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Artificial Intelligence in Smart Cities

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Abstract: In recent years, cities have undergone various changes due to the emergence and adoption of numerous concepts such as sustainable cities, inclusive cities, resilient cities, etc. Today, the focus is on smart cities, which aspire to connect all aspects of urban life. Smart city is a concept that leverages technology and intelligent insights from sensors to make life more comfortable and secure for residents. It reduces the urban consumption of resources, prevents wastage, and enhances comfort and security for residents. The combination of AI and IoT is helping to make the concept of smart cities a reality. This paper investigates the role of AI in the different sectors of the smart cities.

Keywords: *Smart Cities, Artificial Intelligence, Artificial Intelligence In Smart Cities, Urban AI*

I. INTRODUCTION

Cities are centers for economic growth, job creation, new ideas incubator, technological evolution, networking, information sharing, and social transformation. By 2008, half of the world population lived in cities. The continued growth of urbanization presents new challenges. Higher urbanization rates with 10 million inhabitants or

more make it difficult to create a sustainable and cost-effective environment and a high quality of life for the citizens. Many cities of the world have infrastructure that is not adequate for meeting the needs of growing urban population. Figure 1 shows a typical traditional city [1].

Figure 1: A typical traditional city [1].

The concept of smart cities provides a potential solution to the challenges. Many municipalities worldwide are turning to the smart cities concept to improve their infrastructure, communication, and services for residents. The rapid development of new technologies such AI, big data, cloud computing, blockchain, 5G, ICT, and IoT is helping to drive the evolution of smart cities. While several technologies are needed realize the concept of smart cities, the two key enablers of the smart city are Internet of things (IoT) and artificial intelligence (AI). Figure 2 shows the various components of a smart city [2].

Prioritizing changes to urban infrastructure and investing in reliable technology is central to smart city development [3].

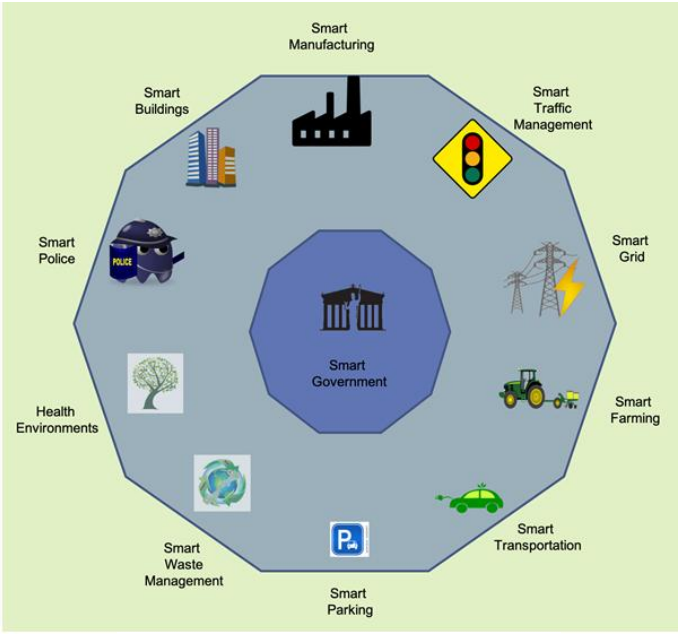

Figure 2: Components of a smart city [2].

II. OVERVIEW ON ARTIFICIAL INTELLIGENCE

The term "artificial intelligence" (AI) was first used at a Dartmouth College conference in 1956. AI is now one of the most important global issues of the 21st century. AI is the branch of computer science that deals with designing intelligent computer systems that mimic human intelligence, e.g., visual perception, speech recognition, decision-making, and language translation. The ability of machines to process natural language, to learn, to plan makes it possible for new tasks to be performed by intelligent systems. The main purpose of AI is to mimic the cognitive function of human beings and perform activities that would typically be performed by a human being. Without being taught by humans, machines use their own experience to solve a problem.

