Recent Trends & Technologies for Smart City Applications with Open Challenges

Nand Kishore Sharma
Amity School of Engineering & Technology, Amity University Chhattisgarh, Raipur, India
Department of Computer Science & Engineering

Surendra Rahamatkar
Amity School of Engineering & Technology, Amity University Chhattisgarh, Raipur, India
Department of Computer Science & Engineering

Abhishek Singh Rathore
Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, India
Department of Computer Science & Engineering

Abstract

This paper inspects current research opportunities in the field of Smart City applications. The subsequent technological jump is found in the field of IoT, Wireless Sensor Network, Machine Learning & Deep Learning and they are contributing to build city-applications such as surveillance, activity recognition, traffic management, etc. But these technologies are having their limitations that need to be addressed. In the city, the devices that are connected through the internet can communicate with each other without the direct involvement of humans, referred to as Smart Objects. These Smart Objects capture the data from their nearby surroundings for computations, so the objective is to use them securely and utilize them efficiently. Hence, various research opportunities come to process the various city-data. This paper offering an investigation of current research possibilities in smart city applications and the role of various technologies to outline the current research opportunities.

Keywords: - Deep Learning, Machine Learning, Smart City, Wireless Sensor Network, IoT, Surveillance, Smart Objects, Traffic Management.

I.INTRODUCTION

In this growing age of technology, many sensors and devices are being used as smart objects to capture the data and sense the phenomena on a single platform. These devices are embedded with software. Numerous devices are generating and collecting a huge amount of multi-media data (audio, images, and videos) from the city, and exchange it for communication and processing. For any type of activity recognition system or analysis, the system suggested multi-media data. The motive is the integration and management of all sensors and devices that are distributed and assembled. So that users can easily recognize and analyze the events from their neighboring events and able to access them remotely in real-time. The devices or sensors are considered as smart objects if they are having sufficient and necessary computation processing skills, these objects are identified by their name tag and address which is unique.

1.1 SMART CITY

The smart city is an innovative city and relies on the smart framework as represented in Fig. 1. This framework comprehends the physical infrastructure, networking system, centralized computing center, and data storage system (also responsible to create the replica of data), software applications & platforms, integration & security, and higher-level domain use-cases.

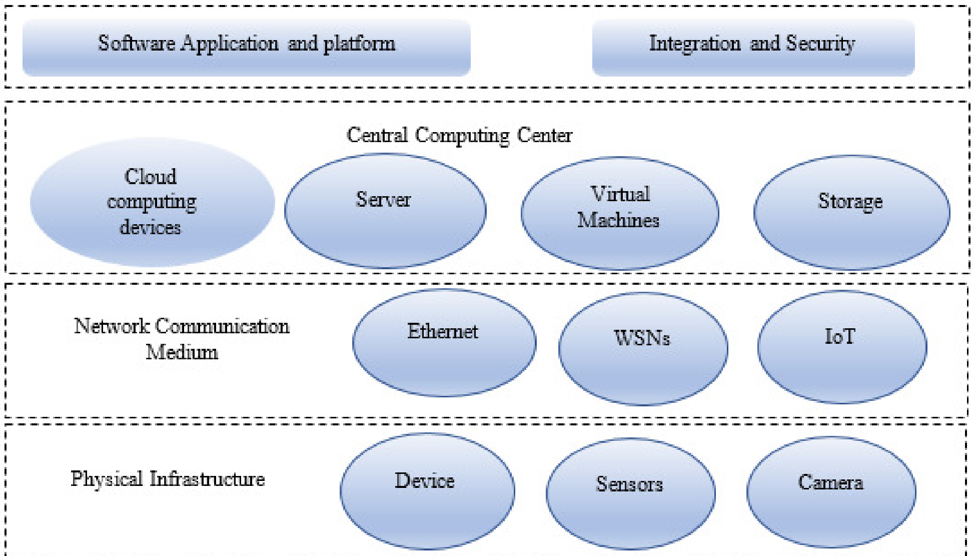

Fig. 1. Smart City framework.

The physical infrastructure requires- sensors, devices, and cameras to capture and generate the data. This data will be used for computation and storage at the central computation center for data processing. Several types of network channels or communication mediums such as- Ethernet, Wireless Sensor Networks (WSNs), Internet of Things (IoT), and Fiber optic cables can be used to send and receive the data from acquisition devices to central computing centers and vice-versa. The data is warehoused in the storage unit after processing through- a variety of servers, cloud computing devices, and virtual machines. Data is protected through a variety of network standard protocols, data security mechanisms, and APIs. Later, the domain use-cases also indicated as applications may be segmented into - Smart city infrastructure, Smart security solutions, and Smart network utilize the data to predict the outcome.

