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Intelligent urbanism with artificial intelligence in shaping tomorrow's smart cities: current developments, trends, and future directions

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Abstract

21st century has witnessed a profound metamorphosis in human civilization, primarily driven by the confluence of advanced network technologies and industrial modernization. This transformative period has expanded our understanding of the world, paving the way for innovative concepts such as the "smart city". At its essence, a smart city harnesses the power of artificial intelligence (AI) to revolutionize urban living, presenting a paradigm shift towards more efficient service models and an elevated standard of living for its inhabitants. Integrating AI into the fabric of urban infrastructure marks a monumental leap in societal evolution, underscoring the imperative to cultivate and advance AI technologies. This paper endeavors to elucidate the multifaceted applications of AI within the domains of smart cities, illuminating its pivotal role in shaping and advancing our contemporary era. From intelligent transportation systems and energy management to public safety and healthcare, AI permeates various aspects of urban life, ushering in unprecedented efficiencies and novel solutions to age-old challenges. The symbiotic relationship between AI and smart cities is explored in detail, showcasing how AI technologies are instrumental in optimizing resource allocation, improving decision-making processes, and ultimately enhancing the overall quality of life. Furthermore, this paper delves into the imperative of fostering the development and advancement of AI technologies within the context of smart cities. It underscores the interconnectedness of technological progress and urban development, emphasizing how a concerted effort to cultivate AI capabilities can propel cities into a future marked by sustainable growth, resilience, and innovation. The exploration of challenges and opportunities in deploying AI within urban environments adds a critical dimension to the discourse, encouraging a balanced consideration of ethical, regulatory, and societal implications. In conclusion, this paper seeks to contribute to the ongoing dialogue surrounding smart cities and the transformative impact of AI. By shedding light on the diverse applications of AI within urban landscapes and emphasizing its pivotal role in shaping the trajectory of our era, it underscores the critical importance of advancing AI technology development for the continued progress of smart cities and, by extension, the broader global community.

Keywords Artificial intelligence (AI), Smart city, Innovation and development, Specific application

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Introduction

The 41st World Expo in Shanghai, during the summer of 2010, themed "Better City, Better Life", stood as a seminal moment for cultural exchange and a reflection on the trajectory of urban development across the globe [1]. This expo underscored an epochal shift recognized by the United Nations and the World Bank: the tipping point where more than half of the world's population came to reside in urban areas, marking the ascent of the city as a central hub of modern human civilization. Over the ensuing decade, this urban proportion has not only sustained but grown, rising from 51 to 55% and, according to projections by the United Nations, is set to swell to 68% by the year 2050. This relentless urban expansion heralds a new normative state for humanity, where urban living embodies the collective experience of our species [2].

A city is demarcated as a densely populated, permanent region with defined limits, where inhabitants are primarily engaged in non-agricultural pursuits [3]. Characterized by high-density human developments, including residences, commercial properties, roadways, bridges, and railroads, urban areas represent highly developed environments. According to the United Nations Department of Economic and Social Affairs, 55% of the global population resides in urban areas, a figure projected to ascend to 68% by 2050 [4]. In 2016, there were hundreds of urban areas with a population of one million and dozens of megacities with populations exceeding ten million. By 2030, projections estimate 662 city areas and 41 megacities, predominantly in emerging regions [5]. This escalating urbanization is poised to exert a substantial impact on the environmental, managerial, healthcare, energy, educational, and security facets of cities. Consequently, smart cities are anticipated to become the standard in major urban centers, leveraging diverse technologies to realize long-term socioeconomic objectives. Modern smart cities employ various technologies to support advancements aimed at realizing sustained socioeconomic goals. A multitude of smart city projects, distributed across diverse geographical locations, is evident through extensive studies, yielding a diverse array of urban visions [6–8].

Scientometric analysis [9] reveals the integration of AI in smart city research since 2008, with noteworthy connections to global sustainable development, particularly in underdeveloped. AI, employed to facilitate smart city solutions, imparts several advantages, including improved water supply, energy management, waste management, and mitigation of traffic congestion, noise, and pollution. Prevailing smart city initiatives predominantly focus on data creation and information acquisition concerning a city's complexity and dynamics [10, 11]. AI propels cities into a new echelon by enabling the utilization of data and knowledge for informed decision-making. Projections indicate that AI will underpin over 30% of smart city applications by 2025, especially in urban transportation solutions, significantly enhancing urban resilience, sustainability, social welfare, and vitality [12]. The burgeoning growth of AI-based smart city initiatives propels ongoing exploration by researchers, government officials, and practitioners, continually seeking innovative information and approaches to elevate cities into smart urban landscapes.

With the burgeoning cityscapes, however, come compounded challenges [13]. The dense clustering of humanity in confined urban spaces has engendered issues such as housing shortages, traffic congestion, environmental degradation, and resource depletion [14]. In response, the clarion call for the 'smart city' concept has been sounded [15]—a beacon of hope leveraging the confluence of the Internet, cutting-edge industrial developments, and the burgeoning field of AI. This concept envisages a city where interconnected systems and services run on the axis of technological innovation to enhance resource efficiency, streamline city management, and ultimately uplift the quality of urban life.

Since IBM's articulation of the "smart city" in 2008 [16], there has been a notable evolution over more than a decade, with an array of "smart applications" incrementally infiltrating urban life. Applications like Google Maps have transformed the art of navigation, intertwining geographical data with urban landscapes to enable intricate route planning from the comfort of one's home [17]. Ridesharing giants like Uber and Didi Chuxing have harnessed vehicle and user data through sophisticated algorithms, streamlining urban transportation [18]. In the realm of public safety, China's "Skynet" and the Domain Awareness System—a collaborative endeavor between the New York Police Department and Microsoft—represent monumental strides in surveillance, deploying millions of cameras and sensors to maintain civic order [19].

