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Smart City Surveillance: Survey on Current Status and Future Trends

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***Abstract*—This paper presents a comprehensive survey on surveillance and security aspects of a smart city. Multiple dimensions of a smart city surveillance system have been discussed. The current trends and methodologies are thoroughly researched and presented. The algorithms of novel methods are reviewed along with analytics and methodologies. Impact of XAI in the smart city surveillance is discussed. Advantages and disadvantages of current infrastructures have been included in the broad literature survey. Lastly, the challenges and future trends are conferred to.**

***Index Terms*— smart city, XAI, video surveillance, security, IOT, flood monitoring.**

I. INTRODUCTION

A. History of Video Surveillance

Video surveillance as a whole or a component of a smart city system is not a novel notion. It has been a core component of a smart city system and has evolved immensely over the decades. As mentioned in literature, the surveillance systems started with video cameras being a rare component of surveillance systems. The CCTV cameras were analogue. For large systems with the usage of multiple surveillance cameras, each camera used to be connected to a separate video device. Later, advancements in terms of manual control such as pan, tilt and zoom were added. Around two decades later, a major breakthrough in terms of color and digital monitors and digital cameras with digital encoding and compression for storage as well as transmission was introduced. Thus, surveillance systems became much more cost effective, and usage amongst the common masses also started.
In the last two decades, research in the field of Artificial Intelligence and thus computer vision has exploded and been successfully applied in surveillance systems, functionalities such as context aware data analytics, object detection, anomaly detection, behavior analysis, violence monitoring, smart monitoring and control, making a paradigm shift from manual, to semi- automated, to fully automated surveillance systems [1][2].

B. Smart City System

With the growing population and rush in lifestyle, it was required that technology be incorporated in the systems and intelligently interconnect them over the internet, providing ease of access to the citizens and efficient workflow.
A Smart City involves three major steps, namely Urbanization, Economic Globalization, and Economic transformation to a knowledge-based economy.
Incorporation of Information and Communication Technologies to make cities 'smarter' and interconnected over the internet, reforming the city's management and resources, is the prime objective of a smart city. The system

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uses internet technologies, service infrastructure and network applications to upgrade a city's services and functioning [3].
The major stakeholders of a smart city are the government, the public and the industrial sector. A smart city infrastructure depends on two major components, namely physical environment and technology and data. From amongst the two, technology is the most basic requirement for the development of a smart city [4].

C. Internet of Things (IOT) in Smart Cities

Internet of things (IoT) is the infrastructural base of a smart city system. It comprises of sub-systems intelligently connected to one another. Sub-systems which incorporate technology are the following:

a. Services of general interest
b. Public order
c. Law enforcement and control
d. Culture and heritage preservation and maintenance
e. Healthcare services
f. General community welfare services
g. City administration and management
h. Traffic control and management
i. Environmental sustainability and pollution control
j. Information processing and data analytics

Video Surveillance is a key component of a smart city system, which monitors the complete ongoing activities of a city. It includes complete monitoring of a city's public places for security. With digital cameras and monitors, as well as the use of Artificial Intelligence algorithms, the video surveillance system of a city has advanced multiple folds.
Video surveillance at the core is a three-step process: video acquisition, data processing and decision making. They could be both day and night cameras, though one featuring both is preferred. Other than the cameras, the system consists of a monitor, a Network Video Recorder (NVR), and a storage device.

