Research on the Empowerment of Smart Community Development through Artificial Intelligence

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Abstract. The artificial intelligence (AI) community is the product of the iterative upgrading of intelligent communities with the emergence of AI technology. Within the specific scope of applications, AI technology mainly emphasizes three major scenarios—public safety, public management, and public services—to realize the smart governance of communities. Currently, AI is still in the weak AI stage, and there are still issues such as perception data, data islands, data dormancy, data decision-making, and data security in smart community management. To address these five issues, targeted technical research can be conducted, and suggestions from five aspects—precise perception, data fusion, data application, intelligent decision-making, and privacy protection—can be proposed to better support the development of smart communities.

Keywords: artificial intelligence technology; smart community; community management

1 Introduction

In the process of building a "smart community," the "smart city" concept for communities is being introduced, through the integration of new technologies such as the Internet of Things, big data, and artificial intelligence (AI), the transformation and development of communities toward intelligence are being promoted.[1]

AI research is a technological science that studies the theory, methods, techniques, and application systems used to simulate and extend human intelligence.[2]Its key technologies include machine learning, pattern recognition, computer vision, fuzzy mathematics, neural networks, natural language processing, and expert systems, among others. In the construction of smart communities, AI leverages important data resources in community governance, it integrates machine learning, algorithmic reasoning, and other AI technologies, and it relies on various smart terminals and management platforms to provide effective scientific decision-making support for smart community construction. However, there are still shortcomings in the management of smart communities using AI. Only by addressing these issues can the further development of smart communities be promoted.

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This article proceeds as follows: The first section briefly introduces the smart community and AI concepts and argues for their importance. The second section describes the specific applications of AI in smart communities. The third part focuses on the issues of using AI for smart community management, while the fourth section proposes feasible solutions to these issues. Finally, the fifth section summarizes the article and provides suggestions for future research.

2 The Specific Application of Artificial Intelligence Technology in a Community

The content of an AI community involves various aspects of community governance, holding great practical significance for advancing the modernization of community governance and improving the public service system. Currently, the application of AI in communities mainly revolves around three core needs—public safety, public management, and public services—focusing on data monitoring, scientific decision-making, and risk prevention and control leveraging AI technology. As shown in Figure 1, in this application system, multiple typical application modules have been developed. With the continuous development and evolution of smart communities, more application scenarios will be integrated into the overall architecture of AI communities. They will form a scalable, iterative, replicable, and promotable pattern and system, further enhancing the intelligence and refinement level of community governance.

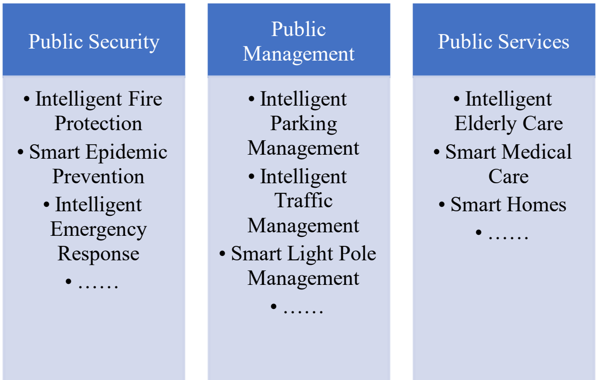

Fig. 1. Infrastructure of an AI Community

2.1 AI-enabled Public Safety

Public security refers to the application of AI technology in a community. This domain is a relatively mature field that involves different professions, such as networks, software, and security, forming the main application scenarios, such as smart security, smart epidemic prevention, and smart emergency response. The public safety-related applications of smart communities include multidimensional collection, perception and linkage through data background technologies such as face big data, human body big data, and Internet of Things big data to achieve comprehensive capabilities such as noninductive collection, noninductive early warning, and multilevel deployment control, greatly improving the level of community security.

