intelligent support for judicial workers and significantly improving judicial office efficiency. The technical team's construction of the "Court DeepSeek Application Experience Center" is a microcosm of Guangzhou's government affairs vigorously promoting intelligent services [10].

Huadu District is building multi-scenario AI models for urban inspection and patrol work to comprehensively enhance intelligence and precision. Haizhu District's "AI Partner" achieves one-click generation of enterprise profiling reports. Yuexiu District's "Ai Xiaoyue" government service robot has achieved 99% response accuracy. Next, Guangzhou will coordinate the establishment of a "one ledger, one mechanism, one platform" pattern for AI large models in the digital government field, promoting the deep adaptation of its self-developed AI middle platform with DeepSeek, and cooperating with domestic advanced large model manufacturers to meet AI large model application needs.

"AI Approval" –Instant Business License Processing. The upgraded "Guangzhou Market Entity Express" mini-program focuses on solving enterprise handling difficulties. By collecting key element information, it "achieves standardized verification and automatic generation of all forms, helping enterprises and the public complete declarations meeting registration conditions and standards smoothly and quickly, further optimizing the handling experience" [11]. Additionally, for enterprise establishment registration applications not involving pre-approvals, the mini-program implements "AI approval" upon submission, using OCR (Optical Character Recognition), precise text and image recognition, and automatic comparison with various standard rules to greatly improve approval efficiency. Simultaneously, it pioneers full-domain standard address comparison, using data empowerment and blockchain technology to ensure information authenticity, consistency, and immutability, eliminating manual verification blind spots. For applications meeting legal forms, approval results can be obtained shortly after electronic signing, promoting "face-scanning approval" and further improving satisfaction. Next, Guangzhou's Market Supervision Bureau will continue to be driven by new AI technologies, exploring more convenient applications in market supervision and government services, continuously

improving the “Market Entity Express” service scenarios, and promoting the realization of “one-place handling, nationwide access” for enterprise registration in Greater Bay Area cities and key national cities.

Guangzhou will further expand DeepSeek large model applications in government services, forming demonstration applications in intelligent approval, intelligent supervision, and intelligent policy push. It will also establish a two-way empowerment mechanism between government data and AI technology, creating a virtuous cycle of “data feeding AI, AI feeding back decisions.” Additionally, Guangzhou will promote human-machine collaborative governance models, forming replicable intelligent solutions in traffic scheduling, environmental monitoring, and other fields.

6. Investing in Smart Urban Management System to Accelerate Digital Transformation of Urban Management

In March 2025, the Ministry of Housing and Urban-Rural Development commended 95 units, including Baiyun District Urban Management and Comprehensive Law Enforcement Bureau, for outstanding performance in the 2024 “Strengthening Foundations, Transforming Work Styles, and Shaping Image” special campaign, with Baiyun District Bureau being Guangzhou’s only commended unit [12]. The bureau continues to deepen smart urban management construction, accelerating digital transformation by investing in the Baiyun Smart Urban Management System, which solves key and difficult problems in urban management and comprehensive law enforcement and advances urban management AI construction. Currently, the Baiyun Smart Urban Management System has been trialed in dozens of regions nationwide.

Previously, the bureau relied on manual patrols to discover problems, resulting in low efficiency and many blind spots. Now, with AI automatic recognition and automatic work order dispatch, problem handling has shifted from “waiting for reports” to “proactive detection.” In 2024, Baiyun District used a “drone + AI” low-altitude inspection model to manage over 4,800 illegal construction cases covering nearly 4.7 million square meters, leading all Guangzhou districts in illegal construction control for three consecutive years. In sanitation, “the bureau uses AI algorithms to manage online personnel and vehicles of cleaning companies, comprehensively improving cleaning quality. Last year, Baiyun District’s sanitation revenue exceeded 452 million RMB, ranking first among all Guangzhou districts for two consecutive years” [12]. In construction waste disposal, the district actively promotes a full-chain collection and transportation system for decoration waste, advancing contracts between townships and disposal enterprises. In waste classification, it continues to reduce and classify waste, improving low-value recyclables recovery systems, with over 7,400 tons of low-value recyclables classified and processed. The case of “Baiyun District Urban Management Bureau Building a New High Ground for Intelligent and Refined Waste Classification Management” was selected as one of 20 typical cases of comprehensive green transformation in Guangdong Province’s 2024 National

Ecology Day publicity activities.