AI is stand-alone independent electronic entity that functions much like human expert. Today, AI is integrated into our daily lives in several forms, such as personal assistants, automated mass transportation, aviation, computer gaming, facial recognition at passport control, voice recognition on virtual assistants, driverless cars, companion robots, etc. AI is not a single technology but a range of computational models and algorithms.

Some forms of AI that are most commonly used in different applications include the following [4,5]:

A. Expert systems: They solve problems with an inference engine that draws from a knowledge base equipped with information about a specialized domain, mainly in the form of if-then rules. Expert systems are the earliest, most extensive, the most active and most fruitful area.

B. Fuzzy logic: This makes it possible to create rules for how machines respond to inputs that account for a continuum of possible conditions, rather than straightforward binary.

C. Neural networks: These are specific types of machine learning systems that consist of artificial synapses designed to imitate the structure and function of brains. They are similar to the human brain. They are made up of artificial neurons, take in multiple inputs, and produce a single output. The network observes and learns as the synapses transmit data to one another, processing information as it passes through multiple layers.

D. Machine learning: This includes a broad range of algorithms and statistical models that make it possible for systems to find patterns, draw inferences, and learn to perform tasks without specific instructions. Machine learning is a process that involves the application of AI to automatically perform a specific task without explicitly programming it. ML techniques may result in data insights that increase production efficiency. Today, artificial intelligence is narrow and mainly based on machine learning.

***E. Deep learning*:** This is a form of machine learning based on artificial neural networks. Deep learning architectures are able to process hierarchies of increasingly abstract features, making them especially useful for purposes like speech and image recognition and natural language processing. Deep learning networks can deal with complex non-linear problems.

***F. Natural Language Processors*:** For AI to be useful to us humans, it needs to be able to communicate with us in our language. Computer programs can translate or interpret language as it is spoken by normal people.

***G. Robots*:** These are computer-based programmable machines that have physical manipulators and sensors. Sensors can monitor temperature, humidity, pressure, time, record data, and make critical decisions in some cases. Robots have moved from science fiction to your local hospital. In jobs with repetitive and monotonous functions they might even completely replace humans. Robotics and autonomous systems are regarded as the fourth industrial revolution.

These AI tools are illustrated in Figure 3 [6]. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. AI systems are designed to make decisions using real-time data. They have the ability to learn and adapt as they make decisions.

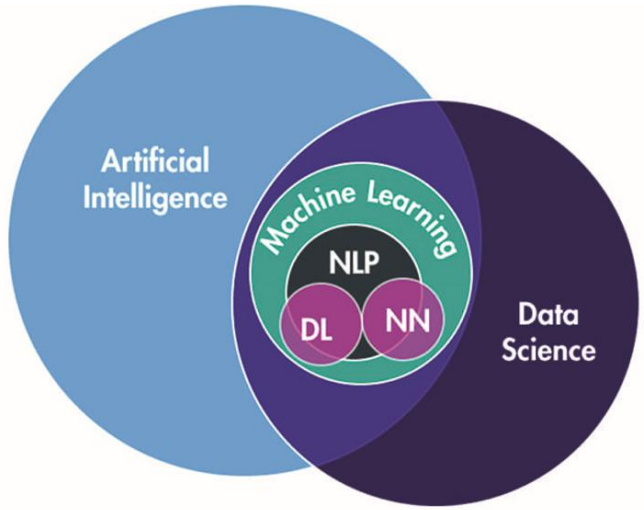

Figure 3: Artificial intelligence (AI) encapsulates several concepts including natural language processing (NLP), deep learning (DL), and neural networks (NN) [6].

III. AI IN SMART CITIES

Everything is getting smart - automobiles, homes, industries, health care, agriculture, and cities. A smart city is an urban area that uses intelligent systems to ease up the livelihood of its people. It consists of safe, secure, and reliable interconnected sensors, actuators, and relays which collect, process, and transmit data. Cities have wealth of data sources, such as ticket sales on mass transit, local tax information, police reports, sensors on roads and local weather stations. The raw data generated is unimaginably bigger than what humans can analyze and process. This is where the role of artificial intelligence comes in.