1.2 SMART CITY APPLICATIONS

Smart City applications are involved in every aspect of our daily life, but to make the system intelligent a well-structured network, smart management system and reliable information are required for quick decisions and responses. Many recent technologies like IoT, Wireless Sensor Network, Machine Learning, and Deep Learning are contributing to develop the Smart City applications. All segment-wise applications as mentioned in Table 1.

Table 1. Segment-wise applications.

Segments	Related reference	Applications
Smart city infrastructure	(Impedovo& Pirlo, 2020) (Bhattacharya et al., 2020) (Stübinger& Schneider, 2020)	• Centralized and integrated controlling • Smart mobility services. • Smart communication interface • Smart lightening system • Smart waste management system • Smart agriculture • Air pollution monitoring system • Adaptive traffic management
Smart security solutions	(Tsakanikas&Dagiuklas, 2018) (Chaudhary et al., 2018) (Tao et al., 2018) (Perwaiz et al., 2018) (Stübinger& Schneider, 2020)	• Integrated surveillance at an open and critical area • Road-side traffic management system • Object tracking and monitoring • Crime detection and monitoring system • Behavioral analysis of people • Abnormal vehicle driving • Activity recognition and classification
Smart network	(Ullah et al., 2020) (Feng et al., 2019) (Ha et al., 2020) (Zantalis et al., 2019) (Stübinger& Schneider, 2020)	• Quick response to emergency services • Road-side assistance • Quick medical and ambulance support for road accidents • Early warning dissemination system • Prevention from unauthorized network access, remotely monitoring and management of network devices

The city produces a massive amount of data from every function, that has some hidden insights about the surroundings. Fig. 2 showing the technologies involved in smart city applications.

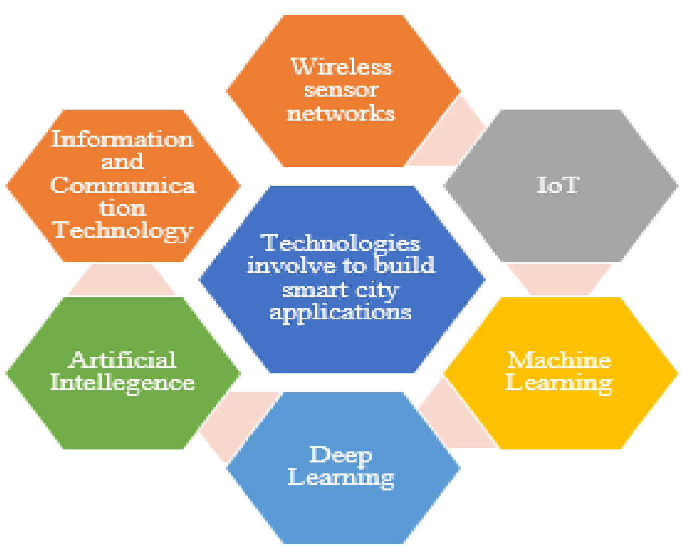

Fig. 2. Technologies involved to build the applications.

Every technology is having its framework for every smart city application. In this paper, the author is mainly focusing on deep learning techniques, Machine learning and IoT enabled with wireless sensors to provide the research directions while selecting the technology. In this research, the author is contributing to present-

- The technologies involved in smart city applications such as deep learning andmachine learning algorithms are used in smart city applications.
- Different types of city-data are used for processing.

1.3 DATA ANALYTICS FRAMEWORK

The smart city paradigm entirely depends on data, fusion data with upended communication technologies. Enormous challenges come in the data collection, analysis, and distribution to improve the quality of human life (Javed et al., 2017). From the data processing perception, understanding the data is highly required because the smart city application positions on the data and its analysis (Chen et al., 2019). The data analysis takes place in the four phases (Kang et al., 2019), (Yuan et al., 2020) as mentioned in Fig. 3. In Phase-I - data capture from the different sensors, Phase-II – pre-processing is applied for cleaning, Phase-III - various data analytics techniques may be used to find out the hidden insights, inference, pattern, and correlation. Finally, data is ready to produce the outcome and predictions.

