Intelligent Surveillance Systems for Smart Cities: A Systematic Literature Review

Nour Ahmed Ghoniem, Samiha Hesham, Sandra Fares, Mariam Hesham, Lobna Shaheen, and Islam Tharwat Abdel Halim

Abstract The concept of smart cities is emerging rapidly with the objectives of using the technology to enhance the efficiency and quality of services provided to the population in such cities. Due to the importance of having continuous and uninterrupted urban space monitoring, many studies have been carried out to propose. Several research topics have already been explored related to. However, given the variety of problems and solutions, it is complex to identify research trends and gaps related to intelligent surveillance systems for smart cities without a systematic review. Therefore, this paper presents a systematic literature review of such a topic. The review revealed current research trends, challenges, and future directions in the area of intelligent surveillance systems. This work provides a list of references to find the mapped papers, thus paving the way for enhancing the efficiency, reliability, and robustness of such systems.

Keywords Internet of things (IoT), Computer Vision, Cloud and Edge Computing, Digital Image and Video Processing, Security and Privacy**.**

1. Introduction

Nowadays, 'Smart City' is a development goal for many cities around the world. The concept of a smart city has been developed by "the implementation of digital technologies in different aspects of urban management and is considered as one of the pillars of the Industry 4.0" [1]. The ultimate goal of a smart city is to create a new urban management perspective that focuses on all aspects of urban real life. In recent times, there has been a lot of research done showing that the surveillance systems are of vital importance for such smart cities. This is justified because the surveillance systems can be considered vision organs of the smart city [2]. Thus, the design of the surveillance systems for a smart city must itself be smart.

In traditional surveillance systems, human operators are the main responsible to manipulate the processing of captured video [3]. Certainly, future smart cities will generate and process an immense volume of data [4]. Hence, various forms of sensing devices (smart vehicles, traffic lights, smartphones, etc.) that are present almost everywhere

I.T.A. Halim
e-mail: Islam.tharwat@miuegypt.edu.eg
Faculty of Computer Science, Misr International University (MIU)

N.A. Ghoniem
e-mail: nour1704021@miuegypt.edu.eg

S. Hesham
e-mail: samiha1707594@miuegypt.edu.eg

S. Fares
e-mail: sandra1701421@miuegypt.edu.eg

M. Hesham
e-mail: mariam1703061@miuegypt.edu.eg

L. Shaheen
e-mail: lobna.mostafa@miuegypt.edu.eg

nowadays can be utilized to develop efficient surveillance systems and urban space monitoring for smart cities. Accordingly, intelligent surveillance systems have been gaining a lot of attention from the scientific community for promising advances in smart cities.

Intelligent adoption of surveillance systems could protect, direct, manage, and influence human beings and property [5]. Nevertheless, several problems such as data quality, privacy, government support, security, and computing paradigm. Hence, to understand the state of the art in studies of such systems, we conduct a systematic literature review that aims to help researchers to identify trends and saturated themes in scientific works published in the last 5 years. We use the insights from the review to understand and outline the perspective for the current research trends, challenges and limitations, and future directions of intelligent surveillance systems and urban space monitoring in smart cities.

The layout of the rest of the paper is as follows. Section 2 delineates the research methodology of this work. The perspective for the current research is discussed in Section 3. Section 4 outlines the current challenges and future areas of exploration on this topic. Finally, Sections 5 provides concluding remarks.

2. Methodology

The main objective of this section is to present the process adopted to perform an unbiased review of the intelligent surveillance systems for smart cities. The systematic review methodology adopted in this work is based on the study of Kitchenham [6]. As depicted in Figure 1, the process is composed of four stages: definition of scope, identification of resources, selection of papers, and categorization and information extraction. Regarding the scope, we elaborated questions to conduct the searches, while in conducting the search, strategies were outlined.

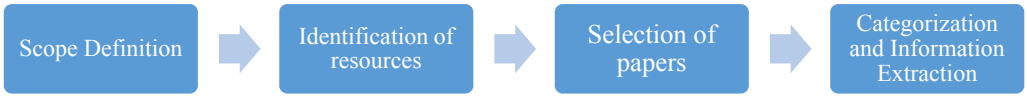

Fig. 1 Stages of Systematic Review.