While these instances showcase the application of AI in various forms, the broader gamut of smart city solutions often revolves around the triumvirate of data collection, networking, and sharing—encompassing platforms like e-government services, remote appliance control, and intricate sensor networks. As AI technology progresses, its capabilities in reasoning, prediction, and decision-making are set to further propel the smart city from a burgeoning concept to a pervasive reality, transforming the essence of urban existence.

The purpose of this review is to explore and evaluate the transformative impact of AI and machine learning (ML) technologies in the conception, development, and implementation of smart cities. As the world continues to urbanize at an unprecedented rate, with the urban population poised to rise to 68% by 2050 [20], the review seeks to understand how these technologies can address

the growing challenges that come with urban density and complexity.

This review encompasses the following aspects. (1) Assess the current state of AI and ML integration in urban areas, identifying key areas of success and potential pitfalls or challenges that have emerged over the past decade. (2) Examine case studies and practical implementations of smart city technologies across different geographies, drawing insights from their impact on traffic management, public safety, environmental sustainability, and urban planning. (3) Evaluate the effectiveness of AI and ML in enhancing the quality of urban life, particularly in how these technologies have been used to tackle issues such as housing shortages, traffic congestion, and environmental concerns. (4) Predict future trends and developments in the field, considering advancements in AI and ML and how they could shape the next generation of smart city initiatives. (5) Identify gaps and opportunities for further research and innovation in the smart city domain, with an emphasis on ethical considerations, data privacy, and equitable access to technology. (6) Provide recommendations for policymakers, urban planners, and technology developers on how to strategically implement AI and ML in urban environments to achieve the goal of "Better City, Better Life".

In essence, the review aims to critically examine the role of cutting-edge technologies in sculpting the cities of the future, ensuring that as urban areas continue to grow, they do so in a way that is intelligent, sustainable, and focused on improving the lives of their inhabitants.

Analysis of AI-related concepts

AI technology was proposed and developed as early as the middle of the 20th century. The emergence of AI technology brought more help and value to the development of human society. The AI system can concentrate on software and store a large number of experts and experiences in a certain field through programming stored inside the computer. Provide people's required suggestions and views.

The background of AI technology

Human work intelligence

AI technology was born in the mid-20th century [21], and its emergence is of profound significance for human society and economic development. The application fields of AI technology are widely used, including many disciplines, such as computer science, information science, mathematics science, engineering technology, and even philosophical psychology. It is an advanced technology type with the ability to learn, communicate, input, and output. Under the guidance of AI technology, all machinery and equipment have become more "smart". The e-commerce system, information community, data, and knowledge society built have achieved effective interconnection and integration of the network and physical space to guide human society to enter the entry of entering the entry of human society. At present, the existing AI technology focuses more on the close connection between its production and the life of human society. It truly improves the various technical application functions in production and life at a level, and subverts the process of social development. Data calculations have gradually formed a simulation change in human intelligence. Specifically, it includes the following 3 changes: First, emphasize the integration and construction of machinery equipment and human-enhanced hybrid intelligence systems. Second, emphasize the construction of new population intelligent systems of machinery, humans, and network organizations. Third, emphasize the construction of more complex intelligent systems, such as intelligent cities that integrate humans, society, physics, and network systems. In urban construction, AI will also be applied to image recognition technology to achieve a wider range of applications of AI technology [22].

Machine learning

ML mainly refers to the scientific improvement of mechanical learning capabilities through system or knowledge recognition, and then gaining new skills and new knowledge. The learning methods provided by ML are similar to humans. If you do not learn systematically or fail to master the appropriate learning method, it may be difficult to master a new problem analysis and solution. Therefore, ML must be continuously innovated and developed. After the current rapid development of AI development, the knowledge system it has established has a specific practical direction, which can solve certain practical problems. It is the most indispensable and important technology in the field of AI. From a professional perspective, ML has highly developed perception and parallel information processing ability [23]. Some traditional and advanced ML algorithms are summarized as follows (Fig. 1).

Development process of AI

AI technology was produced in the 1950s. At that time, the science and technology of the world had entered a new stage of development, the amount of information increased sharply, and the transmission of information was increasingly accelerated. The natural intelligence of human beings could not quickly process such a huge amount of information, and people began to explore the intelligence of people to use people through computers to execute the intelligence that needs to use people. The task that can be completed. In the 1960s, human work intelligence technology was mainly used for research on