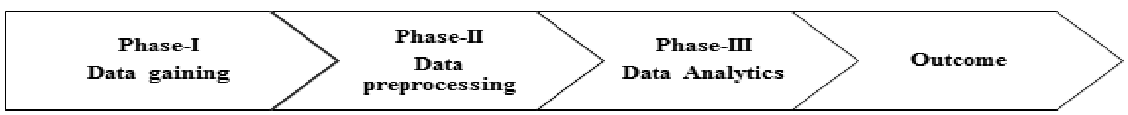

Fig. 3. Phases of data analysis.

II.LITERATURE REVIEW

2.1 Deep Learning

Deep Learning is a collection of Input layer, Hidden layer and Output layer. More hidden layers mean going much depth inside the network. As the data is a significant building block for the smart city, therefor various deep learning techniques are available for data security(Chen et al., 2021). Data are generated by various sources in the city and later that all are used by various deep learning models as represented in Fig. 4.

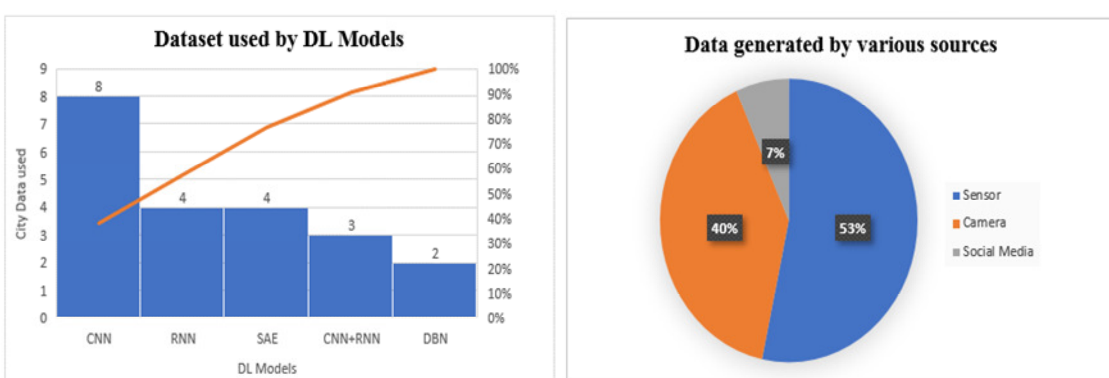

Fig. 4. (a) Dataset used by DL models (b) Data generated by various sources

Table 2 is summarizing the data (Chen et al., 2019), its representation with deep learning models.

Table 2. Outline of the data used by various deep learning models.

Data source	Type of generated data	Data representation	Data description	Deep Learning model
Camera	Vehicle image data, Vehicle license plate, Face, Parking space images.	2-D & 3- D matrix $\begin{matrix} a1,1 & \dots & a1,n \\ .. & .. & .. \\ am,1 & \dots & am,n \end{matrix}$	a is the data, n and m are the columns and rows, the number of rows and columns indicates the resolution of the image.	Convolutional Neural Network (CNN) SqueezeNet (Lee et al., 2019)
Sensors	Road-side vehicle traffic & speed of the vehicle, Human behavior & activity, Human movement	Time categorization data $\{ a_1,a_2,..a_{m...}a_T\}$ Vector [x1; x2;.;xn]	a is a sequence, a_m sequence at time interval m and T is the length.	Recurrent Neural Network (RNN), Stacked Auto Encoder (SAE), Deep Belief Networks(DBN) (Chang & Lu, 2020)

Deep learning has a very powerful tool and technologies those are found capable to deal with data cause and attacks as mentioned in Table 3.

Table 3. Deep Learning practices for data cause and attacks.

Parameters related to data	Deep Learning practices
Data Cause – • Trigerring Dataset • Data Classification • Reduce the dimension of data • Exploratory data analysis • Feature extraction	• Convolutional Neural Network • Generative Adversarial Network (GAN) • Long-Short Term Memory (LSTM) • Deep Brief Network • Restricted Boltzmann Machine
Attack detection & Prevention from attacks- • Phishing attack & detection • Network glitch detection • Intrusion detection • Fraud detection	• Recurrent Neural Network • Convolutional Neural Network • Generative Adversarial Network (GAN) • Long-Short Term Memory (LSTM) • Deep Brief Network • Restricted Boltzmann Machine

The surveillance applications are required where security matters, but manual surveillance looks tedious and time-consuming. In the city, it shelters almost all kinds of abnormal happenings, and surely be useful for theft identification, vehicle monitoring, and violence detection, etc. Still, video surveillance has a significant contribution to unstructured big data.