2.2 AI-empowered Public Management

The application of AI technology in community public management mainly focuses on areas such as high-altitude object throwing control, electric vehicle management, smart parking, and public transportation optimization. This domain includes utilizing data correlation technology and intelligent information processing to analyze and sort through the vast amount of data collected in communities, addressing some of the "tough" issues in community management. Leveraging smart platforms, predictive analysis and mine basic correlated data such as facial recognition, abnormal passages, and the loitering of strangers can be used to anticipate potential issues such as illegal subletting and pyramid schemes in a community. Through video surveillance and image recognition technology, evidence can be gathered to address persistent issues such as high-altitude object throwing, vehicle scratches, and improper waste disposal in a community. Additionally, AI can provide management and services for community water quality and vehicle management, effectively managing parking and charging for motor and nonmotor vehicles, thus enhancing the precision of management.

2.3 AI-driven Public Services

The application of AI technology in community public services is mainly reflected in smart pensions, smart medical treatment, smart homes and so on. Through the implementation of advanced concepts such as intelligent interconnection, intelligent efficiency, co-governance and sharing, green and low carbon, and open and inclusive, as well as the integrated and iterative application of a new generation of information technology, the construction of a smart community provides matching comprehensive supporting and smart service support around the service needs of the whole life chain of community residents, which can greatly improve the service quality of a property. Community intelligence platforms realize intelligent monitoring, intelligent internal response and intelligent control of community events by completing the linkage between various property systems. AI is applied not only to basic services such as reporting and repair, remote meter reading, and community environmental monitoring but also to street sanitation and elderly care services to realize garbage classification, remote monitoring of elderly people in their homes, and atmospheric dust and noise pollution monitoring to provide community residents with a sense of belonging, a sense of gain, a sense of happiness and a sense of security in the community environment.

3 The Shortcomings of Artificial Intelligence Community Construction

From an objective perspective, the high degree of differences between communities leads to the lack of universality of governance theory, and in practice, it is difficult to effectively promote reform and innovation due to the constraints of community social structures and resource access.[3] The rise of AI technology and its applications has been relatively short lived, and there are certain limitations in such technology, as well as unclear paths for its application. As a result, research and practice in the governance models of smart communities have the following shortcomings:

3.1 Perception Data Problem: Perception Data and Transmission Functions Need to be Improved

In the early construction of smart communities, with major breakthroughs in machine vision and other technologies, the enabling application of AI technology at the perceptual level is relatively mature, but there are still many problems.[4] The most common is perceptual information fusion technology, which requires data from multiple sensors. However, due to the integration of data from multiple sensors, it requires a large amount of data and is time-consuming. As shown in Table 1, The three most common information fusion models have their own advantages and disadvantages.[5]

Table 1. Three most common information fusion models

Fusion Model	Signal Level Fusion	Feature Level Fusion	Decision Level Fusion
Ability to communicate data	Poor	Average	Good
Ability to process complex information	Poor	Average	Good
Ability to retain data	Average	Average	Poor

The deployment of sensors in a community is unreasonable, resulting in numerous blind spots in perception. There is a lack of connection and interaction between perception terminals from different systems, making it difficult to form "large-scale collaboration." The perception at the front end lacks data analysis and recognition capabilities. The transmission of a large amount of perception data easily leads to network congestion, requiring enhanced precise perception and automatic recognition capabilities.

3.2 Data Island Problem: Data Barriers Need to be Cracked

Currently, the data in smart communities have been initially accumulated, but their usability is relatively low. It appears with serious information silos, although data has been simply integrated, there still exists the problem of single source of data, fixed monitoring position and details can be hardly found.[6] In practical applications, data collected by different departments and organizations exist in isolation, and integration and standardized processing are lacking, which results in the inability to fully utilize information within and outside a community.[7] On the one hand, massive data occupy a large amount of storage resources, with data duplication and poor consistency between departmental data, leading to problems such as the redundant construction of information systems and data centers. On the other hand, valuable data are difficult to effectively obtain, as departments do not share or open them, hindering business collaboration.[8]

3.3 Data Dormancy Problem: The Value of Big Data Needs to be Tapped

At present, large-scale high-performance data mining is still in the stage of research and exploration.[9] In the construction of smart communities, data analysis and application capabilities are still in the research and exploration stage, smart communities lack the ability to analyze and apply these data effectively, leading to data dormancy. For example, machine learning technologies such as deep learning require vast amounts of data and have high data quality requirements. If the results of training are not applicable in similar scenarios, local adjustments are needed to fine-tune the computation results. However, the inadequate data analysis and application capabilities of machine learning technologies may result in the need for manual intervention or data being left dormant in databases. Therefore, the further development of machine learning technologies will directly impact the results of value extraction from big data.