AI offers the ability to sort through and analyze big data using algorithms to solve problem solve, predict or come to logical conclusions. AI can keep a count of any number of vehicles, pedestrians or any other movements while keeping a track on their speeds. It can carry out face recognition, read license plates, and process satellite data. Smart city uses AI to optimize city functions, drive economic growth, improve quality of life, and underpin governance structures.

The Smart Cities Council promotes three core values that make a city smart [7]:

A. Livability: Cities that provide clean, healthy living conditions without pollution and congestion. This is achieved with a digital infrastructure that makes city services instantly and conveniently available anytime, anywhere. The liveability aspect of cities is influenced by the security and safety therein. Culture, governance, and metabolism form the basis of liveable smart cities.

B. Workability: Cities that provide the enabling infrastructure — energy, connectivity, computing, essential services — to compete globally for high-quality jobs.

***C. Sustainability*:** Cities that provide services without stealing from future generations. A smart city ensures economic growth and quality of life.

IV. APPLICATIONS OF AI IN SMART CITIES

A city is made "smart" when it uses of intelligent or smart technology to improve infrastructure and services in a city. A technology that is helping accelerate the realization of the smart city concept is artificial intelligence (AI). These are some of the following ways AI is helping to realize the smart city concept [8-10].

A. Smart Grid: The smart grid is an electrical power grid that is integrated with an AI-enabled, two-way communication network providing energy and information. AI is a powerful tool to push smart grid into the new generation of power systems. It provides a platform for clean, sustainable, efficient and reliable energy generation, delivery, and consumption. Smart power grid and smart water management helps to produce energy with less pollution in smart cities.

B. Smart Parking: In cities, parking solutions optimize parking spaces in a way that is efficient, smart, and contributes to a better traffic flow. AI can improve parking management in cities by providing authorities with data regarding the availability or unavailability of parking spots. The technology helps authorities to make parking more efficient by allowing them to identify patterns of use of parking spaces. A smart parking app can help the driver find available parking spaces with ease. VIMOC is using AI to make parking easier in Redwood City.

C. Public transit: Urban AI can help harmonize the experience of its riders. Passengers of trains, buses, and cars can provide real-time information through their mobile apps to communicate delays, breakdowns and less congested routes. Mobility data can translate into improved walkability and reduced commute times and make it a win-win-win for all traffic participants. For example, Dubai developed a number of Smart City projects, one of which monitored the condition of bus drivers.

D. Security Surveillance: The safety and security of the citizens are at topmost priority in cities. AI enables real-time monitoring and decision-making, which can help public safety in cities. AI-enabled cameras and sensors can keep an eye on the surroundings to enhance the safety and security throughout in the city. Autonomous flying drones with in-built cameras can track humans, monitor traffic movement, and provide the 2D aerial view imagery mapping. The technology is used by law enforcement agencies for and crime prevention. Police departments around the world are using AI Technologies to undertake policing functions in an efficient manner.

E. Traffic Congestion: Traffic congestion is rising in cities worldwide and is a major challenge in many cities. To solve this problem, cities are turning to the use of IoT and AI-enable traffic solutions. AI-supported traffic sensor systems can use cameras to collect real-time data of vehicles on road. Uber is now using AI to give a better riding experience to its customers.

F. Waste Management: People living in cities generate a lot of waste. There is a need to manage garbage, keep the environment clean, and maintain sound hygiene in cities. By combining AI and IoT, it becomes easier for city authorities to remotely monitor waste levels.

G. Autonomous Vehicles: Perhaps the most revolutionary AI application in transport today is the automation of vehicles. Here the artifact where the artificial intelligence resides is a car or vehicle. Autonomous vehicles are equipped with sensors which make them capable of perceiving the built environment. The AI-enabled vehicle can sense the surrounding urban environment by means of cameras, radars, and lidar systems. The artificial intelligence employs downloadable data to drive the vehicle to a given location, with no human input or supervision. The transition to autonomous cars may likely reshape urban mobility. Figure 4 shows a typical autonomous vehicle [11].