Video and audio recordings are effectively used as complementary mechanisms in existing surveillance systems to counter potential threats that may require the involvement of law enforcement officials. With the participation of multimedia sensors, it is possible to obtain more precise and concrete information. (AL Zamil et al. 2019), introduced a deep learning technique for predicting the class labels of actions at smart cities using four types of audio data (city crowed, home appliance, household items and sounds of human action). The methodology is based on developing the network topology by specifying the number of hidden layers and their neurons, selecting the appropriate features that hopefully distinguish data instances according to the existing class labels, and developing the MLP model using the back-propagation algorithm.

Evaluation of Experiments

The evaluation is based on - Accuracy, Precision, Recall, and F1 Score. To evaluate the result following values are required: (a) TP- True Positive, (b) TN- True Negative, (c) FP- False Positive, (d) FN- False Negative.Obtain the values through the above parameters-

Accuracy = (TP + TN) / (TP + FP + TN +FN)

Precision = TP / (FP + TP)

Recall = TP / (TP + FN)

F1 Score = (2 * Precision * Recall) / (Precision + Recall)

2.2 Machine Learning

Machine Learning is also known as a collection of advanced algorithms capable to perform the task without the direct involvement of human intervention. The algorithms such as K-nearest neighbours, K-means, Support vector regression, Support vector machine,Linear regression, Logistic regression,Random forest,Feed-forward neural network, decision tree, mainly deals with classification, regression, feature extraction clustering, and anomaly detection. All algorithms are used to process the smart city data (Mahdavinejad et al., 2018).

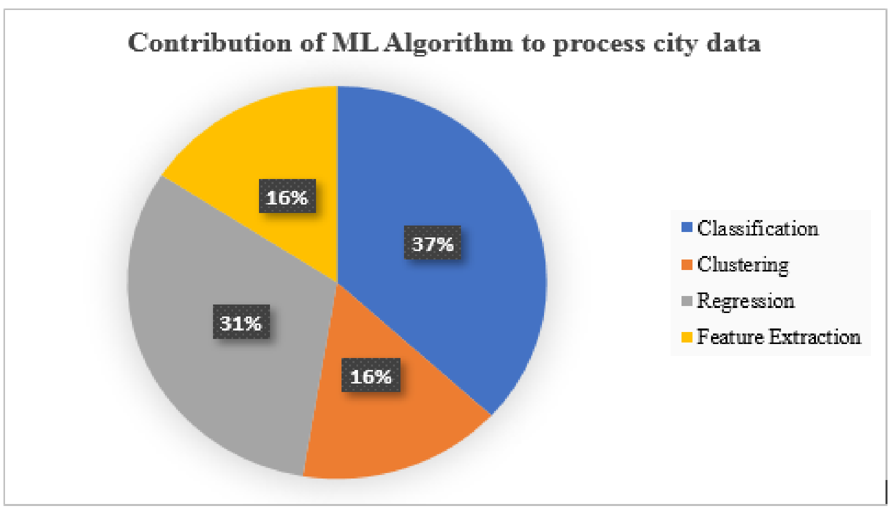

Fig.5. Contribution of a machine learning algorithm in city data analysis.

As shown in the above Fig.5, classification algorithms are mainly used to process the city-data. Classification is the process to assign the class to the input data, where a class can be referred to as target/labels/categories. For instance, the input vector is x, and k is any class then the discriminant function can be represented as Ck. A class can be assigned to input vector x via a discriminant function.

if f(x) > 0, then assigned class C1 to vector x, otherwise assign class C2 to vector x.

The discriminative model is also used for the same work, it acquires the posterior class probability denoted as – p (Ck | x) and uses to assign the class. The classification is referred to as predictive modeling, where a class label is assigned to input data. Fig.6 representing the types of classification and algorithms used in it with applications.