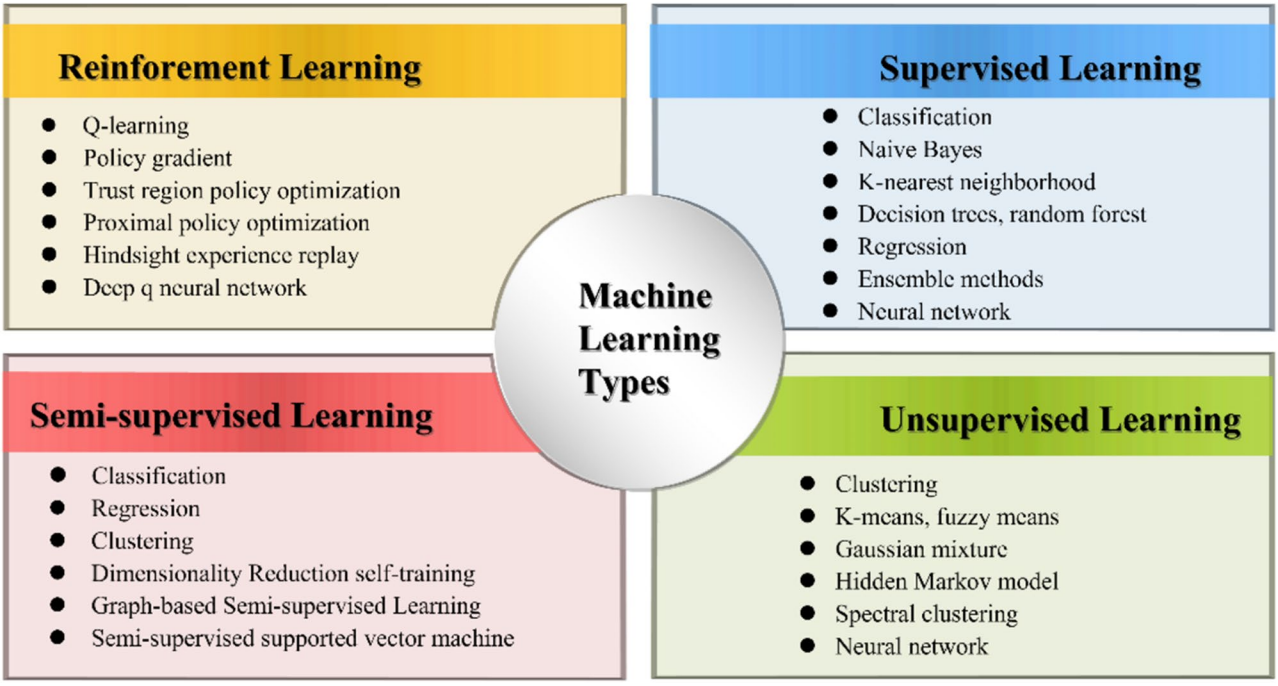

Fig. 1 Traditional ML algorithms

chess, theorem certification, and simple AI expert systems [24]. In the 1970s, with the rapid development of miniature electrical computer technology and integrated circuit technology, the research of the human intelligent expert system entered the application development stage, and some junior commercialized expert systems appeared in the market. The expert system obtains more advanced and accurate knowledge from the minds of human experts and is written as software storage into a computer [25]. As a special software system, the expert system can provide people with knowledge, suggestions, reasoning, judgment, or decision-making opinions to people with a complete comprehensive system with the calculation machine group. It can be used as a complete and independent intelligent tool, and develops from systematic intelligent technology related to systems; it can also be directly used as components and development tools for the new generation of smart machines. Since the 1980s, AI technology has developed rapidly and has been applied to genetic engineering, chemical synthesis, business management, petroleum exploration, legal cases, and expert systems in the military field [26–29]. Japan, the United States, the former Soviet Union, and some countries in Western Europe have strongly funded and led the research and development of AI technology in the way of government support. China started the development of AI technology in the 1960s. At present, China and the United States are comparable in the development and research of AI technology, and they have paid off. The development trend of AI is shown in the figure below (Fig. 2).

Classification and application of AI technology

The core technologies of AI mainly include deep learning, computer vision, natural language processing, and data mining. The subdivided fields of application include intelligent robots, virtual personal assistants, real-time voice translation, visual automatic recognition, recommendation engines, etc. When it comes to deep learning (DL), the first thing you think of is Google's AlphaGo [30]. Through repeated learning and iterative algorithms, you can finally defeat computers in the man-machine war. The relationship between them is shown in the following figure (Fig. 3).

ML is an important method to realize AI. Unlike traditional programming languages, we use a large amount of data to send to the machine for learning. This process is called "training". As long as there are sufficient data and fast computing power, the results will be more accurate. At present, the intelligent operation path based on big data and cloud computing can be better explained under the framework of deep neural networks [31].

The technical principle includes the following aspects. (1) Construct a network and initialize the weights of all connections randomly. (2) Output a large amount of data to this network. (3) The network processes these actions and learns. (4) If the action conforms to the specified action, the weight will be increased; if the action does not conform, the weight will be reduced. (5) The system

