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Video surveillance systems-current status and future trends☆

Vassilios Tsakanikas*, Tasos Dagiuklas

SuiTE Research Group Division of Computer Science, London South Bank University, 103 Borough Road, London SE1 0AA, UK

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ABSTRACT

Within this survey an attempt is made to document the present status of video surveillance systems. The main components of a surveillance system are presented and studied thoroughly. Algorithms for image enhancement, object detection, object tracking, object recognition and item re-identification are presented. The most common modalities utilized by surveillance systems are discussed, putting emphasis on video, in terms of available resolutions and new imaging approaches, like High Dynamic Range video. The most important features and analytics are presented, along with the most common approaches for image / video quality enhancement. Distributed computational infrastructures are discussed (Cloud, Fog and Edge Computing), describing the advantages and disadvantages of each approach. The most important deep learning algorithms are presented, along with the smart analytics that they utilize. Augmented reality and the role it can play to a surveillance system is reported, just before discussing the challenges and the future trends of surveillance.

1. Introduction

During the past decade Video Surveillance Systems have revolved from simple video acquisition and display systems to intelligent (semi)autonomous systems, capable of performing complex procedures. Nowadays, a Video Surveillance System can integrate some of the most sophisticated image and video analysis algorithms from research areas such as classification (e.g. neural networks or stochastic models), pattern recognition, decision-making, image enhancement and several others. Thus, a modern surveillance system comprises image and video acquisition devices, data processing - analysis modules and storage units, components, which are all crucial for the system's workflow.

Literature suggests that surveillance systems have technically evolved under three generations. The 1st generation (1G) is dated back in 1960s, when analog Close Circuit TV (CCTV) systems were first introduced, mainly for indoor surveillance applications. For that time, 1G systems performed rather satisfying, gaining the trust of the market with deployments in banks, supermarkets, garages, etc. Yet, analogue technology constrained their capabilities, especially for recording and distributing processes. In 1980s, digital imaging evolved surveillance systems to the 2nd generation (2G), offering two major advances. First, compression and distribution have now become more efficient and more cost-effective. Second, computer vision algorithms have been introduced to surveillance systems, offering semi-automated functionalities, such as object tracking and event alerting. Finally, since the early 2000s, we can speak of the 3rd generation of surveillance systems, where fully automated wide-area surveillance systems are explored, aiming to offer reasoning frameworks and behavioral analysis

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* Corresponding author.
E-mail addresses: tsakaniv@lsbu.ac.uk (V. Tsakanikas), tdagiuklas@lsbu.ac.uk (T. Dagiuklas).

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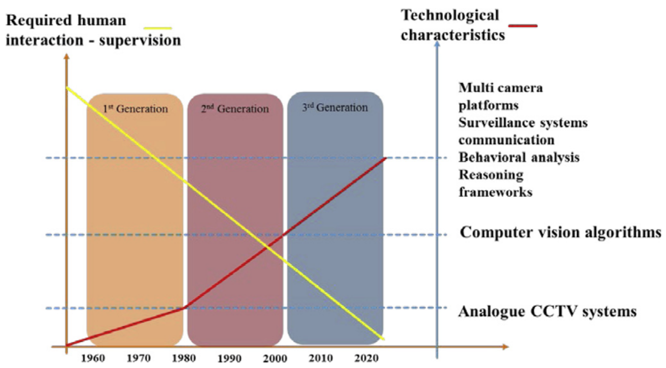

Fig. 1. Evolution of surveillance systems.

functionalities, incorporating and integrating at the same time multi-sensor platforms and data fusion techniques. In Fig. 1, a timeline diagram of the evolution of surveillance systems is depicted.

There are many flavors of Video Surveillance Systems, each one trying to fulfill a piece of the market. Several categorizations can be drawn. Hence, one can categorize Video Surveillance Systems based on the type of imaging modality acquired, producing categories like “one camera systems”, “many camera systems”, “fixed camera systems”, “moving camera systems” and “hybrid camera systems”. Another categorization can be based on the applications which a Video Surveillance System offers, such as object tracking, object recognition, ID re-identification, customized event alerting, behavior analysis etc. Finally, Video Surveillance Systems can be categorized based on architecture a system is built on, such as stand-alone systems, cloud-aware systems and distributed systems.

For most of the time, surveillance systems have been passive and limited in scope. In this context, fixed cameras and other sensing devices such as security alarms have been used. These systems are able to track persons or to detect some kind of events (a person breaking the door or the window), however, they have not been designed to predict abnormal behaviors for instance. During the last years, there was a huge progress in sensing devices, wireless broadband technologies, high-definition cameras, and data classification and analysis. Combining such technologies in an appropriate way will allow to develop new solutions that extend the surveillance scope of the current systems and improve their efficiency. Within the context of surveillance systems, efficiency improvement has two directions. First, the improvement of the video processing algorithms along with the derived video analytics will increase the validity and the accuracy of a surveillance system and second the integration of surveillance systems with cloud infrastructures is expected to improve reliability (e.g. generate alarms under poor lighting conditions etc.), reduce the maintenance costs and increase the response time of the systems.

Surveillance systems have to cope with several challenges, including, but not limited to, algorithmic and infrastructure challenges. Thus, surveillance systems have to adapt with the emerging network and infrastructure technologies, such as cloud systems, in order to provide more robust and reliable services. This trend will also demand the integration of different surveillance systems for extracting more useful knowledge. This integration will require new communication protocols and data formats between surveillance agents, as well as new surveillance adapted databases and query languages. Finally, more accurate algorithms are required, especially in the context of behavioral analysis and abnormal activities detection.

The scope of this paper is to survey the current status of Video Surveillance Systems, aiming to identify the best practices for image and video processing and analysis and highlights research challenges for next generated systems. Additionally, the applicability of proposed algorithms and architectures will be assessed, in terms of time response and scenarios variety. The paper is structured as follows: Within Section 2, the available video sensors from different surveillance systems are presented, Section 3 describes the different modalities that are commonly used in surveillance systems. In Sections 4 and 5 several approaches for the most studied image and video processing algorithms are analyzed, focusing on video analytics and quality enhancement respectively. In Section 6, computing architectures for boosting the performance of a surveillance system are discussed while in Section 7 the future trends on surveillance systems are drawn.

2. Video sensors

Nowadays, there is a variety of video sensors used from surveillance systems. As the technical specifications of the video sensors play a key role to the potential of a surveillance system, in this section we provide an outline of the sensors' technical characteristics.

The oldest and most used type of video sensors is analog video sensors which are used to CCTV (Closed-Circuit Television) surveillance systems. The resolution of the analog cameras is measured in vertical and horizontal line dimensions and typically limited by the capabilities of both the camera and the recorder that the CCTV system is using. In Table 1, common formats of analog cameras are provided, along with their resolution are presented. Until two years ago, the higher resolution for analog systems came from the D1 format. Yet, since 2015 the AHD CCTV (Analog High Definition) cameras were introduced in the market, along with the corresponding recorders. Regarding the FPS (Frames per Second), specification of