REVIEW OF TECHNOLOGIES AND USES OF VIDEO SURVEILLANCE

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ABSTRACT

Modern security and monitoring systems now mostly depend on video surveillance. It covers a broad spectrum of technologies and uses, therefore greatly improving operational effectiveness and safety in many different fields. Thanks to developments in computer vision, artificial intelligence, and networking, video surveillance has advanced impressively from its early use in sensitive surroundings to its general presence in public spaces (Ardabili et al., 2022; Rezaei et al., 2021). Beyond only capturing visual data, video surveillance's main goal is intelligent analysis of image sequences to identify and track things, so helping to comprehend and interpret their activity (Ko, 2011). Advanced algorithms built into modern systems enable them to quickly identify and respond to any hazards or odd events by automatically detecting, classifying items, and spotting anomalies (Alhaidari et al., 2019; Civelek & Yaz, 2016). Security, traffic monitoring, retail analysis, and industrial automation (Patrikar & Parate, 2022) are just a few of the several domains these systems find use in. Furthermore, by providing a multimodal monitoring and anomaly detection (Mãâ¼Ller et al., 2021) integration of video surveillance with other sensor technologies such as sound sensors improves capabilities. Furthermore made possible by the development of cloud-based video surveillance systems is remote access and management of video data, which facilitates real-time and historical analysis from anywhere with an internet connection.

Modern security and monitoring systems now revolve around video surveillance as absolutely essential component. Driven by developments in computer vision, artificial intelligence (AI), and networking, modern surveillance technologies go from simple video recording tools to advanced intelligent systems. This study investigates the technical development, present capabilities, and several uses of video surveillance systems, so underlining their increasing importance in improving operational efficiency and safety in several fields. It also looks at the development of cloud-based solutions as major field innovations and the integration of multimodal sensors.

Keyword: IVA (Intelligent Video Analytics), OD (Object Detection), OT (Object Tracking), MD (Motion Detection), DL (Deep Learning), CNN (Convolutional Neural Network), RNN (Recurrent Neural Network), LSTM (Long Short-Term Memory), YOLO (You Only Look Once), VMS (Video Management System), FR (Facial Recognition), AR (Activity Recognition), AD (Anomaly Detection), SF (Sensor Fusion), CC (Cloud Computing), EC (Edge Computing), SC (Smart Cities), RT (Real-Time), SP (Security and Privacy).

INTRODUCTION

Over the past few years, video surveillance has advanced. Although these technologies were focused on sensitive locations and high security, they increasingly find presence in public and private domains. Surveillance systems are vital in many different fields, including law enforcement, transportation, retail, and industrial operations since security monitoring affects crime prevention and development (Ardabili et al. 2022; Rezaei et al. 2021).

Adoption of video surveillance has been spurred by changes in digital technology and growing public safety needs of communities. Urban canters need intelligent monitoring systems to recognize hazards in real-time and make judgments as they evolve into smart cities. Beyond passive video recording, surveillance increasingly consists on active analysis driven by artificial intelligence that can identify objects analyze actions and flag odd events without human assistance.

Moreover, the declining cost of high-end cameras and storage devices combined with simpler access to cloud computing has made surveillance solutions more flexible and reasonably priced than they were years ago. These advancements have attracted interest not only from government agencies but also from private companies trying to improve operational effectiveness, security, and customer insights.

This study will find technological developments, uses for video surveillance, It will also observe how integration with other sensors and cloud infrastructure transforms the scene with modern monitoring and detects issues that must be resolved for moral and efficient deployment.

LITERARY SURVEY

Numerous studies have contributed to the enhancement of video surveillance systems. Their efforts have concentrated on several domains, including system design clever video analysis, privacy concerns, and fast processing.

Ko (2011) provides a general summary of the way behavior is analyzed by surveillance systems. He studies how these technologies identify human activity and spot odd events to guard homeland security. Deeply exploring how artificial intelligence is making surveillance smart are Rezaei and Azarmi (2021). They highlight how quickly CNNs, RNNs, and other artificial intelligence models have advanced tasks including object recognition and behavior interpretation.

Alhaidari et al. create a real-time object tracking and spotting system (2019). They aimed at accuracy and efficiency. In a related line, Civelek and Yazıcı (2016) examined conventional video analysis techniques. They noted the difficulties of implementing them in the actual world.

Ardabili et al. (2022) focused on clever surveillance systems with artificial intelligence and context-learning capability. Müller et al. (2021) demonstrated the benefits of using several data kinds.

Combining optical and audio data sensor fusion helps to improve anomaly detection.

Patrikar and Parate (2022) investigated AI-powered video monitoring in industrial environments to increase safety and track operations.

VIDEO SURVEILLANCE USING SEVERAL TECHNOLOGIES AND PURPOSES

Technologies and applications in video surveillance are linked and rely on whether the surveillance is stationary or dynamic; so, the application-specific nature of technology use is evident.