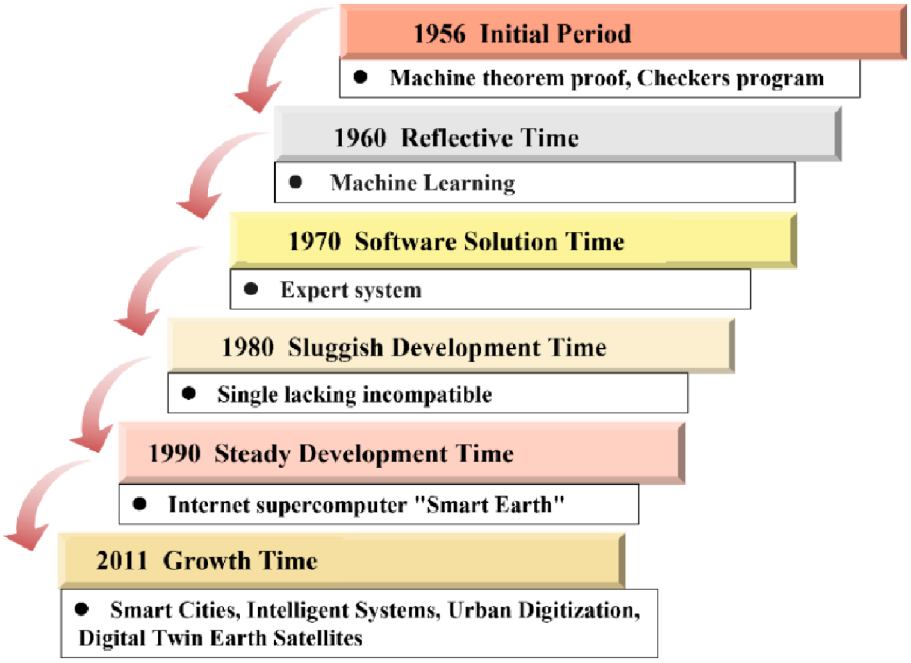

Fig. 2 The development trend of AI

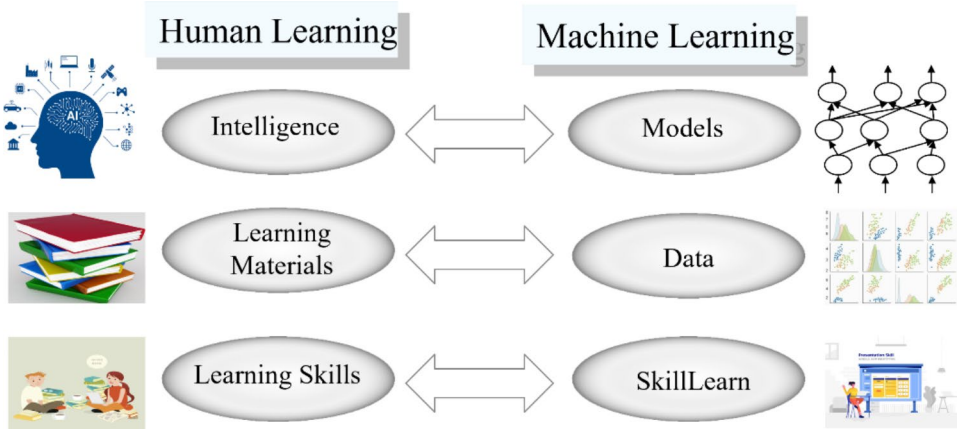

Fig. 3 The relationship between machine learning and human learning

adjusts the weight through the above process. (6) Exceed human performance after thousands of times of learning. Application field: Face recognition can be said to be the most mature application of deep learning [32]. Data Mining (DM) is not a new product. It was proposed many years ago. With the attention paid to the field of AI in recent years, data mining has also been mentioned. Data mining refers to the process of searching hidden information from a large number of data through algorithms, as shown in the figure below (Fig. 4).

Connotation of smart city

Smart cities are smart city models created by technologies such as cloud computing, Internet of Things, and AI. Use advanced information methods to analyze many fields such as urban planning, urban transportation, social security, and people's living policies, and make rapid and timely responses to these fields to achieve intelligent and intelligent urban management [33]. At present, the development of many cities in China is facing problems such as air pollution, garbage pollution, water pollution, traffic congestion, and resource exhaustion [34, 35]. It has adversely affected citizens' health and livelihood, hindering the sustainable development of the city [36]. To solve these problems and create a green and harmonious living environment, it is urgent to promote the changes in citizens' lifestyles by building smart cities. Therefore, the construction of smart cities has very important practical significance. The three elements of a smart city are shown in the figure below (Fig. 5).