II. LITERATURE SURVEY

M.Ahmed Ezzat et al. [8] comprehensively marked progressing smart city environment created by edge computing development, and open research challenges, on contrary the current surveys. Their principal contribution is that it integrated the latest edge computing technologies in the area of smart cities and also instantiated the latest Video Surveillance enhancements to each aspect and discussed the literature on current fields in computer vision applications such as People Counting, Age and Gender Estimation, Action Recognition, Fire and Smoke Detection and Vehicle Detection and provided an absolute outline of the last used datasets by giving a quick description of each dataset.
M. Rashmi et al. [6] devise a human action recognition system based on 3D skeleton model, and a deep learning framework of the same. Human Action Recognition (HAR) is used in smart video surveillance, home monitoring, etc. With the advent of low-cost depth sensors, data is stored in terms of joint coordinated of a person than being stored as an action. This requires significantly less storage and is robust.
G. B. Praveen et al. [26] review the challenges in the Face Recognition (FR) Technology for surveillance of smart cities. FR is an important tool for both biometric and surveillance for security. The method is both non-invasive and low cost. Applications include smart healthcare for hospitals and elderly care home to use FR to track patients, manage medication, and diagnosis and for other applications like staff identification.
H. B. Pasandi et al. [18] propose a platform for conjoin intelligent cross camera video analytics. Some of the current approaches for vision algorithms to make them compatible to IoT devices with limited resources are Downsized ML models, like model compression and designing hardware accelerators, Enhancing Edge resources to require low latency and high privacy and Workload offloading, enabling to choose between local device or cloud to work on a DNN model.
S. Jain et al. [7] proposed an advanced smart city model that contains smart home that meets security characteristic, system, automated streetlights and smart waste management. It also implements gun detection from CCTV footage utilizing neural networks implicitly CNN (Convolution Neural Network) model, image classifier and object detection. It trains a neural network and renders an alarm to apprise potential gun violence to generates an image classifier.

N.S. Mahajan et al. [19] discussed about the security issue in the surveillance. The paper implements abnormal activities detection car parking system, crowd estimation and early fire events detection. It overcomes the existing problems by generating alerts. The system follows the steps which are collection of video sequences, video processing, event identification, abnormal event detection and alert generation. The events are signified using motion and shape features excerpted from video frames.

Abdullah Alshammari et al. [9] concentrate on the security aspect of a smart city automatically as a person can't manually sit and detect abnormal activities every minute. The approach explained in the paper is able to detect human target that might be unusual from the videos collected from the cameras and then a decision-making process identifies whether it is a threat or not.

J. Wang et al. [12] have devised a novel method to recognise a vehicle type using labels from web data. This saves the manual labelling effort of training data. The task of a devising a low cost and effective vehicle monitoring system is challenging due to only slight differences in vehicle appearances and the large distance of cameras from vehicles. The proposed architecture is based on deep CNN model, AlexNet consisting of five convolutional layers and is based on the concept of transfer learning.

L. Hu et al [15] propose an automated object detection algorithm for urban surveillance systems in smart cities, the focus being on smart vehicle license plate recognition and vehicle detection, to provide smart transportation and surveillance. This requires automated object detection techniques to identify vehicles. For vehicle number plate recognition, the unique identification number of the vehicle is extracted from the number region of the number plate.

V. Tsakanikas et al. [20] aim to document the current status of smart city video surveillance systems and the future trends. The video surveillance systems matured in three stages. Analog CCTV cameras in generation 1, introduction of semi-automated functionalities in generation 2 and fully automated wide area surveillance systems in generation 3. From amongst the diversified video sensors available, offering different functionalities, the oldest are the analog video sensors. Several knowledge extraction algorithms are used in the surveillance system to utilize the acquired data for information. These include face detection and recognition algorithms, from the field of computer vision among others. Some algorithms to enhance the quality of video streams, such as foreground/background identification and image/video quality enhancement have also been implemented.

Y. Fan et al. [10] aimed to present a novel early event detection method intended to trigger an alarm to an anomaly, in the minimum possible time frame, before the event ends. The system uses deep learning techniques. The authors made use of a sole image that signify the total temporal circumstance, based on dynamic images obtained by directly applying Rank Pooling to raw image pixels of a video. Thus, in this method, only one image has the ability to capture both appearance and temporal advancement of information in a video clip simultaneously.

Calvillo et al. [14] stated their smart city to be a sustainable and energy-efficient metropolitan centre in a Green and Sustainable Science and Technology classification. It stated that a sustainable city should upgrade resource management and bestow an elevated standard of life. In this scenario, it made use of simulation modelling to evaluate technical and policy outcomes of smart solutions.

III. Impact of XAI in Smart City

XAI stands for Explainable Artificial Intelligence which is one of latest emerging branches of Artificial Intelligence. XAI deals converting the black box models to white box or glass box by providing transparency and interpretability. It provides insights of how a machine learning model makes decisions of its outcomes. A model delivering highest accuracy and efficiency does not ensure that it will have good explainibility.

