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A review of the various advances in smart cities: Application of artificial intelligence and machine learning

Mehran Dadashzadeh[*1], **Farhad Jedari Zarezadeh** [2]

[1]University of Tabriz, Faculty of Civil Engineering, Department of Water Resources Engineering, Tabriz, Iran
[2]University of Tabriz, Faculty of Civil Engineering, Department of Structural Engineering, Tabriz, Iran

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Abstract

Artificial intelligence has played an effective role in human societies and started new concepts in community life. Meanwhile, smart cities are the new issue introduced lately. Smart cities with the aim of providing new standards of urbanization, optimal energy consumption, environment, and ameliorating the economy are propounded. The ideals of smart cities are divided into subcategories that can handle by artificial intelligence. The primary objective of this review is to explore the role of artificial intelligence and machine learning in the evolution of smart cities. In this survey, we present some details of the applications of machine learning techniques in energy grids, public lighting, natural resources, water management, environment, waste management, healthcare, public security, transport, mobility, and logistics. The result of the present study demonstrated that operating artificial intelligence methods in the field of metropolis control is very prosperous.

1. Introduction

The intelligence of a city is largely based on the ways it manages its urban resources (Fokaides et al. 2018). This fact, recently, led to the concept of "Smart Cities" in the scientific forums. The Smart City prospect preliminarily denoted initiatives that utilize digital and ICT-based inventions to ameliorate the expeditiousness of urban services and generate new economic opportunities in cities (Kamal-Chaoui. 2020). But recently Smart Cities have been defined as initiatives or approaches that effectively leverage digitalization to boost citizen well-being and deliver more efficient, sustainable, and inclusive urban services and environments as part of a collaborative. Significantly, "machine learning" is insinuated as efficient equipment to materialize targets of smart cities (Sohail Ibrahim et al. 2020).

The core of a smart city consists of the creation and use of data to generate new services and support decision-making. Data is one of the three major pillars of the Smart Cities, along with technology and people (al-kamoosi and Al-Ani. 2019). In the presence of big and complex data, it's difficult to precisely decide the most accurate and efficient actions. The best possible analysis of the big data can be carried out using machine learning to reach an optimal decision (Liu et al. 2019). The machine learning ecosystem is both extensive and complex, with many possible ways to subdivide or classify its members (Paeglis et al. 2018).

This study focuses on clarifying the application of machine learning in smart cities by considering its characteristic features and application areas. Possible areas of smart cities are suggested to illustrate the application of innovative machine learning patterns in the empirical research presented in this study.

2. Machine Learning strategies

There are two approaches of machine learning algorithms to apply an informative classification (LeCun et al. 2015). One frequently used classification scheme outlines two broad groups of machine learning algorithms: supervised learning, where the model is presented with both a set of labeled example inputs and desired outputs (called the training dataset), with the goal to learn a mapping from inputs to outputs. The second informative approach to classifying machine learning algorithms is based on the desired type of output of the given model. Due to the wide range of

* **Corresponding Author**

*(mehrandadashzadeh@tabrizu.ac.ir) ORCID ID 0000– 0001– 9521– 7330
(farhadjedari@yahoo.com) ORCID ID 0000– 0003– 2762– 3577

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domains of a smart city, clustering is notable due to its broad and general applicability and can be employed to carry out cluster analysis on methods and algorithms.

3. Application of Machine Learning in Smart Cities

The various advances to the definition of smart cities are mainly related to two different factors, I) The way cities can steer themselves to achieve the goal of optimization, and II) The domains that are more critical for a cleverer usage of urban resources (Neirotti et al. 2014). The domains in which urban development policies are applicable can be classified as ''hard'' or ''soft''.

Hard domains refer to energy grids, natural resources, energy and water management, waste management, environment, transport, mobility, and logistics, and by contrast, soft domains include areas such as education, culture, policies that burnish competitiveness, inventions, and social adjuncts, as well as communication between local public bureaucracies and the citizens (Neirotti et al. 2014).