3.4 Data Decision-making Problem: The Level of AI Technology for Assisting in Decision-making Needs to be Improved

The level of artificial intelligence assisted decision-making has achieved very good results in image recognition and some gaming fields, but in community management, the level of assisted decision-making still needs further improvement. These recent shortcomings and concerns have been documented in both the scientific and general press, such as biases in healthcare or hiring and face recognition systems for people of color, and seemingly correct decisions later found to be made for wrong reasons.[10] Therefore, it is necessary to further explore the application of AI in event prediction and decision-making tasks, taking into account various aspects such as technology, morality and ethics, and the delineation of responsibility, to enhance the capability of AI in regard to decision empowerment.

3.5 Digital Security Issues: Data Risks Need to be Vigilant

Digital technology has brought enormous dividends, but it has also caused a series of risk problems, such as data abuse, privacy exposure, and security crises, and increased the technical complexity of smart community construction. [11] As shown in Figure 2.

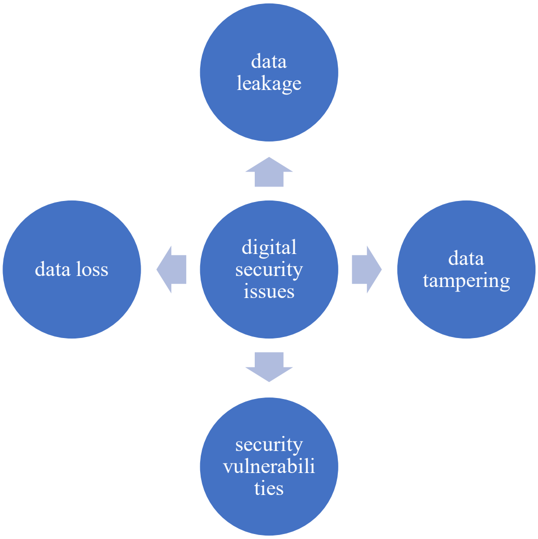

Fig. 2. Classification of data security issues

As digital technology becomes widely integrated into human life, individuals' preferences, life trajectories, and other personal information are increasingly exposed to the scrutiny of big data. The security of personal information for citizens faces daunting challenges. Moreover, with the significantly reduced cost of data breaches, malicious actors can systematically exploit vast amounts of data once they infiltrate a data hub using hacker techniques. In particular, with the massive amount of data collected by smart communities, the risks to data security are even greater.

4 Suggestions for Artificial Intelligence Community Construction

In response to the five problems above, technical research can be conducted in a targeted manner to meet the needs of communities in terms of accurate perception, data fusion, data application, intelligent decision-making, and privacy protection.

4.1 Accurate Perception: Establish a "Perception-service-technology-Application" Technical Framework

In general, the technical architecture of a smart community can be divided into four hierarchical layers: the perception layer, the basic service layer, the key support layer, and the smart application layer.

The perception layer serves as the foundation of a smart community, encompassing perception control components, perception control gateways, and sensor networks. Through this layer, information about the environment and perceived objects is collected and transformed into standardized data formats, which are then transmitted to the network layer. Following predefined rules, the intelligent control of objects is achieved through perception control components.

The basic service layer focuses on data transmission. By exploring service-oriented integration methods for data and applications, services are provided externally through unified service interfaces, adhering to a common data standard without altering the underlying business systems. This layer maximizes the integration of services from different vendors, bridging various application data silos.

The key support layer primarily involves the development of lightweight algorithms, libraries, intelligent analysis models, and software technologies suitable for front-end computing nodes with minimal computational and storage resources. This layer also aims to enhance the performance of key devices such as front-end chips and sensors and mature front-end intelligent algorithms. Additionally, research is being conducted on the application of 5G technology in community intelligent governance. Such research includes developing systems for high-throughput data transmission, rapid data mining and analysis, synchronous warning technology, and the optimization of integrated management platforms compatible with 5G.

