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A review on deep learning for future smart cities

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The advancements in Information and Communication Technologies (ICT) made the concept of Smart Cities into reality. In a smart city several Internet of Things (IoT) sensors are deployed across several locations to collect the data about traffic, drainage, mobility of citizens etc. and the insights gained from these data are used to manage resources, assets etc. effectively. Deep Learning has been used extensively on the data generated by IoT sensors in a smart city by several researchers. In this article an attempt is made to survey several state-of-the art on usage of Deep Learning on Smart City data. Several future research directions are suggested at the end of the article.

KEYWORDS

deep learning, smart city, smart education, smart health, smart mobility, urban modeling

1 | INTRODUCTION

The evolution of IoT[1] along with big data analytics,[2] machine learning has turned the idea of a smart city into reality. The idea behind a smart city is to effectively render services to the residents in the smart city using advanced technologies and data analytics on data collected by sensors.[3] The smartness of a city is determined by technology driven infrasructure, initiatives on environmental issues, smart public transportation, usage of technology to reduce crimes and burglaries,[4-6] providing safety to citizens, etc. Deep Learning (DL) is a machine learning technique which can be used effectively to gain insights from the data, understand the patterns from the data and classify/predict the data.[7-9] In this article a review on state-of-the-art literature on usage of Deep Neural Networks/Deep Learning on several verticals/applications of a smart city is presented. Rest of the article summarizes the aforementioned state-of-the-art works.

2 | DEEP LEARNING FOR URBAN MODELING FOR SMART CITIES

The percentage of people living in cities worldwide has doubled in last 50 years.[10] Urban and rural areas evolve to address technological innovation, while presenting new opportunities for public safety connectivity and overall experience to residents and visitors. In Reference 11 the authors used intelligent computer vision and deep learning models to identify the slums, traffic rate prediction. This model aims to recognize a wide range of nuances between developed and undeveloped regions. In Reference 12 the authors proposed smart parking using deep learning, IoT, and

wireless communication. This proposal aims to reduce the time to find a free slot for parking in shopping malls, railway stations, etc. Using Deep Learning (DL) and IoT sensor determines the best place to park in less time. Versatile connectivity in urban areas is achievable with special attention to network availability, network bandwidth, network media and network topology.[13] Smart street polls using machine-learning approaches can save up to 50% more energy.[14] Sustainable power distribution can be achieved by focusing on power generation, distribution, power transmission.[15]

3 | DEEP LEARNING FOR INTELLIGENT INFRASTRUCTURE OF SMART CITIES

By 2030, 60% of the world's population will live in cities.[16] Currently, most cities experience problems like congestion, non-sustainable, non-resilient. Now addressing all these challenges is becoming even more important as a result of rapid population growth and global warming. Infrastructures are cities' backbone, and they play a key role in resolving these challenges.

In Reference 17 the authors have integrated deep learning techniques in an intelligent infrastructure model. The intelligent system monitors energy consumption, traffic rate, and takes the decision based on its severity. In Reference 18 the authors proposed an intelligent deep-learning routing mechanism to handle massive amounts of data generated from different sensors, reducing the problem of network congestion.

4 | DEEP LEARNING FOR SMART MOBILITY AND TRANSPORTATION

The transportation system is enabled through an iterated cloud platform, AI, connecting vehicles, people, infrastructure and logistic partners. In the city, the sensors of the autonomous refuse truck detect all movements in the vicinity of the environment and reacts automatically to any potential incidents, making sure citizens are safe and preventing accidents before they happen. In Reference 19 the authors used deep learning, data analytics, communication technologies to link people, roads and vehicles to solve various traffic-related issues. This work focuses on various initiatives aimed at creating a vehicle centered, safe environment and comfortable transport. One of the safe driving support systems designed to prevent drivers from overlooking or missing red lights.[20] Pedestrian Detection System uses an AI, 3D stereo camera that can detect multiple pedestrians in the surrounding area. It benefits drivers operating around obstacles and blind spots.[21]

5 | DEEP LEARNING FOR SMART URBAN GOVERNANCE

Most of the people now-a-days live in metropolitans which has been the main reason for building smarter cities. The authors review the concept of public management[22] which aids in analyzing the government policies and features of the smart city. Public management is also important to gain insights on the dynamic requirements of the smart city. A public opinion is an important factor for the betterment of the government policies towards urbanization.

6 | DEEP LEARNING FOR TO RESILIENCE AND SUSTAINABILITY OF SMART CITIES

Information generation is increasing day-by-day. There is a dire need to develop an efficient network to share this information which can be used for the betterment of the smart cities. The major challenge faced is environmental resource constraint. This could be solved by designing a smart network which can reduce the pollution levels as well as aid people to lead a better life.

The authors in Reference 23 implement an intelligent fault detection method using clustering and deep learning techniques. There are various utilities/tools which aid in decision making of power systems. The usage of these tools

require specialized knowledge in electrical system and cannot be used by everyone. A novel platform called SureCity[24] is presented which resolves the existing challenges to aid in building smart sustainable cities.

7 | DEEP LEARNING FOR SMART EDUCATION

The present education system has introduced novel learning methods to empower the students. One of such learning technique which is prevalent is Flipped Classroom Learning Method (FCLM). The authors analyze the implementation of Online Flipped Classroom Learning Method (OFCLM) in a distance education[25] scenario for young adults. This method is proven to increase the higher order thinking skills of the learner through online brainstorming sessions. The authors in Reference 26 asses the learners interaction in using mobile based CRS for the entrepreneurship course. The authors in Reference 27 implement a face detection system for evaluating the effectiveness of the content by using the learners' facial emotions. Big data analysis has rendered a chance of analyzing the psychology of a leaner. The authors in Reference 28 propose a novel emotion-sensitive method to determine the learners' interest based on the position of the head and facial emotions. The major challenge of online learning is the retention rate. This might be due to several factors such as presentation of the content as well as the lack of interaction with the trainer. The authors in Reference 29 analyze temporal sequential classification problem to predict the retention rate of the students by utilizing the interactional events embedded in the online learning system.