2.1. Scope Definition

This stage aims to elaborate on the Research Questions (RQ), which delimit the scope of work. This review focuses on the following research questions to be better suited for the objectives and the purposes of this review:

RQ1: What are the general research trends of the papers that address the topic of intelligent surveillance systems in the context of smart cities?

RQ2: What are the current challenges and limitations of the proposed intelligent surveillance systems in the literature?

RQ3: What are the future research directions for this topic?

2.2. Identification of Resources

The improper identification of the reviewed papers can lead to inaccurate and inconsistent conclusions [7]. Therefore, the review began by adjusting a specific search string and identifying the digital libraries that produce relevant results. Thus, an extensive search using (Document Title: ("Smart Cities" OR "Smart City") AND "surveillance") as a query text is conducted within the most prominent scientific digital libraries (IEEE, ACM, Springer, and Science Direct). The search is filtered to show only the articles that were written in English and published between 2015 and 2020 in a peer-reviewed journal or conference. Also, all duplicates were eliminated. It was obtained 94 papers, which went through a selection of studies process, leaving only those relevant to the review.

2.3. Selection of Papers

The third stage of our research methodology aims to recognize the relevant papers that should be included in this review. First, we excluded papers that and are not full publication, not applied to smart cities, and have five pages or less. As a result, a total of 43 articles had been identified. Second, the remaining papers were assessed for their relevance through quality screening according to the following quality criteria: the overall quality of writing, clarity of results, feasibility of the proposed system, and clearness of the research aim. Accordingly, 22 papers remained. In the following phase, the remaining papers were categorized according to their general research trends.

2.4. Categorization and Information Extraction

The fourth stage deals with categorization, which consists of a classification of the papers to obtain more detailed information about the reviewed papers. Here, the created categories represent the current research trends and the general focus of the reviewed papers that address the topic of intelligent surveillance systems for smart cities. In consequence, the reviewed papers are classified in this review according to their main focus into five main categories: 1) Internet of Things (IoT), 2) Computer Vision, 3) Computing, 4) Digital Image and Video Processing, and 5) Security.

In this review, the data extracted from each paper were author's information, the title of the paper, the source (conference or journal), year of publication, indexed keywords, aim and objective of the study, the technical part related to the proposed system, results or findings, future work, and conclusion.

3. Research Trends of the Intelligent Surveillance Systems for Smart Cities

The research trend categories help to solve question RQ1, identifying what the main focus and objective are of selected papers. For the research trend, five categories were defined. The first category is the Internet of Things (IoT), which includes works that focus on developing smart city surveillance systems using the concept of IoT, with different techniques, to achieve their goal. The second classification is computer vision, which contains works that related to computer vision to improve algorithms for automated object detection and tracking to develop efficient applications in smart cities. The

third category is called computing, which focuses on work utilizing various techniques of computing to achieve proposed surveillance systems with low cost, low storage consumption, and high performance. The fourth category is entitled digital image and video processing, which is considered is a particular case of signal processing, where the input and output signals are video files or video streams. Finally, the fifth category is related to the work that focuses on discussing several security vulnerabilities issues, which are introduced due to the heterogeneous nature of the surveillance systems in smart cities.

3.1. Internet of Things (IoT)

In today's digital world, IoT has proved itself to be of great significance to various industries around the world. The utilization of IoT increases rapidly, especially in smart cities [8]. In addition to its low cost and efficient performance, IoT provides a wide range of opportunities for smart cities by consuming data to manage, monitor, and organize everything within the city. Hence, IoT is believed to be the key for establishing a successful smart city.

In [9], the authors proposed solutions for challenges frequently encountered when working on surveillance systems, such as cost and delay. In order to overcome these limitations, the author presented Raspberry Pi as an IoT device. (Raspberry Pi is a single-board computer that is relatively cheap, yet powerful. It has many interfaces and can be used as an IoT device to develop productive systems). The results of the paper demonstrate that, compared to other methods, this IoT approach performs better. The system is reliable, has low cost and can be implemented in real-time.

Similarly, the work in [10] used IoT hardware platforms to tackle the obstacles by presenting a low-cost surveillance system. The proposed system provides real-time monitoring and motion detection. Moreover, it notifies the user via email when an abnormal action occurs. Three modules are used for managing the system. These modules are Raspberry Pi 3, Raspberry Pi Zero, and ESP -32. Results show that the system successfully reached a low-cost solution for surveillance in smart cities.