Other areas of application of AI in smart cities include urban governance, AI-powered robots, drones, healthcare, smart health, smart tourism, smart building, home automation, cybersecurity, combating social problems such as homelessness, ridesharing, personal assistant, and crowd sourced data collection.

Figure 4: A typical autonomous vehicle [11].

V. BENEFITS

The application of AI in smart cities has several benefits for humans as well as the environment. AI benefits a city's transportation, education, environmental protection, public safety, and more. Combining AI with IoT can provide intelligent systems that cities need to minimize straining existing infrastructure, prevent deterioration of the environment, minimize traffic congestion, reduce urban crime, improve sanitation, reduce pollution, ease parking management, and enhance comfort and security for residents. Some benefits can come in many forms, including reduced crime, cleaner air, more orderly traffic flow, and more efficient government services.

AI is playing a big role in making urbanization smarter by making cities equipped with advanced features for citizens to live, walk, shop, and enjoy a safe environment. Other benefits include [12].

- AI will curb pollution and reduce CO2 emission.
- Many cities are turning to smart technologies to ease traffic congestion and optimizing mobility.
- AI in security cameras or drones can recognize the human faces and trace their identity.
- AI technologies are taking the management of urban services out of the hands of humans, operating the city in an autonomous way.
- AI creates more sustainable cities, maintain infrastructure, and improve public services for residents and visitors.

VI. CHALLENGES

Making cities smart faces several challenges like administration, sanitation, traffic congestion, security surveillance, parking management. Other challenges include [12]:

- AI as a technology has limits and its applicability has been slow in adoption.
- The devices and equipment, and sensor technology required to develop smart cities are sophisticated and costly.
- Monitoring people or watching their activities can be a challenge as the use of IoT and sensor technology increases.
- The threat of cyber-attacks is a critical issue for smart cities.
- Awareness, education, and transparency on the purpose of data collection are crucial.
- Covering all age, gender, class and income group of people from society is necessary.
- Making urban AI a reality involves several challenges in the areas of privacy, security, accuracy, and bandwidth.

It has been argued that the more revolutionary and disruptive a smart technology is, the greater is likely to be the transformation of the city that integrates it.

VII. THE FUTURE OF AI IN SMART CITIES

Individuals, city officials, policy makers**,** and futurists have long envisioned smart cities of the future where residents and visitors thrive. Smart cities are designed to efficiently manage growing urbanization, energy consumption, maintain a green environment, improve the economic and living standards of their citizens. Cities should plan for a smooth transition towards the future in two ways. First, they should have a short-

term of investing in the technological innovations that are already available on the market and integrate them into the existing systems. Second, cities should have long-term plan characterized by infrastructure and vehicles communicating with each other and with people [11]. For example, cities may update their fiber infrastructure for the purpose of better traffic management and for future connected and automated vehicles.

The future of smart cities relies heavily on artificial intelligence. AI and IoT are becoming increasingly integral to how the world operate. Much advancement in AI within the smart city will come from automation of the routine. In the future smart cities, everything from parking, waste management, traffic management, public safety, water and energy management, and citizen engagement is "smart" and efficient.

Technological advances are constantly reshaping the realization of smart-city initiatives which are being implemented across different geographical locations. Various technologies such as information and communication technology (ICT), artificial intelligence (AI), machine learning (ML), robotics, and Internet of things (IoT) will play an outstanding role realizing the concept of a smart city. While some progress has been made toward the future, cities continue to face complex challenges, including infrastructure maintenance, population growth, and environmental degradation.

CONCLUSION

A smart city is one that makes use of information and technologies to enhance the quality and performance of urban services. The transformation from traditional to smart cities will be spearheaded by artificial intelligence applications. AI technology is accelerating far more quickly than anyone could have imagined. Organizations that have implemented AI technology is reaping its consistent benefits. City planners and engineers are now using AI and IoT to deal with increasingly complex environments. They should use AI tools for the welfare of citizens. For more information about artificial intelligence in cities, one should consult the books in [13-15] and related journals: *Frontiers in Sustainable Cities* and City *Pulse*.

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