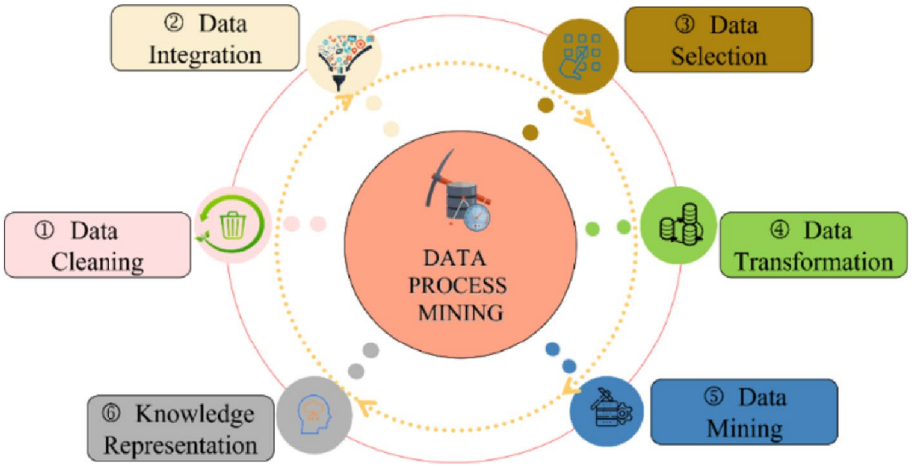

Fig. 4 Data mining

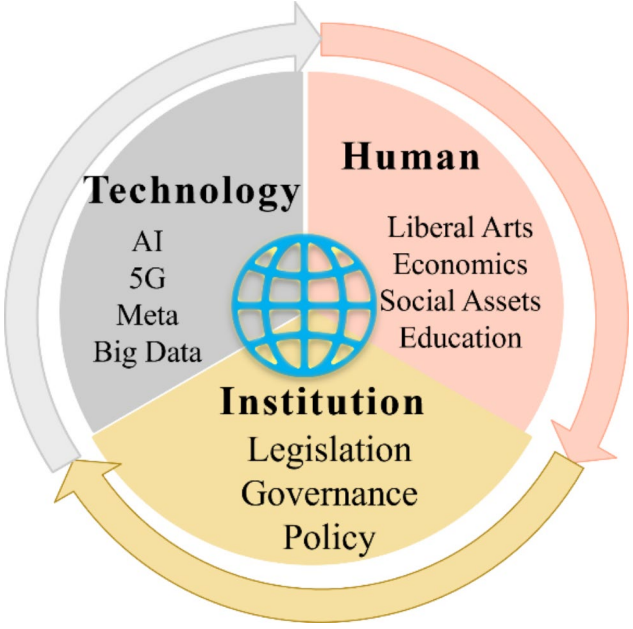

Fig. 5 The three elements of a smart city

To better promote the rapid development of AI, more and more cities have put forward the views of smart cities in recent years. With the emergence of various high-tech means, smart cities have also appeared on the stage. Smart cities are important stages of modern cities, and they integrate urban development concepts such as intelligent, harmonious, energy-saving green. The development of smart cities can be divided into two periods [37]. First of all, the digital stage has established urban databases to achieve urban informatization and digitalization [38]. Then, in the stage of intelligence, persist in human-oriented thinking, and use AI technology to create urban smart ecosystems and smart brains [36]. The construction of smart cities in our country is still in the initial stage. Smart cities are a new type of urban construction type. Government departments should think about how to improve the level of urban governance and management so that cities serve the people [39].

The fusion and understanding of some concepts of smart city are shown in the figure below (Fig. 6).

Meaning of smart city

Today, building smart cities has become a hot topic in China. The new theme of the city's "Thirteenth Five-Year Plan" plan is a smart city. For the first time, the 18th National Congress of the Communist Party of China proposed to promote urbanization with informatization. It can be seen that smart cities are an indispensable part of urban development [40]. It is of great significance in solving the "big city disease", improving the efficiency of urban management, and improving the quality of the city's citizenship [41].

In the 1990s, the relevant concepts of smart cities gradually formed abroad. Some scholars believed that the information and communication technology that was now emerging should be introduced into urban construction and urban management as a kind of urban function [42, 43]. Then, the European Union proposed building smart cities in terms of economic development, public life, social management, transportation, and environmental environment [44]. The extensive research of domestic smart cities was that in 2008, the concept of a "Smart Planet", started. The definition of smart cities has not yet formed a unified concept at home and abroad, and the understanding of the term "wisdom" in the context of Chinese and Western contexts is also different [45]. From the perspective of urban management, smart cities, as a solution to the "big city disease", were proposed. Researchers believed that smart cities were a creative city management complexity solution [46]. From the perspective of urban and city strategy, Smart City is considered to be a comprehensive development strategy

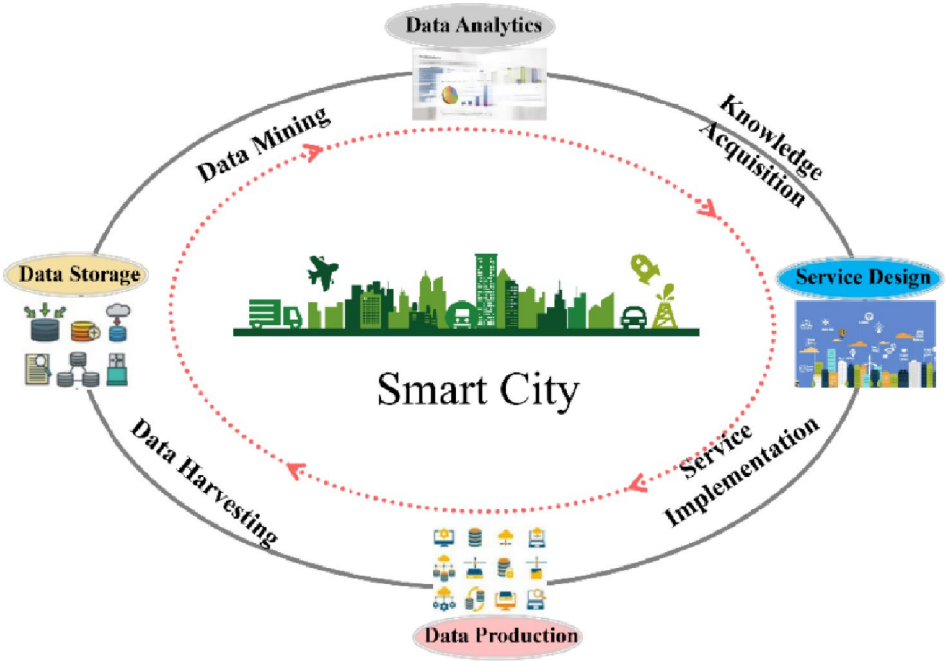

Fig. 6 Proposed research methodology

of cities with comprehensive city management, industry development, public services, and administrative efficiency [47]. As the urban form of innovation in the 2.0 era, smart cities can realize the urban function, population supply, land supply, infrastructure, public facilities, and industrial layout [48]. The balance of the five aspects realizes the sustainability of the city.