In proportion to hard domains, soft domains cannot be examined by Machine Learning due to the fact that they are investigated based on urban planning and people's behavioral habits (Wataya and shaw. 2019). As a result, the hard domains are discussed in this review.

3.1. Energy grids

The machine learning applications in the smart energy grid include predictions of loads and price, cascading failure prediction, power generation and control, fault detection and diagnosis, and detection of cyberspace attacks among others (Sohail Ibrahim et al. 2020). The spectrum of machine learning applications in the smart grid is spanning from the general comprehensive perception of the underlying systems, to intelligent and adaptive decision-making and finally towards the real-time or near real-time operations in the context of smart grids.

To be detailed on this issue, energy consumption in public buildings does not fulfill the assumptions of linearity; The machine learning methods have been selected to be used due to their nonlinearity and ability to learn from historical data (recorded similar situations). Three machine learning methods have been used for creating predictive models of energy consumption and efficiency of public buildings: artificial neural networks (ANNs) and recursive partitioning methods such as CART decision trees, and random forests (Zekić-Sušaca et al. 2021).

3.2. Public lighting, natural resources, and water management

There are many challenges facing traditional public-lighting management systems, such as the number of damaged lamps that need replacement each year, the impact of extending the system by adding lamps, and lamp type on the failure rate. Generally, challenges are considered in the two sections: I) Challenges facing lighting contractors and II) Challenges facing lighting managers (Mirzaei et al. 2020).

Due to mentioned challenges, the machine learning approach is advocated. ANN is a significant utilization of machine learning. According to this issue, some of the situations that arise with respect to street lighting include any overload in the electricity passing through the luminaries, which has to be adjusted; dimming or switching off street lights in the presence of natural light, and reducing light intensity based on the amount of illumination provided by natural light (Mohandas et al. 2019). The commodity of utilizing ANN is that once an associated situation recurs, the solutions are generalized from past data and applied instantly. Thus, ANN learns from a set of examples to manage associated situations as they occur subsequently.

In the case of natural resources and water management, Machine learning methods, particularly ANNs, have been commonly and successfully used in water systems management (Imani et al. 2021). On the other hand, resilience is an increasing idea that validated to be a conductive approach in preparing engineering systems to engage with emerging challenges. Researchers believe that the integration of machine learning techniques to predict water quality resilience can provide an opportunity for more effective adoption of resilience to tackle the emerging challenges. One potential improvement on the horizon will be using more conducive machine learning methods such as deep learning or deep reinforcement learning.

3.3. Waste management

Waste management is an essential activity and operation from the start to waste clearance. This involves trash collection, transportation, processing and disposal, monitoring, controlling, and separating waste management (Kepa et al. 2020). Artificial intelligence for smart cities plays a prominent role in taking solid waste collection seriously since it is remarkable for the environment and influences society (Chen. 2022).

Also, machine learning plays a crucial role in automated sorting techniques leading to greater precision and better waste separation quality (Ismaila et al. 2022). In addition to navigational and tracking capacity storage waste processing analysis and optimization of the required information would, in the end, enhance the entire waste management efficiency by improving the waste collection by advancing the program.

3.4. Environment

In the field of Environment, countries, and societies are paying frequent attention to the construction of ecological civilization and environmental protection (D'Amico et al. 2021). This has also been reflected to a certain extent in urban space planning. It can be seen that in the process of urban construction and development, urban space planning has more emphasis on ecological civilization and the ecological environment (Chen. 2021). Putting protection into important links and main content, it is obvious that the proportion of ecological strategies in urban spatial planning is increasing, and it is showing an upward trend year by year.

With recent advances in environmental monitoring technologies, huge volumes of complex environmental data are being generated continuously. Because this data is dynamic, heterogeneous, multidimensional, multi-source, and extensive, it must be organized, integrated, and visualized to be informative for environmental monitoring and decision-making programs (He et al. 2010). Data mining and machine learning methods categorize this huge amount of data and provide the best output by examining the favorable conditions for the environment.