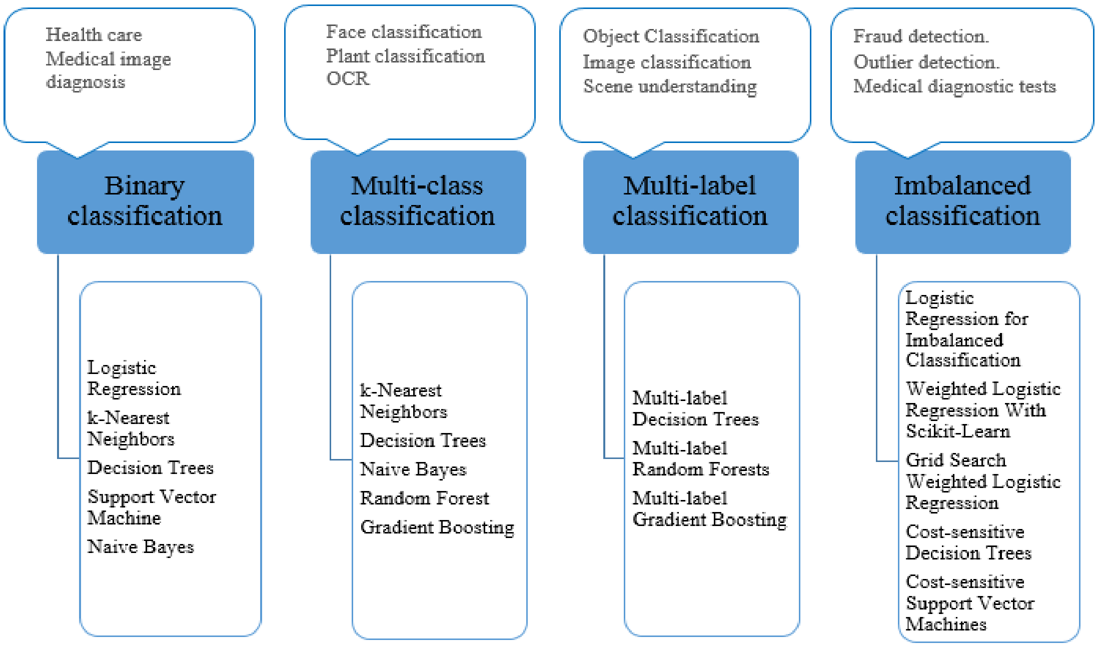

Fig. 6. Algorithm used for classification with applications.

Evaluation Parameters of The Classifier

Accuracy and Error rate are the metric to evaluate the performance of the classifier. Classification belongs to supervised; it means data is labeled. In the testing phase, during prediction, the accuracy is measured by Right Prediction (RP), and Total Predictions (TP). To calculate the error rate, count the Wrong Predictions (WP). The accuracy and Error rate are the complement each other.Accuracy: 1- Error rate, and Error rate: 1- Accuracy.

Accuracy = RP / TP (also represented in percentage by multiplying it by 100).

Hence-

Accuracy = (RP /TP) *100

Error rate = WP / TP, or Error rate = (1- (RP /TP)), also represented in percentage through-

Error rate = (1-(RP/TP)) * 100

Another method to evaluate the Accuracy as mentioned in the below Table 4, is the confusion matrix, which can be calculated via counting the sum of all cases as –

Table 4. Confusion matrix

	Positive Prediction	**Negative Prediction**
Positive Class	True Positive (TP)	True Negative (TN)
Negative Class	False Positive (FP)	False Negative (FN)

Accuracy = (TP + TN) / (TP + FN + FP + TN)

Error Rate = (FP + FN) / (TP + FN + FP + TN)