Information resources of smart cities

In the context of the favorable economic conditions in our country, the process of urbanization has accelerated, and the rural population has gradually moved towards cities. The capacity of the city is not enough to support the large population of the population, and it is difficult to meet the public's urgent demand for urban resources [49]. Therefore, to alleviate the "urban diseases" in the process of urban development, help cities transform into a new type of sustainable development of cities, and the construction of smart cities with new technologies and new ideas slowly begins, gradually becoming a new era trend. In developed cities such as London, Seoul, Tokyo, etc., the world's first technologies and new concepts are used in the construction of the city, sounding the horn of the construction of smart cities [50]. At the same time, some cities in China are also trying to find a starting point that conforms to the construction of smart cities. Combining the national conditions of the country and the development process and informatization of the city itself, the use of new technologies and new concepts to accelerate the informatization process of the city and improve the city [51]. The overall competitiveness breaks the inherent thinking, transforms thoughts, and establishes a highly -efficient, low-carbon, sustainable highly competitive city [52].

Since 2012, the concept of smart cities has swept through the entire China. Relevant policy documents on the construction of smart cities have sprung up. Among them, there are many national documents. Related content includes the evaluation system of smart cities, and related plans for smart cities, etc. In recent years, the "Guide to the Top Flash of the City" and "Smart City SOA Standard Application Guide" were promulgated. Under the leadership of national policies, cities at all levels have actively responded to propose the development plan for smart cities. The number of cities is as high as 500, which is one of the few. Adhering to people-oriented principles, smart cities respond to the needs of residents with a new generation of information technology and vigorously build important components such as smart transportation and smart medical care to improve the comprehensive strength of the entire city and the happiness index of the people. After a step-by-step development of smart cities in recent years, it has also been gradually transformed from the initial stage of the river crossing the river to the rational exploration stage.

However, in the in-depth construction of smart cities and the huge changes in the information environment, the city has gradually formed an irreversible dependence on the carrier carrying a large amount of data and information [53]. Safety issues and security risks have emerged, and information security issues have gradually risen from a very small influence to the perspective of

national security strategy [54, 55]. Information security issues have penetrated everyone's daily life. Today, smart cities are rich in content and many types, such as snow-capped projects, smart medical insurance, and smart communities. These require a new generation of technology as a support and depend on the actual transport of the entire city. However, while improving the quality of the city, these new technologies also expose a lot of predictability and more unpredictable security risks. The network security should be protected. It can also improve the security of smart cities' information security. Information security of smart cities is an indispensable and important task in the current construction of smart city. There is a large amount of information in the network. To be maintained by network security, it is urgent to solve information security problems. However, looking at the development of the entire information security, ensuring the information security level of smart cities is mainly due to management. The phrase "three-point technology and seven points management" in the security industry is passed down from the population, which is enough to explain the importance of management. Many security events can be avoided through management methods in many smart cities. With the deepening of new technologies, the information environment of smart cities is becoming increasingly complicated, and information security risk management of smart cities will be a problem that its interests need to be solved urgently. Once the information security risk management is not in place, it may lead to the leakage of personal privacy, and a management situation that is difficult to control in cities occurs. Based on this, how to strengthen the management of information security risks in smart cities, establish a scientific and standardized performance evaluation index system, build a model of performance security risk management performance evaluation models, comprehensively and reasonably evaluate the status of information security risk management of smart cities, find information security. The problems in risk management have been proposed, which has become an imminent task and problem at this stage.

Application of AI in smart city

The development of AI has gradually become complete and mature and has been widely used in many fields. At the same time, these fields have also put forward new requirements for AI techniques. The Internet of Things is an outstanding product of the development of the Internet, e-commerce, and other fields, and also proves that people's living standards are gradually developing in the direction of modernization, intelligence and humanization. Under such circumstances, scientists use technologies such as AI, cloud computing, and big data to accelerate the development of the Internet of Things industry. It has become a must for people to further improve the value of AI technology. Given the development direction of predecessors, pre-planning AI will play a greater role in the Internet of Things, e-commerce, and other networks while promoting smart cities. In the process of applying AI construction of smart cities, human work intelligence can also be used in different aspects such as education, travel, and cultural construction. Culture is the inherent motivation for the development of smart cities. Only by promoting the ideal moral quality and cultural level of the people to meet the standards of smart cities, can we truly build smart cities. Nowadays, people's pursuit of material pursuits is gradually moving towards spiritual culture, which is also one of the development directions of human work intelligence. The construction of a smart city needs to rely on the joint efforts of each city resident.

In the construction stage of smart cities, image recognition technology under human work intelligence skills has been widely used in multiple fields. With this technology help, the image recognition technology system established has a variety of functions, such as fingerprint recognition, gait recognition, face recognition, etc. These technologies promote the development of our country's information technology. Therefore, the specific application of AI and ML technology in smart cities is mainly reflected in the following aspects.

Gait recognition

Gait recognition is mainly to complete its authentication and recognition through the man's walking method and expression form. Related research surveys show that human gait mainly contains 24 types of different types of types [56]. If these ingredients are fully considered, gait can become the unique form of human individuals. Compared with traditional recognition methods such as iris recognition and fingerprint recognition, gait recognition has the advantages of natural, authenticity, and difficulty disguising [57, 58]. Based on these advantages, gait recognition has a deeper accomplishment in the construction of smart cities and other fields [59]. Step recognition is mainly used in the field of security. First of all, gait recognition technology is used in the video surveillance system, which can not only give full play to huge value in terms of fire security, handling cases, and counter-terrorism, but also in a short period to survey criminal suspects from top to bottom in a short time. Secondly, gait recognition can also play its efficacy in terms of property security, the custody of valuables, and the significance of major items. After incorporating gait recognition technology, the sensors in the items will conduct in-depth analysis based on the gait of the people to determine whether the person has the motivation to theft, destroy, or other bad, and send a strong alarm ring according to

the actual situation. Finally, gait recognition can also be applied to the medical field. Because healthy people are different in terms of walking methods and forms of people who have health problems. Through the application of gait recognition, they can judge whether the human body has problems in a short time. If the body is hugging, you can quickly find out which organ indicators in the body are problems.