The smart application layer mainly supports applications such as smart governance, smart property management, smart security, smart community healthcare, and smart elderly care. It is closely integrated with big data analysis and service layers. This layer establishes unified government services, property management, smart homes, healthcare, and security websites and apps, incorporating unified identity authentication and security mechanisms. The aim is to maximize the user experience and minimize usage costs.

4.2 Data Fusion: Establish an "Aggregation-connectivity-utilization" Data Pooling Platform

Data integration, guided by the principles of data sharing, interconnection, and business collaboration, aims to overcome the administrative barriers between departments and transition from a fragmented, project-based approach to information technology construction to a more centralized and efficient mode of development. Data integration involves three key stages: aggregation, connectivity, and utilization (see Fig.3).

First, it is essential to consolidate data dispersed across various departments on a unified platform, laying the foundation for data applications. Second, upon consolidation, it is imperative to establish standards and mechanisms for open data sharing, addressing institutional and technical challenges associated with data openness and sharing. Following aggregation and connectivity, proactive efforts should be made to develop more applications, fostering synergies among the interconnected datasets and driving the transformation of government departmental workflows to better achieve streamlined administration and decentralization.

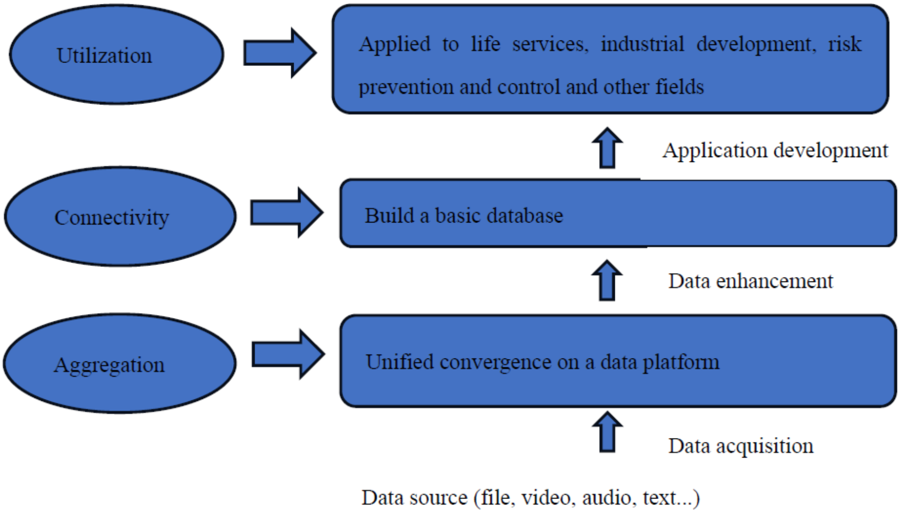

Fig. 3. Schematic Diagram of Data Coordination

4.3 Data Mining: Strengthen Data Analysis and Application

Enhancing deep data mining can effectively address the issue of dormant data. AI technology analyzes and mines the collected data to discover correlations and patterns, aiding communities in uncovering new value from big data, which in turn provides decision support and intelligent services. Cloud Computing-based Data Mining can realize distributed mining of data information, and realize real-time and efficient data information mining. [12] Its data mining process has five main steps (see Fig.4).

The first step, data selection. According to different needs, the target processing data is screened from the massive data to improve the mining efficiency. The second step is data preprocessing. Data preprocessing includes data integration, reduction, cleanup, and transformation, as well as conceptual layering and discretization. The third step is pattern discovery. Finding the right data presentation pattern for users from the data is also the main process of knowledge discovery.The fourth step is the mode assessment. The mode assessment refers to the evaluation and revision of data presentation patterns to improve the final knowledge model. The fifth step is the representation of knowledge. This refers to sending the data that is finally discovered to the user in a visual way.

Fig. 4. Five steps to data mining

Therefore, in the process of building a smart community, cloud computing data mining methods can be used, analyze the following types of data.