7. “Guangzhou Eagle Eye” Assisting High-Quality Urban Development

The R&D team of Guangzhou Urban Planning Survey and Design Research Institute overcomes difficulties, continuously promotes surveying and mapping technology innovation, increases surveying and mapping technology investment, actively develops new surveying and mapping technologies and equipment, and deeply integrates them with IoT, 5G, AI, and other new technologies. It has built a comprehensive, three-dimensional, intelligent low-altitude remote sensing monitoring network—Guangzhou Eagle Eye—serving as the “sky eye” of smart cities and creating multiple intelligent application scenarios. It provides efficient and intelligent services for Guangzhou’s urban planning, natural resource management, urban management, water affairs, transportation, and other fields, meeting the needs of “one collection, multiple uses,” transforming urban construction from governance to “intelligent” governance.

7.1 Building an Integrated Air-Space-Ground Intelligent Remote Sensing Monitoring Network

Modern social governance requires weaving a comprehensive, three-dimensional, intelligent social perception network, strengthening ubiquitous perception, terminal networking, and intelligent scheduling systems to achieve real-time, dynamic, and three-dimensional perception and discovery of various information in modern society for one-time collection and multiple uses. To this end, the institute pioneered the construction of a low-altitude remote sensing monitoring network—Guangzhou Eagle Eye. It is an air-based IoT that deploys multiple low-altitude aircraft (such as drones and light aircraft) intelligent base stations in operation areas, using AI, edge computing, 5G communication, IoT, and other emerging technologies to achieve high-frequency, unmanned, and fully automatic three-dimensional monitoring of surface resources.

The main infrastructure of “Guangzhou Eagle Eye” is drone airports. “Guangzhou plans to build 150 drone airports covering the entire city (except no-fly zones), achieving the goal of twice-weekly coverage of key areas, once-weekly coverage of general areas, and reaching any location in Guangzhou within 5 minutes” [13]. Simultaneously, by deploying mobile service support vehicle systems to compensate for insufficient coverage of seas, forests, and mountainous areas by automated drone airports, the system achieves full-area coverage and diversified inspection scenarios, completing coverage of specific scenario inspection services such as maritime patrols, forest inspections, and emergency rescue, helping urban governance enter a new stage of intelligent scenario monitoring.

7.2 Efficient Monitoring with Drone Airports

Drones achieve unattended and long-term continuous operation through autonomous takeoff/landing, flight, and charging/battery swapping, suitable for situations requiring high flight frequency or single tasks that cannot be completed in one flight. This provides all-weather, all-element, high-frequency, and real-time intelligent identification monitoring services for monitoring areas. Haizhu District has built high-frequency, all-weather, low-cost illegal construction dynamic monitoring hardware infrastructure by deploying five automated drone airports. It conducts regular, automated, and intelligent monitoring at a frequency of covering the entire district once weekly, collecting high-precision, high-frequency, all-element drone image data and automatically pushing it to a sequential image database as the basis for image comparison and clue discovery. Through the dual 加持 of “drone airports + AI,” Haizhu District has created two major brands: illegal construction clue discovery and handling, and illegal construction governance 3D “one-map” visualization, forming a full-process illegal construction monitoring and management system.

7.3 Mobile Road Measurement Vehicle Automatic Monitoring

While drones can achieve large-area, low-altitude rapid patrols and monitoring, they struggle to capture images obscured by trees or vertically hanging small objects like advertising signs, requiring ground-based mobile road measurement for supplementary collection. To this end, the institute independently developed a mobile road measurement vehicle integrating panoramic cameras, high-precision inertial navigation, laser scanners, six SLR cameras, and multi-topic AI algorithms. It can automatically monitor scenarios such as illegal street occupancy, garbage exposure, full garbage bins, random garbage stacking, and leaning advertising signs. With measurement accuracy better than 5 centimeters under good satellite signals, it can convert monitored clues into work orders and automatically push them to relevant departments for handling. Through technological and application innovation, Guangzhou has effectively solved problems of low efficiency, poor timeliness, and high costs in conventional monitoring methods, innovating urban management and governance monitoring and law enforcement models.