XAI can be very well incorporated in smart city development as it will reduce the human dependency and providing explanations of the results an AI module makes. A. Alshammari et al in the paper [22] proposed a mass surveillance system in healthcare to resolve medical issues like the COVID-19 pandemic. It provided with a method by taking multimodal data source as input and classifying the patients into categories of covid-19 patient and normal using the confidence score from the outcome. LIMA (Local Interpretable Model Agnostic) algorithm is utilize for applying XAI. It then applied knowledge mapping and graphs to generate explanations in form of visualizations of the X-Ray. It will help in reducing the overcrowding at places like hospitals, pathologies etc. XAI reduces the burden of health workers and physicians as the results of the disease is provided along with the reasons of why a disease has occurred.

D Thakker et al. in the paper [23] proposed a hybrid model making use of Explainable Artificial Intelligence to resolve the issue of drainage blocking and flood monitoring in smart cities. It is making use of Convolution

Neural Network and then applying semantic rules to classify images into 3 categories namely, partially blocked, fully blocked and no blockage.
D.L. Marino et al. in the paper [19] proposed a model to perform intrusion detection. Most of the models of deep learning for cyber security are categorized as black box models. To reduce the complexity and enhance the understandability adversarial machine learning can be used. It takes the misclassified samples as input and modify them until successful classification using adversarial approach and the explanations for the misclassification are provided in the form of deviation plots.

IV. Article Selection and Comparison

Various definitions of the phrase of smart city have been proposed in different journal articles belongs to different journal groups in the Web of Science since 2015. Given the importance of smart cities in the scientific area and real-world solicitation, the paper collected the pertinent studies between 2015 and 2020 in the ongoing literature and conferred in Table1.The definitions found mostly relate to the priorities and the characteristics of a smart city. The paper delineated a comprehensive literature grid for applications of smart cities based on evolutions of smart city themes, proposed methods, benefits, and limitations. Moreover, the chief key point of each article with distinguishing methodologies is provided in the literature table I.

V. Current Research Challenges and Future Direction

In spite of the possible benefits of the Smart City surveillance systems, they are hindered by various critical provocations and restrictions that need additional research in the upcoming time. This section sums up the ongoing research challenges and future regulations as follows:

A. Privacy

Smart city applications collect and store enormous amount of user data, thereby putting the user privacy at risk. In case of identification applications such as face recognition, the complete privacy of a citizen is at stake. Though the issue of privacy has been raised, no significant measures have been taken to resolve it. Also, the elevated reliance of smart cities' surveillance systems on shared facts needs accurate awareness to the power of those systems to be strong against various attacks.

B. Security

The IoT applications are vulnerable to several attacks. Even though some measures have been taken to enhance the security of smart city applications, the problem has not been completely resolved.

C. Reliability

Owing to the network issues in some places, the smart city applications may not be reliable enough. For example, tracking a vehicle using GPS may not be a very effective method. Furthermore, real time monitoring using surveillance cameras may be a challenge in such a scenario. For future work the paper suggests utilizing numerous conceptual study and building resolution-constant feature descriptors to obtain the high level of accuracy.

D. Data Management

A big problem of smart city system is Big Data. An enormous amount of data is collected. Even though measures have been proposed to reduce this data amount and manage it, none has been effective enough to bring into practice.

E. Cost

The cost of effective smart city surveillance is still a challenge. There is a trade-off between functionality and cost. For a smart surveillance system, the cost is still an unresolved issue. There is a need of a system that is both cost effective and rich in functionality. In the upcoming years, the paper proposes enhancing the IoT low-cost traffic surveillance system through its connection with the cloud to supply additional characteristic to the system, like imparting number plate recognition and conferring online receipts.

F. Real-time analysis and prediction

There is an essential need to enhance the performance of real-time analysis in smart cities' surveillance systems in order to prevent upcoming disastrous events from occurring. Some techniques are developed to assist overcoming this challenge. Apart from that, it is recommended that not only inspect past or real-time events but also predict future events.