3.5. Transport, mobility, and logistics

Connected and Autonomous Vehicles, Unmanned Aerial Vehicles and Personal Aerial Vehicles, Mobility-as-a-Service, Internet of Things, and Physical Internet, approved set of definitions that critically underpins the nexus of Artificial Intelligence, transport, and the smart city (Wortmann and Fluchter 2015; Kim et al. 2018).

Smart Mobility is one of the main concerns in modern cities, which focuses on providing sustainable transport systems and logistics to allow smooth urban traffic and commuting by mainly applying information and communication technologies. They also include approaches that harness personal information to provide useful recommendations for small-scale personal management like searching for free parking spaces (Baskar et al. 2011). Some conventional control approaches such as static feedback control (SFC) and traditional Artificial Intelligence techniques based on historical data such as case-based reasoning and rule-based systems were developed to determine control actions. However, these approaches had their respective drawbacks such as trouble coping with the dynamics of the traffic networks and the techniques did not have a learning mechanism to deal with unseen situations to automatically update their model (Nallaperuma et al. 2019). The advancement of machine learning has paved the way for a generic and flexible way to develop intelligent and adaptive traffic control systems.

3.6. Healthcare

The increasing availability of electronic health data (EHR) presents a major opportunity in healthcare for discovery and practical applications to improve healthcare by providing accurate medical diagnosis, predicting diseases in the early stages, and disease analysis. Many smart devices gather data related to human health and there is a growing industry of such devices. The authenticity of information is very significant in predictive models, unfortunately, this information is not structured and cannot use in the mentioned models. Artificial Intelligence networks are known for their ability to handle large volumes of relatively messy data, including errors in labels and large numbers of input variables (Bhardwaj et al. 2017). Operators do not have to specify which variables need to be considered for prediction and in what combinations; instead, neural networks can learn representations of the key factors and interactions from the data itself. Due to these advantages, the use of machine learning in the realm of healthcare has become prevalent. The EHR data collected can be mined for several possible applications. The entire contents of the EHR like medications, admission details, vital signs, etc. can be analyzed using machine learning algorithms to estimate the probability of a patient reacting adversely to antibiotics or to accurately measure the patient's risk of contracting common hospital spread diseases such as Clostridium difficile infection (Weins et al. 2014).

3.7. Public security

The smart city safeguards possible risks for residents, organizations, and other institutions. Protection measures enforcement is a significant factor to monitor city agencies and taking accountable operations in the emergency incidents (Ahmed et al. 2021). In this field, the relevant needs of public security and police affairs are met by the public security information analysis and mining system as an auxiliary analysis instrument. The effectual institution of this system means that the investigative opinion of case-handling personnel is expensive, and the case can be encountered with higher efficiency than the manual system. It can extend applicable decision-making and a basis for police work, which has very essential practical urgency (Li and Cui. 2021, Yu et al. 2021). Through the related academic research on machine learning, the police department's ability to enforce the law and combat terrorism will be greatly improved. Based on the specific characteristics of crime and associated security tools, data mining technologies primarily include the following: information sharing and collaboration, intelligent text mining, security association mining, classification and clustering, and spatial and temporal crime pattern mining. Despite the use of traditional methods, simple methods like machine learning and data mining and their impact on the proposed system will be of great importance.

4. Conclusion

A detailed evaluation is contemplated as a preparatory contribution to conceive empirical research in order to obtain a better comprehension of the current development of Smart Cities. Based on this issue, eleven main approaches to Smart Cities deployment are classified, energy grids, public lighting, natural resources, water management, environment, waste management, healthcare, public security, transport, mobility, and logistics.

In this study, the common point of mentioned approaches is the application of machine learning to obtain the targets of each field. Machine Learning strategies are used to expose a beneficial and standard alternative instead of traditional methods. The result of this study revealed that operating artificial intelligence methods in the field of metropolis control is very booming. Additionally, machine learning was found as a global algorithm to generate targets for smart cities, and machine learning behavioral filters in the various domains mentioned are defined based on the tendencies and evolutionary patterns of each smart city, which largely depend on local context factors.

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