7.4 Intelligent Application Scenarios Empowering Various Industries

“Guangzhou Eagle Eye” has created a new monitoring model achieving one-time collection and empowering N intelligent applications, providing all-weather, all-element, low-cost, high-frequency data collection and inspection services for various Guangzhou departments. Its application scenarios are extensive, covering natural resources, public security, urban management, transportation, water affairs, emergency management, environmental protection, energy, agriculture, and forestry. It provides high-frequency, efficient, and intelligent technical services for land illegal use and illegal construction patrols, city appearance improvement, illegal construction governance, river patrols, embankment main-

tenance, water construction site supervision, traffic congestion detection and guidance, road hazard investigation, accident site surveys, and forest fire monitoring.

Currently, “Guangzhou Eagle Eye” has achieved full drone airport coverage in Haizhu and Nansha districts. It has been applied in natural resources, urban management, emergency management, and other fields, realizing automatic drone flight and shared results data across departments. The institute also uses drones to conduct full-coverage patrols of agricultural land in pilot towns, effectively identifying suspected illegal land use patches, completing over 10 monitoring operations and extracting more than 1,000 patches, playing an important role in farmland protection. Additionally, based on remote sensing interpretation large models, it conducts quarterly classification of marine natural resource development and utilization in key management areas within Guangdong Province, achieving full-coverage, high-precision marine natural resource monitoring.

Furthermore, “the Smart Guangzhou Spatiotemporal Big Data Platform has launched 230 map services, providing services to nearly 200 units and over 1,000 users since its launch, with total visits exceeding 1.275 billion” [13]. Aiming for good governance in large cities, the institute will support Guangzhou in accelerating “Eagle Eye” construction through infrastructure + information platforms + AI + application scenarios, forming a comprehensive, three-dimensional, intelligent unmanned airport eagle eye system, expanding upstream and downstream industrial intelligent application scenarios, and providing efficient and intelligent services for Guangzhou government departments and the public.

8. Problems Faced by the Metaverse in Urban Governance

8.1 Data Security Issues

The metaverse has a large number of users, and massive amounts of user privacy data and sensitive data are collected daily. Who owns this data, and who controls it? This harbors both astonishing advantages and terrible risks, requiring cities to have a highly reliable system for regulation. Although the metaverse is still in its early stages, researching these issues now is crucial for its future healthy development.

8.2 Standard Control Issues

People from different cities in the real world can meet, make friends, and form teams in the virtual world, and they should have common standards; otherwise, endless disputes will arise. Who will regulate and coordinate these issues? Moreover, “as mixed reality technology develops and matures, people increasingly cannot distinguish between virtual and reality. Whoever controls the virtual world basically controls the entire life of related individuals” [4]. This poses enormous challenges for control.

8.3 Need for Basic Behavioral Norms and Ethics

All interactive behaviors between people, organizations, and all things must have basic behavioral norms and ethics. Interactions between virtual individuals or organizations must have basic moral bottom lines and publicly recognized basic behavioral norms to enable the entire system to operate smoothly. Civilization formation is a slow process that requires good guidance to shape a beautiful civilization form imperceptibly.

8.4 Need to Deepen Understanding and Application of Digital Twins

“The definition of digital twins is not limited to physical object twins but also includes human and process twins, which is a leap in digital twin technology” [4]. When digital humans appear in digital twin business scenarios, people have basically entered the metaverse threshold. In industrial enterprises, digital twins typically start from components, to equipment, devices, production lines, workshops, and finally to entire factories—that is, from single twins to composite twins, and finally to organizational twins. The transition from single twins to organizational twins represents the leap of digital twin technology from digital technology to the metaverse. Its key elements are the addition of processes, especially the addition of humans as “digital life,” and the spatiotemporal information necessary for life.

It is recommended that relevant departments conduct in-depth research on the above issues of data security, standard control, basic behavioral norms, and the deepening and expansion of digital twin and smart contract applications, and propose corresponding countermeasures.

9. Metaverse Boosting Urban Transition to Carbon-Silicon Civilization Integration

As the representative of carbon-based life, humanity has had unprecedented impacts on Earth’s environment through wisdom and technology, changing landforms, climate, and ecosystems, and creating a rich and colorful human civilization. Empowering urban governance through the metaverse will accelerate the transition of cities and society from carbon-based civilization to the integration of carbon-based and silicon-based civilizations.