Moreover, other modules are also used to enhance surveillance systems for smart cities, such as Arduino and CC2500 which are suggested in [11]. The aim of this paper is to detect suspicious movements in apartments. Arduino UNO, which is a microcontroller board, receives an input from the sensor when any unusual activity takes place. Then, the data gets transmitted to CC2500, which transfers the information to a competent authority. As the systems previously discussed, this system offers a low-cost solution and low power consumption. However, it performs poorly in the absence of an Internet connection.

The work presented in [12] concentrates on reducing the data needed to be stored in urban surveillance systems. As IoT-driven object detection algorithms are often complex, the purpose of this system is to provide a low complexity algorithm for vehicle detection and/or vehicle license detection. A method is used to filter out the desired objects from the digital camera imaging sensor. This method is not only simple and easy to implement, but it also extracts important information from the image and reduces the amount of data to be stored.

The authors in [13] proposed a traffic monitoring system using Ontology. The system is developed to help in predicting incidents so that smart cities become more secure. When the system encounters or detects an unusual event from IoT devices, the Dynamic Bayesian Network (DBN) computes the probability that this incident might occur to prevent it or reduce the amount of damage that could take place. However, some defects may appear in the system in case of congestion. The incidents here could be more than one event occurring at the same time, so the system is required to observe every action.

Another traffic monitoring system for IoT-based smart roads is introduced in [14]. where roadside sensors (RSU) monitor and detect vehicles on the road. Moreover, they keep track of the number of vehicles in the street to determine if there are any road congestions. If there are, the system notifies the user via an Android application. The results are promising, as the system utilizes the sensors to acquire accurate information.

3.2. Computer Vision

There is a rapid pace in researches related to computer vision to improve algorithms for automated object detection and tracking to develop efficient applications in smart cities especially the surveillance related. This section aims to review some of those papers and summing them up

In [15], the authors introduced a fast vehicle detection algorithm for smart traffic surveillance application, the method used is a combination of the Mixture of Gaussians (MOG2) algorithm to extract the region of interest and using the H-SqueezeNet which is a lightweight deep neural network algorithm is trained to verify the car category which was bus, car, and truck. Comparing the introduced method with other traditional techniques, it proves that the old techniques could detect cars more but can't detect trucks or buses, unlike the proposed technique. Also, it performs well for different categories and can learn their global features, but it achieved an average detection speed of 39.1 FPS.

Besides, the authors in [16] discussed the impact of resolution on detection accuracy, by using a combination of Histogram Oriented Gradient (HOG) and Support Vector Machine (SVM) for pedestrian detection. This experiment was carried out with three criteria detection accuracy, recall rate, and F-measure. After this experiment, it is observed that there is an optimal resolution to balance between speed and accuracy but the more resolution is decreased the more pedestrians were missed.

Also, the development of a system for detecting violence in videos is the aim of the work in [17], via using some calculation methods of acceleration between video frames, those methods where histogram of optical acceleration (HOA) and histogram of the spatial gradient of acceleration (HSGA), with support vector machines to classify and achieve good detection rates. The results show accuracy rates between 85% and 97% depending on the complexity of the datasets used. This method proposed is a new method to detect violence using soft computing methods that provides promising results in a more complicated situation. But the system depends only on the movement of the people in social media videos. Also, it does not have strong evidence that it can detect abnormal acts in real-life scenarios.

3.3. Computing

Nowadays cloud computing has extremely affected smart cities. It is fundamental to process big data and implement IoT. Alongside, fog, edge, and mobile computing are getting to be prevalent as well. These computing technologies vary by their purpose and design but frequently complement each other. Herein, various papers are found discussing and illustrating the importance of using different techniques of computing to achieve efficient surveillance systems in smart cities.

The work in [18] mainly focuses on developing a fog computing infrastructure that utilizes deep learning models in order to process the video captured by surveillance cameras. The authors used Deep Neural Network (DNN), Shallow Neural Network (SNN), as well as fog nodes to obtain needed information. The observations show that both the DNN and SNN models, at the various levels of fog infrastructure, assist with processing and analyzing the surveillance video, and order the vehicles progressively. Therefore, they manage the delay-sensitive applications. These methods work efficiently with low latency, low cost, and rapid decision.