2.3 Internet of Things (IoT) and Wireless Sensor Network

Various wireless sensor network technologies are existing and use to build smart city applications, but among them, IPv6 over Low-Power Wireless Personal Area Network is found most promising. To send a very less amount of data with low-power energy-efficient protocols makes it suitable. The ZigBee is also popular just because of its low-cost computing power, the Bluetooth Low Energy (BLE) is mainly used in small range connectivity applications like smart homes, healthcare systems, hence it became the key technology. The traditional wi-fi signals are no longer useful for activity recognition because the signals can be modulated hence novel wireless sensor technologies may be used to recognize the activity, gestures, identification, and mobile object tracking. In this technology, there is no need to wear or carry the devices, because the devices can function to detect the actions remotely. The technology has grown and developed human-computer interaction devices like RFID, Radar, ultrasonic sensors, and cameras for intelligent communication. The architecture proposed by (Yazici et al., 2019), for a multilayer automatic surveillance system consisting of wireless multimedia and scalar sensors for outdoor applications. The data collected by scalar and multimedia sensors are processed and fused at three different layers. The generated data may be structured or unstructured hence there is a need to enhance Big data analytics. In IoT, there are six main elements to manage all activity (Gupta et al., 2016). Object-ID and address within the computer network are used for identification purposes. Electronic Product Codes (EPC) and Ubiquitous Codes (uCode) are some of the methods available for identification purposes and some addressing methods like IPv6 and IPv4 are used for addressing. All offerings are characterized into four classes (Gigli & Koo, 2011) as- Identity-related issues, Aggregation of services, Collaborative and Ubiquitous Services. Moreover, the security and confidentiality of data become the biggest challenge (Mavropoulos et al., 2017). Due to the need for heavy and real-time computation energy-efficient systems are required (Khan et al., 2012). Although numerous studies have been conducted regarding green communication technologies (Barker &Hammoudeh, 2017). More precisely, all emerging technologies for supporting wide-area Machine-to-Machine (M2M) networks, are grounded on IoT devices (Dhillon et al., 2017), attentive to the standards for data communications, services, and support for Machine-to-Machine (Gazis, 2017). The technologies involved in IoT technology provide many opportunities and facilitates to implementation of its applications (Triantafyllou et al., 2018). In service-based architecture, middleware is accountable to provide the deployment of devices as a service (Ngu et al., 2016). Internet of Things technology is grounded on WSNs, the resources used in this technology are limited and expensive (Mamdouh et al., 2018). More robust measures must be taken to allows system developers to advance their methods for better security mitigation (da Costa et al., 2019), (RadoglouGrammatikis et al., 2019) defined four-layer communication architectures that contain- Perception Layer, Communication Layer, Support Layer, and Business Layer. (Fan et al. 2018), predicted that citywide human mobility is critical, during effective management and regulation of city governance, especially during a rare event. In general, there are two broad categories for human mobility: routine human mobility and irregular human mobility. Routine human mobility takes up a large proportion of an entire historical dataset. Thus, making an accurate prediction of routine human mobility guarantees that a system will function for most of the time.

III. DISCUSSION &OPEN CHALLENGES

In the audio dataset, the distribution of data is playing a vital role. The audio data are captured from different sources so there is a possibility that the captured data may be complete or incomplete or not enough to extract the information. In this situation, the correlated data should be used to extract the information which can work on behalf of missing or weak audio data.However, fusing image data with audio data will surely increase the success rate. The combination of different information search modalities (fusion) will provide more accurate results than a single modality.The collection of meaningful data, the fusion of data, processing of data, to find out the hidden insights and correlation between the data constituted a major field of research. The challenge is to handle this massive amount of data, because the complete performance is straight proportionate to the features of the data and its management service. The deep learning & machine learning technique is suitable as discussed in this paper, because it does not need human intervention, but they also have own constraint - Resources & computation limitations. Plenty of human-computer interaction devices are exist and commonly used for computations but still, they are having limitations such as range and natural or artifact phenomena. Analyzing and Monitoring information on networks should be timely. The smart city network architecture is an inter-connection of many smart objects, So, it is enforced to have an effective naming and identification system. There must be a mechanism to allow the object to describe itself with the help of their nearby accumulated sensors and devices to enhance the processing. Each Smart object involved in the system should be thinking like a human. In smart mobility, energy-efficient accurate object detection and classification, the fusion of data, scalar data, and advanced sensor nodes are required. New effective models and algorithms are required for data integration and management.

IV. CONCLUSION

This paper conducted a detailed analysis to compare and discussed various suitable technologies that are involved with smart city applications. In all applications, there are huge research opportunities available. Every existing technology like Deep learning, Machine learning, Wireless sensor networks, Internet of Things that desire to be involved in the advancement of the computing paradigm of the smart city should be aiming to drop the energy consumption to provide an enhanced and effective solution for real-world and real-time challenges. All existing technologies discussed in this paper founds fit somewhere as the elementary requirements but still having some issues and need to be taken care of to provide solutions for explicit applications. Through the research conducted in this paper, the author addressed the need for data fusion and collection to provide a better result for smart city applications and offerings. The research directed in this paper can assist scholars and professionals and motivates them towards developing a new and more efficient model, algorithm, and smart devices to fill the existing gaps. And, also deal with the important deficiencies, that are discussed in this paper.

References

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications. *IEEE Communications Surveys & Tutorials*, *17*(4), 2347-2376. https://doi.org/10.1109/comst.2015.2444095.

Barker, P., &Hammoudeh, M. (2017). A Survey on Low Power Network Protocols for the Internet of Things and Wireless Sensor Networks. *Proceedings Of The International Conference On Future Networks And Distributed Systems*. https://doi.org/10.1145/3102304.3102348.

Bhattacharya, S., Somayaji, S., Gadekallu, T., Alazab, M., &Maddikunta, P. (2020). A review on deep learning for future smart cities. *Internet Technology Letters*. https://doi.org/10.1002/itl2.187.