9.1 Humans Helping Silicon-Based Civilization Grow from Infancy

In the rise of silicon-based civilization, humans play a crucial role in helping it grow from infancy. From the perspective of technological development, human promotion of silicon-based civilization began with exploration of semiconductor technology. With the development of new-generation information technology, “these advances not only make the carriers of silicon-based civilization—computers—more intelligent and powerful but also create conditions for emerging technologies like AI” [14].

9.2 AI as an Important Milestone in Human Promotion of Silicon-Based Civilization

In recent years, breakthroughs in AI technologies such as deep learning and neural networks have enabled machines to learn, reason, and make decisions like humans. “From image recognition to speech recognition, from natural language processing to intelligent robots, AI has been widely applied in various fields, profoundly changing people’ s life and work modes” [14]. Behind these applications is human in-depth research and continuous exploration of AI technology, endowing machines with intelligent “brains” through massive data training and algorithm optimization, enabling them to demonstrate powerful intelligent capabilities on a silicon basis.

Although silicon-based civilization shows great potential, carbon-based species also have irreplaceable unique value. From an evolutionary perspective, carbon-based life has formed highly complex and diverse ecosystems through billions of years of evolution. This ecosystem complexity and stability have been accumulated over long periods, which silicon-based civilization currently cannot replicate. Even if silicon-based civilization can create intelligent machines, these machines will find it difficult to integrate into existing carbon-based ecosystems, let alone replace carbon-based life’ s position in ecosystems.

From cultural and emotional perspectives, the rich emotions and cultural creativity possessed by carbon-based life are difficult for silicon-based civilization to match. As the representative of carbon-based life, humanity has created rich and colorful cultural forms such as music, painting, literature, and philosophy. These cultural achievements are crystallizations of human wisdom and emotion, reflecting human cognition of the world and perception of life. Human emotions—love, hate, joy, sorrow, etc.—give life unique meaning and value. “While silicon-based civilization has powerful capabilities in computing and logical processing, they lack emotions and cultural creativity, cannot experience and express these rich emotions, and find it difficult to create cultural works with profound connotation and appeal” [14]. Therefore, carbon-based life has an irreplaceable position in culture and emotion.

From the perspective of cosmic diversity, carbon-based species and silicon-based civilization are not mutually exclusive but can coexist and complement each other. The universe is so vast and full of infinite possibilities that different forms of life and civilization may emerge and develop in some corner. Silicon-based civilization may have advantages in some aspects, such as powerful computing capabilities and adaptability to harsh environments, while carbon-based life shows unique charm in other aspects, such as rich emotions and creativity. Their coexistence can bring richer and more diverse landscapes to the universe, jointly promoting cosmic evolution and development. For example, humans can use silicon-based civilization technology to expand living spaces and improve quality of life, while silicon-based civilization can draw inspiration from carbon-based life’ s culture and emotions for more comprehensive development.

9.3 Social Civilization Built on Consensus and Consensus-Based Systems

Since civilization's birth, all civilizations have been built on consensus about community. Human rights and interests certification is confirmed by other humans and human systems, a confirmation right that carries the inefficiency, delay, and even unfairness of manual operation. The way human society executed social consensus in the past is called "carbon-based consensus," where individuals are empowered to interpret abstract consensus clauses and make judgments.

As human technology systems develop, more and more adjudication power has been given to machines, which we can call "silicon-based consensus." The greatest consensus of humanity in the 21st century is digital cognition and mathematical language. Social civilization is built on consensus and consensus-based systems—a trust based on human abstract consensus, while consensus execution is often by power agents who are also individuals. Although people often hope that legal arbitrators are emotionless judgment machines that can enforce laws impartially in the law enforcement system, this can only be an assumption.

"One of blockchain technology's great contributions is reconstructing trust networks between people, greatly reducing trust costs, while enabling consensus based on digital cognition and mathematical language to truly play a systematic role, thereby establishing a more advanced social civilization" [15]. How does blockchain achieve this role?

9.4 Smart Contracts—Solving Trust Issues Between Strangers

In traditional acquaintance societies, trust between people was often established through group public opinion, tracing the past, and providing guarantees. For example, for someone who frequently borrows money without repaying, when we trace their past actions, we won't trust their repayment promises. The rapid development of the internet and mobile internet, along with increasingly frequent population mobility, has moved us from acquaintance societies to stranger societies, where we buy from online shop owners we've never met and discuss business with potential overseas clients whose backgrounds we don't know. In such stranger societies, tracing the other party's past becomes difficult, and group public opinion is hard to function.