The main objective of the authors in [19] is to induce and monitor an object by online performing trajectory analysis. As the anomaly conduct happens, glyph is to display the action. A real-time trajectory-based technique has been developed to detect atypical behavior in videos. An automated method is presented to track and keep count of the number of vehicles. By means, the tracker method yields the trajectories of vehicles, which are used for event identification and vehicle count. Experimental results showed that the proposed technique, in comparison to other algorithms, gives robust vehicle density assessment and event data. The system performs the trajectory analysis, without previous knowledge of traffic circumstances, and automatically identifies the anomalous trajectories.

As well, the main purpose of the work in [20] is to produce a framework for distributed video summarization over a multi-region fog computing model. In the fog network, the nodes depend on Raspberry Pi. As surveillance videos are allocated on various nodes, a summary is produced over the fog network. The author mentioned various methods to achieve the proposed approach: MQTT protocol, which is an algorithm for implementing video summarization over the distributed Fog nodes. The results of the paper show that memory utilization of the cluster is very high even for small jobs. This is because the Hadoop and Apache Spark-based clusters consume a lot of memory and the RAM available in the Raspberry Pi is li. The high CPU and memory utilization observed in the large jobs implies that there is constantly swapping in the memory and smaller jobs have to wait even if completed earlier. The system is accomplished effectively with low cost and low power consumption.

Moreover, the authors in [21] mainly focus on fog-edge computing. The aim is to offer a video surveillance service that presents various video acquiring technologies. Such services include plug-and-play, flexibility, scalability, and the quantity of transmitting and getting devices. The authors illustrate that the service collaborates with two kinds of devices: (SAN) distributed on the territory of a smart city permitting Data Flow Senders to access the platform via Wi-Fi or 4G technologies. (NAN) are the entrance nodes of the Telco Network. Both SANs and NANs are acknowledged according to the SDN/NFV standard model by utilizing general-purpose x86-based hardware equipped with a software SDN switch and a virtualization domain. The results shown illustrate that the proposed video surveillance system is achieved with high performance and scalability.

In [22], the main goal is that a customer can utilize their mobile phone camera and technology to share the information about any up normal action with anyone, to give consciousness and to inform the competent authority with necessary and needed information about the event. The authors mentioned the methods of achieving the purpose, Users interact with an android application to capture video and assign it to the cloud. Python is utilized for collaborating with the cloud and processing the video then returning it to the customers. Ubuntu is utilized as the working environment. The authors found that various parameters affecting the average waiting time for clients as signal and internet connection stability. Therefore, it leads to uncertainty estimation of delays. The proposed approach is achieved with unlimited storage capacity, low cost, and rapid response.

The article [23] aims to provide a high quality of service to the citizens of a smart city. The system incorporates a model for data sharing between truck drivers in real-time to perform waste collection and dynamic route optimization. The author mentioned the methods to accomplish the proposed approach effectively. It becomes conceivable to provide clients with the most ideal directing for each truck. The results show that the system handles the case of ineffectual waste collection in distant areas within the Smart City. Surveillance cameras are incorporated for capturing the problematic areas and provide evidence to the authorities

3.4. Digital Image and Video Processing

Digital image and video processing techniques are used in several sets mainly in developing intelligent surveillance systems for smart cities. We will review its usage and some of its different useful techniques.

In [24], the authors focused on the Unmanned Aerial Vehicle (UAV) so they constructed a full device coverage network with UAV cluster in heterogeneous communication for smart cities by defining the scheduling problem of UAV cluster and designed an optimized performance-enhancing scheduling algorithm. The simulated results illustrate the efficiency, viability, and robustness of the introduced approach in terms of the framework life cycle, video decodable frame rate, the ratio of UAV flight time to the framework life cycle, throughput, and latency.

The proposed work in [25] mainly focuses on the video visualization usefulness for traffic surveillance and that the data analytics can solve a lot of challenges that we face in this topic nowadays. The proposed algorithm aims to convert the traffic video to google map via the association of google maps and visualization the results of the time-stamped glyph and its semantic information on google map. Glyph-based visualization is considered to be a typical method of visual design in which the data set is defined by a selection of visual objects. The experiments show that the introduced visualization method produces encouraging results and makes it effective to transmit relevant information while minimizing the necessity for an exhaustively colossal amount of video data to be searched. Although the only flaw in this proposed system is that, due to the heavy transmission load, it was difficult to view multiple traffic videos simultaneously.