Accessible Video Surveillance Technologies

- Considering about capturing, preparing, and evaluating video data
- Different kinds of cameras: IP, PTZ, thermal, panoramic
- Computer vision and artificial intelligence techniques
- Systems of video management, or VMS
- Edge as well as cloud computing
- Sensor integration (motion, thermal, audio)
- secure data encryption and networking

Application of video surveillance

- Technologies applied in the actual world
- In law enforcement and crime prevention
- Transportation and traffic control
- Loss preventability and retail analytics
- Automation in industry and safety issues
- Patient surveillance and healthcare
- Management of Smart Cities
- Security in an educational institution

ALGORITHMS APPLIED IN SYSTEMS OF VIDEO SURVEILLANCE

Intelligent video analysis is mostly enabled by algorithms. The main categories are below:

Motion Detection Models

- Background subtraction
- Optical Movement
- Frame Differentiation
- Visual Flow
- Deep Neural Learning
- Motion Detection Based on Events (Event Cameras)

1. Subtraction of Background

Searches moving items in the current frame by comparing it to a reference backdrop model.

Frame differencing: Subtract the current frame from the one before it.

Running average: Over time constantly update the backdrop model.

Lighting changes and shadows benefit from the Gaussian Mixture Model (GMM).

It's appropriate for stationary, regulated contexts; but, the dynamic approach needs work.[8],[10], 13"[16]".

2. Optical Movement

For computation of brightness between frames

Lucas-Kanade Method: fit for small communities with continuous flow.

Horn-Schunck Method: guarantees the motion fields' smoothness.

Works with moving cameras and detect slight motion benefit from it; but, computationally intensive outputs will be sensitive to noise and lighting changes [9][14].

3. Frame differencing

Basic approach for sequential frame subtraction.

Steps involved:

- Two frames captured.
- Computation of absolute difference.
- Apply a threshold to highlight the area.

It has great speed and simplicity of implementation. Accuracy can be compromised for slow or minor motions and cannot identify stationary objects that have moved but remain in their original location [10].

4. Deep Learning Approaches: RNN, CNN

3D CNNs,YOLO, Recurrent Neural Networks (RNNs)

It takes a lot of data set even if it has great accuracy and sophisticated scene handling capacity.[2],[3][6][7][11][14][15].

5. Motion Detection Based on Events for Event Cameras

Event cameras track scene changes at the pixel level rather than recording frames. For high speed, it is rather quick and efficient, but it requires dedicated hardware. [12], [16].

Methods of object detection and tracking : YOLO, SSD, Faster R-CNN, Kalman Filter, SORT / Deep SORT

Algorithms in Facial Recognition : Haar Cascades, LBPH, FaceNet , DeepFace, ArcFace and ArcSync

Behaviour and Activity Recognition: 3D Convolutional Neural Networks, Spatio-Temporal Graph CNN (ST-GCN), LSTM and RNN, Hidden Markov Models (HMM)

Anomaly Detection: Generative Adversarial Networks (GANs), Autoencoders, One-Class SVM, and Isolation Forests.

Fusion Algorithms in Multiple Modes: Bayesian networks with feature-level and decision-level fusion

VIDEO SURVEILLANCE TECHNOLOGY'S DEVELOPMENT

Nowadays, the advancement of surveillance technologies in the field of digital images (video) under artificial intelligence (AI) fast increases intelligence. Early systems were manually supervised; today, artificial intelligence is helping to regulate all activities and take required action.

CLOUD COMPUTING AND MULTIMODAL SENSORS

Integrated with other sensors, video monitoring becomes much more effective. As in:

Acoustic sensors pick out alarms, yelling, and glass breaking. Useful in low-visibility settings, thermal sensors detect body heat. Provides remote accessibility, strong analytics, and centralized video storage under cloud infrastructure.Greater situational awareness, less false alarms, and better decision-making are made possible by this mix.

CHALLENGES AND FUTURE DIRECTIONS

Even with fast advancement, numerous difficulties still exist:

Legal and ethical questions abound when facial recognition and behavioural tracking are used.

Maintaining the integrity and confidentiality of video data remains absolutely vital in data security.

System interoperability integration of several hardware and software systems may prove challenging.

Managing large volumes of data while keeping low latency presents a continuous technical challenge related to scalability and real-time processing.

- Using federated learning and edge artificial intelligence for local data processing.
- Improving cross-domain surveillance that is, merging drone footage with CCTV.
- Emphasizing open algorithmic government and privacy-preserving artificial intelligence.

Fitness Evaluation

- The fitness of each solution is acquired by the fitness function that defines the relevant parameters and FeTSO obtains the better values. The accuracy metric is utilized for evaluating the fitness where the optimal solutions have better fitness values. The fitness function is mathematically formulated as,

$$\mu\left(B_{f,g}^{u}\right) = \max\left(Accuracy\left(B_{f,g}^{u}\right)\right) \quad (18)$$

Where, μ corresponds the fitness function and $\mu\left(B_{f,g}^{u}\right)$ denotes the fitness function of the f^{th} solution in the current iteration u.

CONCLUSION

Simple recording devices to sophisticated, context-aware systems able of real-time analysis and decision-making have evolved from video surveillance. These systems are changing security, safety, and operational intelligence across industries by including cloud computing, multimodal sensors, and artificial intelligence. Future advancements have to carefully balance ethical issues, efficiency, and creativity to guarantee acceptable use in society.

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