First, demographic data should be analyzed to improve community services: By analyzing the demographic data of community residents, such as their age, gender, occupation, and educational background, it is possible to understand the demographic characteristics of a community. These data serve as a basis for community planning and resource allocation. For communities with a greater population of elderly individuals, tailored health and safety services can be provided to effectively meet their needs.

Second, behavioral data should be analyzed to promote business development: Analyzing residents' behavioral data, such as their travel patterns, shopping habits, and social networks, provides insights into their needs and preferences. By utilizing shopping habit data, it becomes possible to optimize community business layouts and logistics distribution, providing targeted support for a community's commercial development and services.

Third, environmental data should be analyzed to optimize the community environment: Analyzing environmental data such as air quality, noise levels, and energy consumption evaluates a community's environmental quality. Such analysis provides decision support for environmental improvement and resource management.

Fourth, safety data should be analyzed to enhance resident safety: Analyzing safety data such as surveillance videos and alarm records helps identify abnormal events and forecast risks. Timely measures can then be taken to intervene and handle situations, thereby enhancing a community's security protection and emergency response capabilities and ultimately increasing residents' sense of security.

In deep data mining, in addition to optimizing data algorithms, it is crucial for system designers to fully understand the business scenarios. They must be able to identify the key data needed based on this understanding, achieving a comprehensive integration of business, data, and technology, thereby efficiently realizing data mining objectives.

4.4 Intelligent Decision-making: Promote Data Iteration and Optimization

To make intelligent decisions with AI technology, continuous data collection, analysis, and evaluation are required, along with ongoing refinement and improvement of decision-making systems, assisting community managers in making scientifically rational judgments. This process is a continuous iteration process, necessitating assessment, adjustment, and reassessment to avoid an excessive reliance on intuition in decision analysis by managers, leveraging the role of AI technology in decision support.

Data iteration refers to the repeated collection, analysis, and application of data to improve and optimize business decisions, product development, and service provision in smart communities. Data optimization involves discovering optimization opportunities and issues through data analysis and improving and enhancing strategies, decisions, and services in smart community construction based on data insights. Both data iteration and data optimization demonstrate the ability to perceive information synergistically in complex businesses. This perception can not only display real-time business demand-driven holistic information about a community's entire status but also predict the future trends of key status information based on historical data and current decisions, forming evaluable decision criteria and assessing the short-term and long-term impacts of current decisions, thereby assisting managers in making scientifically rational decisions.

4.5 Privacy Protection: Improve the Data Security Management System

The protection of data privacy and security should be prioritized to ensure that data applications have rules, boundaries, and forbidden zones.

First, technological protection is emphasized. The localization and self-reliance of the core products of system platforms should be accelerated. Large companies with strong network security capabilities can collaborate to develop cloud security add-on products that meet government data security requirements, jointly building a robust firewall.

Second, mechanism protection is implemented. For sensitive data involving public safety and personal privacy, every system user must undergo digital certificate authentication, and usage records are kept for every operator logging into the system. It is important to cooperate with national authoritative security and assessment institutions to carry out network security assessments, supervision, and audits to prevent illegal operations and tampering.

Third, legal protection is enforced. It is important to explore data security standards and norms for data applications and promote data security and privacy legislation. The rights of individuals regarding access, deletion, modification, and recourse of information data should be clarified, and a data leakage accountability mechanism should be established.

5 Conclusion

Smart community construction involves complex system engineering, and AI is still in the weak AI stage. It is time to gradually solve the actual combat ability of algorithms and data structuring and even hardware- and basic-level problems such as chips, sensors, operating systems, cloud computing, and big data and promote the construction of AI communities. This article analyzes the problems existing in smart community management and proposes suggestions involving five aspects: precise perception, data fusion, data mining, intelligent decision-making, and privacy protection.

With the development and protection of AI technology, future AI communities can not only provide convenient life services for community residents and timely, accurate decision analysis for management departments but also help enterprises analyze residents' consumption preferences from vast amounts of community resident data, actively promote services and commodities, and achieve refined operation. This is not only a requirement of the era for the intrinsic development of Chinese cities and structural support for sustainable development but also the necessary path to realize the modernization of the urban governance system and governance capabilities.

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