With an effort to tackle the big data storage and transmission issues, the authors in [26] address the video compression techniques Block-level Boundary Matching (BBM) and surveillance rate-distortion optimization algorithm (SRDO) to conquer these challenges. These algorithms efficiently apply video compression by using the concept of video encoding. The results demonstrate that after applying these algorithms, the IoT surveillance videos will require less storage and the transmission performance will improve.

3.5. Security

The most disregarded, yet demanding, issue in surveillance systems is security. This is justified because several vulnerabilities and issues are raised as a result of the need to process multiple video-flows from various and heterogeneous cameras deployed around the city. This section aims to discuss some of the security issues related to this topic.

The authors in [27] introduced a BlockSee, a blockchain-based video surveillance system to jointly provide immutability and validation to surveillance videos and camera settings. The main objective of the proposed system is to make them, in case of events, readily available to authorized users. The promising results obtained with BlockSee pave the way to new distributed city-wide monitoring systems.

The work [28] illustrates focuses on deterring the crime as well as ensuring the safety of citizens, which can be considered an extremely important feature required for security applications in smart cities. The authors assumed that existing security-related video analysis systems suffer from several limitations including lack of real-time response. Therefore, they used convolution neural networks in order to propose intelligent video surveillance (IVS) that can send an alert automatically in case of an emergency like intrusion detection, thieves' attacks, and fire. The given results revealed that the proposed IVS can achieve very low false alarm rates.

As well, the work in [29] discusses how to overpower the security challenges of Wireless Sensor Networks (WSN) in order to improve IoT security. An Efficient Algorithm for Media-based Surveillance System (EAMSuS) has been proposed, which offers a high security-level and attains less memory consumption.

4. Current Research Challenges and Future Directions

Despite the potential benefits of the proposed intelligent surveillance systems, they are hampered by several critical challenges and limitations that require further research in the coming years. This section summarizes the current research challenges and future directions as follows:

- **Cost:** Cost-reduction efforts are always at the top of the challenges that are thought of. Therefore, researchers are done to improve the hardware cameras to achieve full coverage with a low cost or proposing algorithms and techniques to provide high efficiency even with low-resolution cameras [10][16]. In the future, we suggest enhancing the IoT low-cost traffic surveillance system by connecting it with the cloud to offer further features to the system, such as providing plate number recognition and presenting online receipts [9].
- **Scalability:** it has become a significant aspect of the consideration of any system. Many systems face various scalability challenges in attempting to take advantage of the latest generation compute, network, and hardware [20][21]. Hence, a more robust fog architecture could be further investigated in order to extremely improve and enhance the scalability in the intelligent surveillance systems [20].
- **Reliability and efficiency:** The quality of the data captured by intelligent surveillance systems is one of the most difficult problems recognized in this topic. Along with this challenge comes the issue of the reliability of sources. As the algorithm is applied to detect an event is not fully accurate itself. So there is an issue about how the algorithm should be integrated with the detected results.

Many image processing and computer vision techniques and methods are used to enhance the quality of videos [16][18][19][24]. We suggest for future work, utilizing various theoretical analysis and constructing resolution-invariant features descriptors to achieve the highest percentage of accuracy [26].

- **Real-time analysis and prediction:** In order to prevent future catastrophic events from occurring, it is essential to enhance the performance of real-time analysis in smart cities' surveillance systems. There are methods developed to help overcome this challenge [13] [14]. Besides, it is suggested that not only analyze past or real-time events but also predict future events [30].
- **Security and Privacy:** The most neglected, yet important challenge faced by intelligent surveillance systems are associated with security and privacy. It is important to observe and overpower such obstacles when developing those systems for smart cities [27][29]. As well, the high dependency of the smart cities' surveillance systems on the shared information requires precise attention about the ability of those systems to be resilient against various attacks [31].

5. Conclusion

This paper presented the results of a systematic review on intelligent surveillance systems for smart cities. As the main contribution, we provided throughout this review a categorization for the current research trends/focus on this topic. A discussion on each category is also given presented with a focus on the aim, constraints, and results of the proposed systems. Finally, the relevant challenges and future research directions are discussed to guide the potential research communities about the recent progress in the area of intelligent surveillance systems for smart cities.

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