Face recognition

Face recognition technology is the most representative identity technique in AI and ML, and has widely used applications in many fields [60]. Firstly, the application of face recognition in the field of security [61]. At this stage, high-definition monitoring equipment in social development has been fully popularized and applied, providing a guarantee for the implementation of face recognition techniques. After the case, the suspect's facial features can be extracted in the video and provided conditions for the analysis of the case for the surrounding activities. After the case occurred, you can monitor the videos of the suspect's posture and facial features, capture the activities of its small-range activities, and help with the case analysis. Secondly, the application of face recognition in the financial field [62]. With the continuous development of society and the economy, there are more and more ways to pay for products to buy products. Advanced payment squares such as QR codes will cause some uneasiness, which cannot meet people's many aspects of needs. In contrast, it can be seen that the types of funds paying for face payment have a more unique and security advantage, and they are gradually recognized by society.

Finally, the application of face recognition in access control [63]. The access control system is the need to ensure the safety of people's living environment. Because of the uniqueness of the face and the difficulty of replication to provide effective basic guarantees for their identification, through scanning recognition of the face, it can be used as a special "key" that opens the door. The community can record the appearance of the residents in the unit building through the access control system, which not only effectively guarantees the safety of the residents, and prevents them from entering and leaving the community at will, but also reduces the trouble caused by the loss of the key. At this stage, face recognition is mainly composed of 3 application modes, namely: 1: 1 face recognition, 1: N face recognition, and M: N dynamic control. The former identification mainly compares the characteristics of the face of the current person with the portrait characteristics in the database and obtains the matching process in a short time, which is mainly reflected in the face-to-face ticket check, boarding, and payment. The middle model refers to querying the face data of the current user in a large number of portrait databases. In simple terms, one goal is selected in the n people. The later model is a face comparison of individual embodiments that exist in the specified range. It is mainly used in multiple fields such as VIP customer management systems and campus face recognition systems.

Application of face recognition fusion technology

The application of gait recognition and face recognition fusion technology is applied to the application range of AI and ML techniques [64]. The combination of step-state recognition technology and face recognition technology is highly recognized by smart cities. For example, the application database network (DBN) depth trust network, builds multiple stacking effect systems with certain restrictions. Under normal circumstances, the two forms of network space layers constructed after the effective integration of these two identification technologies mainly cover the two forms of hidden layers and significant layers. Through the assumptions of these two levels, the specific requirements and standards of the Boltzmann model construction are controlled. Its application value cannot be underestimated. From the perspective of the overall eyes, the effective combination of gait recognition and face recognition and face recognition uses network construction methods such as convolutional neural networks and full connection layers, focusing on the decrease in the distance within the design range, effectively controlling the combination of network training for network training Supervision, according to the distance and goals within the range, and adopt relevant technical fusion application methods.

Intelligent medical treatment

Introduction to the introduction of AI technology in intelligent medical care can not only effectively strengthen the level of medical rescue, but also fundamentally provide personal and property security guarantees for the people [65]. Under normal circumstances, related units of medical care can build intelligent and advanced medical systems, collect sets and check more information resources related to patients in this platform, and provide information basis for subsequent treatment of treatment workers. At the same time, the hospital can use the intelligent medical system to adopt remote diagnosis, healing, and physical examination for patients who have the conditioning to provide effective medical services for patients who are in different regions, reducing physical contact between medical personnel and patients with infectious diseases, controlling control, controlling control Virus spread and spread. At this stage, AI is the most widely used in medical institutions to set up intelligent alarm settings. Putting warning bells next to the bed, medical rooms on different floors are used as the

Table 1 Intelligent medical treatment

Representative AI technology	Application of Medical treatment in Smart Cities	Challenges
Image analysis and processing	Diagnosis and treatment Prediction of CT images	Algorithmic overfitting. The inequality is obvious. Interpretable weakness. Privacy protection. Lack of reliable verification. …
Neural Network & brain-computer Interface	Improving eyesight, Restoring limb function, Treating Alzheimer's disease	
Reinforcement learning	Medical robot	
Natural language processing	Medical literature and case analysis and knowledge reasoning	

main control venues. If a patient has an emergency or other problems, he can inform the medical staff the first time. This information can be summarized in Table 1.

Smart transportation

During the development of smart transportation in the construction of urban modernization, the number of cars gradually increased, and the problem of urban traffic jams became more and more serious. The use of image recognition technology to deeply analyze the traffic conditions of the road can provide dynamic road traffic and information related to the traffic management department, and make reasonable adjustments to the signal instructions on the road to achieve effective traffic guidance. With the integration of AI technology into intelligent maps, we can scientifically and reasonably be planning on the specific routes of travel, complete the intelligent and modern regulation of the actual traffic conditions, and effectively control the traffic phenomenon on the traffic road [66, 67].