Chang, G., & Lu, H. (2020). Integrating Gray Data Preprocessor and Deep Belief Network for Day-Ahead PV Power Output Forecast. *IEEE Transactions On Sustainable Energy*, *11*(1), 185-194. https://doi.org/10.1109/tste.2018.2888548.

Chaudhary, S., Khan, M., & Bhatnagar, C. (2018). Multiple Anomalous Activity Detection in Videos. *Procedia Computer Science*, *125*, 336-345. https://doi.org/10.1016/j.procs.2017.12.045.

Chen, D., Wawrzynski, P., &Lv, Z. (2021). Cyber security in smart cities: A review of deep learning-based applications and case studies. *Sustainable Cities And Society*, *66*, 102655. https://doi.org/10.1016/j.scs.2020.102655.

Chen, Q., Wang, W., Wu, F., De, S., Wang, R., Zhang, B., & Huang, X. (2019). A Survey on an Emerging Area: Deep Learning for Smart City Data. *IEEE Transactions On Emerging Topics In Computational Intelligence*, *3*(5), 392-410. https://doi.org/10.1109/tetci.2019.2907718.

da Costa, K., Papa, J., Lisboa, C., Munoz, R., & de Albuquerque, V. (2019). Internet of Things: A survey on machine learning-based intrusion detection approaches. *Computer Networks*, *151*, 147-157. https://doi.org/10.1016/j.comnet.2019.01.023.

Dhillon, H., Huang, H., & Viswanathan, H. (2017). Wide-area Wireless Communication Challenges for the Internet of Things. *IEEE Communications Magazine*, *55*(2), 168-174. https://doi.org/10.1109/mcom.2017.1500269cm.

Fan, Z., Song, X., Xia, T., Jiang, R., Shibasaki, R., &Sakuramachi, R. (2018). Online Deep Ensemble Learning for Predicting Citywide Human Mobility. *Proceedings Of The ACM On Interactive, Mobile, Wearable And Ubiquitous Technologies*, *2*(3), 1-21. https://doi.org/10.1145/3264915.

Feng, C., Arshad, S., Zhou, S., Cao, D., & Liu, Y. (2019). Wi-Multi: A Three-Phase System for Multiple Human Activity Recognition With Commercial WiFi Devices. *IEEE Internet Of Things Journal*, *6*(4), 7293-7304. https://doi.org/10.1109/jiot.2019.2915989.

Gazis, V. (2017). A Survey of Standards for Machine-to-Machine and the Internet of Things. *IEEE Communications Surveys & Tutorials*, *19*(1), 482-511. https://doi.org/10.1109/comst.2016.2592948.

Gigli, M., & Koo, S. (2011). Internet of Things: Services and Applications Categorization. *Advances In Internet Of Things*, *01*(02), 27-31. https://doi.org/10.4236/ait.2011.12004.

Gupta, S., Sharma, N., & Dave, M. (2016). Internet of Thing: A Survey on Architecture and Elements. *International Journal Of Engineering And Management Research (IJEMR)*, *6*(5), 239-242. Retrieved 26 February 2021, from.

Ha, N., Xu, K., Ren, G., Mitchell, A., &Ou, J. (2020). Machine Learning-Enabled Smart Sensor Systems. *Advanced Intelligent Systems*, *2*(9), 2000063. https://doi.org/10.1002/aisy.202000063.

Impedovo, D., & Pirlo, G. (2020). Artificial Intelligence Applications to Smart City and Smart Enterprise. *Applied Sciences*, *10*(8), 2944. https://doi.org/10.3390/app10082944.

Javed, B., Iqbal, M., & Abbas, H. (2017). Internet of things (IoT) design considerations for developers and manufacturers. *2017 IEEE International Conference On Communications Workshops (ICC Workshops)*. https://doi.org/10.1109/iccw.2017.7962762.

Kang, Y., Yang, B., Li, H., Chen, T., & Zhang, Y. (2019). Deep Spatio-Temporal Modified-Inception with Dilated Convolution Networks for Citywide Crowd Flows Prediction. *International Journal Of Pattern Recognition And Artificial Intelligence*, *34*(08), 2052003. https://doi.org/10.1142/s0218001420520035.

Khan, R., Khan, S., Zaheer, R., & Khan, S. (2012). Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges. *2012 10Th International Conference On Frontiers Of Information Technology*. https://doi.org/10.1109/fit.2012.53.