G. Scalability

It has grown to be an important factor to take into account when evaluating any system. Many systems struggle with scalability issues when attempting to utilise the most recent hardware, network, and computing capabilities. The scalability of intelligent surveillance systems could therefore be substantially improved and enhanced by additional research towards a more reliable Smart city Surveillance systems.

Each category of the research trends considered earlier has its own goals, benefits, and challenges. Table 1 provides a comparison between the different ways in terms of their themes, Reference, Year, Proposed Method, Advantage and Limitation.

TABLE I. SCIENTIFIC STUDIES IN SMART CITIES

Ref	Year	Themes	Proposed Method	Advantage	Limitation
Rashmi M. et al [6]	2020	3D- HAR, Smart City, Smart Surveillance	Deep Neural Learning Model	reduced the computational cost and also demonstrated promising performance	Can't differentiate multi subject human actions.
Shubham Jain et al. [7]	2019	Internet of Things (IoT), Deep Leaning, Smart City, Smart Home, Smart Waste Management System, Smart Streets	Data Analysis and Simulation	A methodological image classifier with lower energy, bandwidth over heads and latency, and provide better accuracy which ensures better privacy	Does not integrate other types of IoT nodes/sensors such as audio, motion, etc.
Esposte et al. [8]	2019	Inter smart city	Smart city simulator	capable of scaling horizontally up and down to handle a changing workload	does not allow for experiments across domains and does not incorporate other smart city scenarios.
Abdullah Alshammari et al. [9]	2019	smart city, surveillance, IoT.	object detection from a video stream	Multi-camera video surveillance system to automate the video monitoring and to minimize the human involvement for monitoring	N/A
Yaxiang Fan et al. [10]	2018	Video surveillance	Deep Learning using VGG-16	Fast detection of anamoly even before the event is terminated.	Only a single detection either fall detection or violence detection and cannot detect multiple actions.
Navarro and Macro et al [11]	2018	Smart Governance	PEST (Political, Economic, Social and Technological) analysis	Presents fresh patterns in urban governance as well as more specific information about the performance of complicated networks.	N/A
Jitian Wang et al [12]	2018	Convolutional Neural Networks, Vehicle type recognition, surveillance images, Smart City	Simulation and scenario analysis	highly suitable for real-world vehicle type recognition.	Does not used for large-scale annotated web-nature data
Yeh et al [13]	2017	Smart citizens, smart living	Self-administered questionnaire	Embarks on smart City initiatives	Data collecting on demographics that is not official.
Calvillo et al. [14]	2016	Smart energy, smart grid	Energy system modelling	one of the best solutions at a low cost that promotes wiser, more effective cities.	Selection of system parameters and energy constraints.
Ling Hu et al. [15]	2016	Urban surveillance, smart city	IOT with Digital Image Processing	Automatically detects object vehicles fast and accurately and lowers the storage volume of Big Data	N/A
Z. Shao et al. [16]	2016	Smart Camera, video surveillance	Big Data and Data Mining	Pre-alarms abnormal behaviour and gives alarms by analysing	N/A

				big video data using front ed Smart camera	
Anagnostopoulos et al. [17]	2015	Smart Waste Management	Simulation and dynamic waste collection architecture.	Dynamically responds to change in the production of waste in high priority areas.	Unexpected circumstances including worries about waste production

VI. CONCLUSION

Currently, the automation and security are given the highest priority in every industry as well as in housing societies. The paper is focused on reviewing the new technologies that arise with coming years from the past. Some papers focused mainly on the use of sensors in the home automation while some focused on the secure communication platform. The concept of smart streets is also booming as maintaining traffic in big cities is toilsome. A capillary video surveillance platform is proposed which provides striking features for video capturing and surveillance The prime aim of this research was to uplift apprehension of the scientific community about the ongoing position of the smart city concepts disclosing its crucial future trends, which incorporates floating cities utilizing IoT technologies and applications. The paper also described the ongoing advances of scientific studies and the possible implementation of current research challenges on different smart city concepts to lead the potential research communities regarding the latest advancement in the field of intelligent surveillance systems for smart cities.

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