8 | DEEP LEARNING FOR SMART HEALTH SOLUTION

Artificial intelligence has opened the scope to build smart healthcare solutions using newer and advanced concepts like deep learning. Concepts like transfer learning and deep learning approaches models have been extremely helpful in classifying breast cancer from breast cytology images. The resultant classification and predictions of the breast cancer tumor images, prove to be more accurate in comparison to the traditional deep learning architectures.[30] Similar adaptations have been observed in the segmentation of cervical cancer images based on wireless network technology. Although the approach of Deep learning methods have been used for the purpose of calculation and analysis of the data generated from the MRI image segmentation method. The results of the deep learning and wireless network based model reveal almost twice the efficiency than the traditional deep learning approach.[31] Deep learning models along with acoustic simulations have been used to analyze cry sounds in the neonatal units to detect health conditions of new born infants and take necessary health measures in case of any anomalies are detected in their health conditions.[32] The use of deep learning methods have encouraged development of automated systems to upgrade the quality of human life. In alignment to the same, automated electroencephalogram (EEG) pathological detection system based on deep learning method have been developed which could capture the brain signals in the form of EEG signals in spatio-temporal representations and detect the possibility of a person suffering from pathology.[33] Various mobile app solutions have gained popularity in measuring diets and monitor general health and well being related attributes. These multi-access physical monitoring devices are often used in the form of wearable devices integrated with mobile apps, help to detect any anomalies in the body due to deficiencies in nutrient intakes across all age groups thereby creating a smart health environment.[34]

9 | DEEP LEARNING FOR SECURITY AND PRIVACY OF SMART CITIES

The smart cities of the present centuries are a gift of massive innovations in information and communication technologies. The citizens of these smart cities are connected through smart phones and sophisticated gadgets integrated with IoT leading to unimaginable conveniences and improvements in their lifestyles. Although devices such as Smart meters, smart home appliances, smart healthcare devices enable such conveniences but have associated challenges pertaining to security and privacy of information and maintenance of data integrity barring unauthorized access. Deep learning and related technologies have been successful in providing successful solutions to such security breaches in applications where big data technologies and IoT is deployed.[35] One such implementation is presented in[36] where anomaly detection - IoT (AD-IoT) is deployed using Random Forest Algorithm to detect anomalies at the distributed fog nodes in IoT devices. To detect intrusions in the IoT network for smart city devices, Botnets have potential to threaten the security of such devices wherein deep learning frameworks are deployed to identify authorized behavior from botnets at the application layer

of the domain name system services. Deep learning frameworks to classify discriminate normal and abnormal behavior from the domain names.[37] Deep learning methods are involved to identify candidates for development of the services and its delivery processes. This solution reduces network traffic between the edge communication using node to node communication protocol. The communication between the fog and cloud layers uses computational solutions which are secured and reliable outperforming the traditional semi-cooperative and non-cooperative techniques.[38]

10 | CHALLENGES

It is evident from the aforementioned discussions that Deep learning is rapidly changing the way cities operate, support and maintain all possible amenities such as transportation, electricity, healthcare, connectivity and various others. But selection of the appropriate technology that would integrate effectively and efficiently with the smart city services remains to be a prominent challenge. The mindset of the administrative bodies to adopt to these technologies and incorporate them in the regular services and departments is also an important challenge. There exist pre-conceived notion on the initial investment of such technologies which would increase the budget. But once implemented it would lead to economically better output is also a fact that remains less understood. The time-sensitive applications in the smart city environment require real-time and also non real-time streaming of data. Development of frameworks that incorporate big data analytics and fast data analytics also acts as a challenge. There exist various machine learning algorithms[39] integrated in the smart devices, but most of them tend to be heavy-weighted. The need for light-weight ML algorithms for resource constrained devices ensuring security, privacy is another challenge to work on. The datasets used for deep learning applications are also sometimes not available readily and in enough size to confirm results through simulations.

11 | FUTURE DIRECTIONS

There are quite a few promising future directions in the implementation of deep learning and machine learning methods in smart cities. It is known that a training model provides accurate results when similar feature sets and distribution models form the training and testing data. Transfer learning is a future direction of research wherein the distribution of training and testing is altered or transferred from one platform to another. Researchers should also focus on integration of semantic technologies in smart city applications to enable better interaction of smart devices with the users of the same. The use of virtual objected integrated with DRL algorithms would help in creating virtual representations of physical objects so that the objects can function automatically. Lastly, usability of the smart devices play a significant role. The technologies and devices in smart cities are often mobile and wearable allowing minimal spaces for users to touch screens which lesser technically savvy users and aged citizens often find it challenging. Integration of speech recognition technologies allowing natural language understanding in smart devices is also a potential area of research. It is extremely important to understand that in the process of creating such intelligent devices it important that we do not end up creating islands wherein applications are created exclusively lagging non-integration with one another.

12 | CONCLUSION

In this article a review on application of Deep Learning on several aspects of smart city like smart urban modeling, intelligent infrastructures, smart transpotation, smart governance, sustainabilty, smart education, smart health solutions, security and privacy[40] is presented. Several challenges of using deep learning on smart city data are also highlighted. In the end future research directions on usage of deep learning on smart city applications are suggested.

CONFLICT OF INTEREST

The authors declare no potential conflict of interests.

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