Kortuem, G., Kawsar, F., Sundramoorthy, V., & Fitton, D. (2010). Smart objects as building blocks for the Internet of things. *IEEE Internet Computing*, *14*(1), 44-51. https://doi.org/10.1109/mic.2009.143.

Lee, H., Ullah, I., Wan, W., Gao, Y., & Fang, Z. (2019). Real-Time Vehicle Make and Model Recognition with the Residual SqueezeNet Architecture. *Sensors*, *19*(5), 982. https://doi.org/10.3390/s19050982.

Mahdavinejad, M., Rezvan, M., Barekatain, M., Adibi, P., Barnaghi, P., &Sheth, A. (2018). Machine learning for internet of things data analysis: a survey. *Digital Communications And Networks*, *4*(3), 161-175. https://doi.org/10.1016/j.dcan.2017.10.002.

Mamdouh, M., Elrukhsi, M., & Khattab, A. (2018). Securing the Internet of Things and Wireless Sensor Networks via Machine Learning: A Survey. In *2018 International Conference on Computer and Applications (ICCA)* (pp. 215-218). Beirut, Lebanon; IEEE. Retrieved 26 February 2021, from https://ieeexplore.ieee.org/document/8460440.

Mavropoulos, O., Mouratidis, H., Fish, A., &Panaousis, E. (2017). ASTo: A tool for security analysis of IoT systems. *2017 IEEE 15Th International Conference On Software Engineering Research, Management And Applications (SERA)*. https://doi.org/10.1109/sera.2017.7965757.

Ngu, A., Gutierrez, M., Metsis, V., Nepal, S., & Sheng, M. (2016). IoT Middleware: A Survey on Issues and Enabling technologies. *IEEE Internet Of Things Journal*, 1-1. https://doi.org/10.1109/jiot.2016.2615180.

Perwaiz, N., MoazamFraz, M., & Shahzad, M. (2018). Person Re-Identification Using Hybrid Representation Reinforced by Metric Learning. *IEEE Access*, *6*, 77334-77349. https://doi.org/10.1109/access.2018.2882254.

RadoglouGrammatikis, P., Sarigiannidis, P., &Moscholios, I. (2019). Securing the Internet of Things: Challenges, threats and solutions. *Internet Of Things*, *5*, 41-70. https://doi.org/10.1016/j.iot.2018.11.003.

Stübinger, J., & Schneider, L. (2020). Understanding Smart City—A Data-Driven Literature Review. *Sustainability*, *12*(20), 8460. https://doi.org/10.3390/su12208460.

Tao, D., Guo, Y., Yu, B., Pang, J., & Yu, Z. (2018). Deep Multi-View Feature Learning for Person Re-Identification. *IEEE Transactions On Circuits And Systems For Video Technology*, *28*(10), 2657-2666. https://doi.org/10.1109/tcsvt.2017.2726580.

Triantafyllou, A., Sarigiannidis, P., &Lagkas, T. (2018). Network Protocols, Schemes, and Mechanisms for Internet of Things (IoT): Features, Open Challenges, and Trends. *Wireless Communications And Mobile Computing*, *2018*, 1-24. https://doi.org/10.1155/2018/5349894.

Tsakanikas, V., &Dagiuklas, T. (2018). Video surveillance systems-current status and future trends. *Computers & Electrical Engineering*, *70*, 736-753. https://doi.org/10.1016/j.compeleceng.2017.11.011.

Ullah, Z., Al-Turjman, F., Mostarda, L., & Gagliardi, R. (2020). Applications of Artificial Intelligence and Machine learning in smart cities. *Computer Communications*, *154*, 313-323. https://doi.org/10.1016/j.comcom.2020.02.069.

Yazici, A., Koyuncu, M., Sert, S., & Yilmaz, T. (2019). A Fusion-Based Framework for Wireless Multimedia Sensor Networks in Surveillance Applications. *IEEE Access*, *7*, 88418-88434. https://doi.org/10.1109/access.2019.2926206.

Yuan, H., Zhu, X., Hu, Z., & Zhang, C. (2020). Deep multi-view residual attention network for crowd flows prediction. *Neurocomputing*, *404*, 198-212. https://doi.org/10.1016/j.neucom.2020.04.124.

Zantalis, F., Koulouras, G., Karabetsos, S., &Kandris, D. (2019). A Review of Machine Learning and IoT in Smart Transportation. *Future Internet*, *11*(4), 94. https://doi.org/10.3390/fi11040094.