Blockchain technology mainly solves trust issues between strangers through smart contracts. In blockchain systems, once recorded information or data becomes permanent records that cannot be revoked or easily tampered with. With authentic and trustworthy data or information queries, establishing stranger trust naturally becomes simple and efficient. The widespread application of smart contracts in the metaverse will further enhance blockchain's role as a "trust machine," integrating needs and production among network nodes within the digital world, promoting further refinement of economic division and broader social collaboration in the metaverse era, and will certainly create new economic

miracles.

9.5 Blockchain' s Algorithmic Mechanism: More Efficient, Fairer, More Trustworthy

Even the most just and selfless people cannot guarantee strict rule-following in all scenarios, always being more or less affected by emotions, moods, experiences, and cognition. Blockchain technology ensures fairness and justice through algorithmic mechanisms. Through asymmetric encryption, consensus mechanisms, voting mechanisms, and master nodes, it fully ensures that all nodes in the entire blockchain system can automatically and securely exchange data in a trusted environment. Algorithms have no emotions and are therefore absolutely rational. As long as rules are set, they can be executed automatically with absolute fairness and impartiality. Obviously, blockchain' s algorithmic mechanism is more efficient, fairer, and more trustworthy.

The current internet and mobile internet have high trust costs. In the near future, the metaverse will be a virtual existence even more detached from reality than the internet and mobile internet. How to establish lower-cost collaborative trust relationships is a question worth deep consideration. The metaverse is a virtual world where trust relationships between people, between people and institutions, and between institutions, as well as how to conduct fair and reasonable transactions to avoid fraud traps, become major issues. Blockchain technology brings down to cost reduction and efficiency improvement of social trust mechanisms, also showing people more possibilities for the future metaverse era.

In the future, “blockchain + metaverse” will build a “four-dimensional” world, crossing reality and virtuality, creating a new dimension to ensure order in the metaverse world.

9.6 Automation: Intelligent Digital Protocols Automatically Execute

The most basic construction unit of various architectures is natural persons. Before software, human social order was defined and disseminated in book form through laws, with enforcement conducted by law enforcement personnel—a network system of organic humans. “Truth + legal book system + human enforcement” has many defects [15]. To solve these problems, humans have been working hard. Social operation systems are built on laws and various other regulations, which people call “manual operation systems.” Software makes automated social operation systems possible. With software and blockchain concepts, social rules can hopefully be softwareized. After rule softwareization, rule execution can be automated, which people call “automatic operation systems.” Human society' s current social governance system is still in a “handicraft” state. Just as industrial industries developed from handicrafts to automated IoT systems, human society' s governance systems are also undergoing major transformation. The transition from “handicraft” to “automatic execution” in social governance is a historical trend. Social governance automation will certainly arrive, and

human consensus on digital cognition and mathematical language will certainly become humanity's greatest consensus, becoming the development foundation for metaverse virtual civilization.

In the future, in the metaverse era, human society's operation will not need to go through power centers in most scenarios but will be based on traceable machine trust. "Carbon-based civilization will deliver automatic social execution mode to silicon-based civilization. A highly developed metaverse society will be one automatically executed by AI or intelligent digital protocols. This automatic execution method will be global and will certainly become a milestone in human social operation history" [15].

Entering the digital era, digital intelligence technology is effectively empowering the modernization of urban governance. In recent years, Guangzhou has leveraged "digital" governance thinking and metaverse technology, with digital intelligence driving and scenario traction as the main line, continuously exploring innovative smart paths for urban governance, continuously achieving new results, and realizing high-quality urban development. As an aggregation of new-generation information technologies including AI, blockchain, cloud computing, big data, IoT, VR/AR/MR/XR, and digital twins, metaverse technology will help Guangzhou and even the Greater Bay Area's urban and social governance become more digital-intelligent, scientific, and modernized, and accelerate the transition from carbon-based civilization to the integration of carbon-based and silicon-based civilizations. The Greater Bay Area will become a demonstration area for high-quality development and a pioneer in Chinese modernization.

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

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