Development prospect of AI in digital twin smart cities

The development prospects of AI in digital twin smart cities are vast and varied, with the potential to fundamentally transform how urban environments are managed, planned, and experienced. Digital twins are virtual replicas of physical entities, including buildings, infrastructure, and even entire cities. When integrated with AI, these digital twins can become dynamic, intelligent systems that simulate real-time urban activities and predict future outcomes. Here's how AI can be expected to contribute to the development of digital twin smart cities (Fig. 7):

Fig. 7 AI contributes to the development of digital twin-smart cities

- Urban Planning and Management: AI can analyze data from a digital twin to optimize city layouts for traffic flow, energy consumption, and environmental impact. Planners can use these insights to make evidence-based decisions that enhance sustainability and livability.
- Predictive Maintenance and Infrastructure Management: AI can predict when urban infrastructure might fail or require maintenance by analyzing data trends. This can minimize downtime, save money, and extend the lifespan of assets.
- Energy Optimization: AI can optimize energy distribution and consumption patterns within a smart city by analyzing data from various sources, including energy grids and buildings. It can dynamically adjust energy supply to match demand, promoting efficiency and reducing waste.
- Disaster Simulation and Response: Digital twins can simulate disasters such as floods or earthquakes, allowing AI to help in planning response strategies and emergency services deployment, potentially saving lives and resources.
- Traffic and Transportation Systems: AI can manage and simulate traffic flow to optimize transportation systems, reduce congestion, and improve air quality. Autonomous vehicles integrated into the digital twin can also be optimized for route planning and traffic management.
- Public Safety and Security: AI can enhance public safety by monitoring urban environments for unusual activities or hazards and can be instrumental in coordinating responses to emergencies or threats.
- Environmental Monitoring and Sustainability: AI can track environmental conditions such as air quality and noise levels, helping to enforce regulations and promote public health. It can also assist in the management of resources, like water and green spaces, ensuring sustainable city growth.
- Economic Modeling: By simulating different economic scenarios, AI can help policymakers understand the potential impacts of their decisions on urban economics, enabling better strategies for economic development.
- Healthcare Services: AI can manage and predict healthcare needs within a city by analyzing data from healthcare providers and population health trends. This can lead to better healthcare planning and emergency preparedness.
- Citizen Engagement and Services: Digital twins can provide a platform for citizen engagement, allowing residents to interact with the city's AI to report issues, get information, and use municipal services more efficiently.
- Real Estate and Development: By simulating changes in the urban landscape, AI can help investors and developers understand the potential impact of their projects on the local environment and economy.
- Integration with IoT and Smart Devices: AI can process the vast amounts of data generated by IoT devices spread throughout smart cities, turning this data into actionable insights and operational intelligence.
- Governance and Regulation: Digital twin technology, augmented with AI, can help in policy-making by simulating the impacts of regulations before they are enacted, thus allowing for better governance.
- Education and Training: Virtual environments created by digital twins can be used for the education and training of city planners, engineers, emergency responders, and citizens, providing immersive learning experiences.

While the development prospects are promising, there are also challenges to consider, such as data privacy concerns, the need for significant investment, interoperability between different systems and technologies, and the potential for job displacement. Addressing these challenges requires careful planning, robust policy frameworks, and ongoing dialogue between technology providers, city planners, and the public.

Conclusion

In summary, the inexorable march toward smart cities stands as a testament to the evolutionary trajectory of human society. This progression is deeply intertwined with the prudent incorporation of AI and ML technologies, which have become the bedrock of advanced technical solutions such as facial and gait recognition. These technologies are not simply auxiliary enhancements but fundamental components driving the emergence of new technological and economic growth points within the urban tapestry. Such advancements are pivotal in fostering the dual progression of material and spiritual civilization—improving the tangible infrastructure of daily life while also enriching the intangible qualities of community and cultural cohesion. The impact of AI and ML transcends mere technical prowess; it has become an economic engine that catalyzes innovation and prosperity within urban environments. The sophisticated analysis and predictive capabilities of these technologies empower smarter, more sustainable urban planning and development. This, in turn, bolsters economic vitality, creates employment opportunities, and enhances the overall quality of life. Moreover, the synergy between AI/ML and urban development is nurturing a habitat that is not only more efficient and safer but also more responsive to the needs and aspirations of its inhabitants.

Looking to the horizon, it is evident that AI and ML will continue to evolve and expand their influence on the fabric of urban living. The future of smart cities will be characterized by the synthesis of multiple technologies, coalescing to address the intricate mosaic of human needs in production, living, and environmental stewardship. This convergence will necessitate a nuanced optimization of technologies, ensuring that the digitization of urban spaces remains aligned with sustainable practices and equitable access. Yet, as we embrace the dawn of this technologically rich era, we must also be vigilant stewards of the ethical dimensions these innovations entail. It is imperative that the integration of AI and ML into the heartbeat of smart cities is guided by principles that uphold privacy, security, and inclusivity. Ensuring that the benefits of smart city developments are equitably shared will be essential in avoiding societal fractures and fostering an environment where technology serves as a bridge to a more enlightened, harmonious urban life.

In conclusion, the narrative of smart cities is being written in the language of AI and ML, with each technological advancement scripting a new chapter in the story of human civilization. As these intelligent systems become increasingly woven into the urban fabric, they promise to enhance the very contours of human existence, reshaping our physical spaces and cultural landscapes to create cities that are not only smart but also wise, compassionate, and inclusive. This is the bright promise of a future where technology and humanity converge in the pursuit of a better, more connected world.

Author contributions

Z.Y. and L.J.: Designed the structure, and English writing of the whole paper; L.Z. and X.H.: Literature searching about"Applications of Artificial Intelligence in Smart Cities" and organized the literature review; X.Z. and X.H.: Future Trends and Potential Developments; L.J. and Z.Y.: Proofread the entire manuscript for coherence and grammar.

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Data availability

No data were used to support this study.

Declarations

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

The authors read and approved the final manuscript.

Competing interests

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