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DEVELOPMENT OF A VIDEO SURVEILLANCE SYSTEM FOR MOTION DETECTION AND OBJECT RECOGNITION

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***Abstract*: This article explores the development of a video surveillance system that utilizes cutting-edge technology to analyze the video stream in real-time, identify motion, and recognize objects within the video stream. The functionality of this system enables it to provide a high level of accuracy in identifying objects, even in low-light conditions or with low-resolution cameras. The software system has been designed as a user-friendly desktop application with the latest technologies and features that will ensure its relevance and easy maintenance in the future. To ensure that the developed desktop application meets common optimization requirements, extensive testing has been conducted to evaluate its resource usage. The resulting system is an efficient and reliable tool for monitoring and detecting movement in various locations, providing enhanced security measures and public safety.**

***Index Terms*: open CV; computer vision; monitoring; motion detection; objects recognizing.**

I. INTRODUCTION

The development of video surveillance systems has become increasingly important in recent years, as businesses and individuals seek to enhance their security and monitor their premises. One of the key features of modern surveillance systems is their ability to detect and recognize motion and objects, allowing for more effective monitoring and analysis. The development of a video surveillance system for motion detection and object recognition requires a combination of hardware and software components. This may include cameras, sensors, processing units, and algorithms designed to analyze video feeds in real-time. The system must be able to distinguish between different types of motion and objects and respond appropriately based on predefined rules or instructions.

There are many potential applications for such a system, including in the fields of security, traffic management, and industrial automation. By detecting and recognizing objects and motion, the system can help to identify potential threats or hazards, monitor traffic flow, and optimize manufacturing processes.

Overall, the development of a video surveillance system for motion detection and object recognition requires a multidisciplinary approach, involving expertise in computer vision, machine learning, and hardware design. As technology continues to advance, we can expect to see even more sophisticated and effective surveillance systems in the years to come. There are various methods for creating a video surveillance system that is capable of motion detection and object recognition:

Camera selection: The first step in creating a video surveillance system is to select the appropriate cameras. There are many different types of cameras available, with varying resolutions and features. For motion detection and object recognition, it is important to choose cameras that have a high frame rate and resolution, as well as built-in motion sensors.

Motion detection algorithms: Once the cameras have been selected, the next step is to develop algorithms for detecting motion. This may involve using simple threshold-based approaches to detect changes in pixel intensity or more sophisticated techniques, such as optical flow analysis or background subtraction. The aim is to identify regions of the video that contain motion and ignore areas that remain static.

Object recognition algorithms: After the motion has been detected, the next step is to develop algorithms for recognizing objects within the scene. This may involve training machine learning models to classify objects based on their appearance or movement characteristics. Object recognition can be challenging due to variations in lighting, camera angles, and object occlusion, so it is important to use robust and adaptive algorithms.

Integration with alerting systems: Once motion and objects have been detected, the system needs to alert the appropriate personnel or systems. This may involve triggering alarms, sending notifications to mobile devices, or integrating with other security or automation systems.

Data storage and analysis: Finally, it is important to store and analyze the data collected by the system. This may involve using cloud-based storage solutions or on-premise servers. Analyzing the data can provide valuable insights into patterns of motion or object movement, which can be used to optimize security, traffic management, or industrial automation processes.

Testing and optimization: After the system has been developed, it is important to test and optimize its performance. This may involve collecting data in real-world scenarios and analyzing the system's accuracy,

sensitivity, and false-positive rates. The system may need to be tweaked or adjusted to optimize its performance, and ongoing monitoring can help to identify areas for improvement.

Integration with other systems: In many cases, a video surveillance system will need to be integrated with other security or automation systems. This may involve integrating with access control systems, building automation systems, or security management platforms. Integration can help to streamline workflows and improve the effectiveness of the overall security or automation system.

Compliance with regulations: When developing a video surveillance system, it is important to consider any relevant regulations or privacy laws. For example, in many jurisdictions, video surveillance systems must comply with data protection laws and regulations, and there may be specific requirements around data retention, access control, and transparency. Ensuring compliance with relevant regulations is important to avoid legal or reputational risks.

Maintenance and support: Like any complex system, a video surveillance system requires ongoing maintenance and support. This may involve monitoring the system's performance, performing regular maintenance tasks, and providing technical support to end-users. Regular software updates and security patches are also important to keep the system secure and up-to-date.

Overall, developing a video surveillance system for motion detection and object recognition requires a holistic approach that considers hardware, software, integration, compliance, and maintenance. By carefully planning and executing each step in the development process, it is possible to create a system that is effective, reliable, and compliant with relevant regulations.

One of the most popular software libraries for developing computer vision applications is OpenCV (Open Source Computer Vision Library). OpenCV is an open-source library that provides a wide range of functions for image and video analysis, including motion detection and object recognition.

OpenCV provides a comprehensive set of tools for image and video processing, including image filtering, feature detection, object recognition, and tracking. The library supports a wide range of programming languages, including C++, Python, and Java, making it accessible to a wide range of developers.

One of the key advantages of using OpenCV for developing video surveillance systems is its extensive community support. OpenCV has a large and active community of developers who contribute to the library, share knowledge and expertise, and provide support to other developers. This community-driven approach helps to ensure that OpenCV remains up-to-date and relevant, with new features and improvements added regularly.

OpenCV also provides a range of pre-trained models for object recognition and detection, which can significantly reduce the time and effort required to develop a video surveillance system. These pre-trained models can be fine-tuned to specific use cases, providing a more accurate and tailored solution.

One of the key strengths of OpenCV is its cross-platform compatibility. The library is designed to run on a variety of operating systems, including Windows, Linux, macOS, iOS, and Android. This makes it easy to develop applications that can run on multiple platforms, without having to rewrite the code from scratch.

OpenCV can be used with a range of programming languages and development environments. OpenCV also provides support for hardware acceleration, which can significantly improve the performance of computer vision applications. For example, OpenCV can be used with GPUs or specialized hardware such as Intel's Movidius Neural Compute Stick for improved processing speed and efficiency.

In summary, OpenCV is a versatile library that can be used in a variety of environments and programming languages. Its cross-platform compatibility and support for hardware acceleration make it a popular choice among developers working on computer vision and video surveillance applications.

II. RELATED WORKS

The article [1] has conducted research on the real-time detection and motion recognition of human-moving objects based on deep learning and multi-scale feature fusion in the video. This work aims to develop a highly accurate and efficient system for detecting and tracking human motion in real-time.

The research represents a significant advancement in the field of human motion detection and recognition, offering a highly effective and efficient solution that can be applied in various domains such as security, public safety, and healthcare.

The research [2] is on a motion-based object detection method. This work aims to develop a highly accurate and efficient system for detecting and tracking moving objects in a video sequence.

The proposed method utilizes motion detection techniques to detect changes in pixel intensity between successive frames of a video sequence. The system then uses these motion vectors to segment moving objects from the background and applies a series of image-processing techniques to refine the detected objects.

The research [3] on a motion detection system is implemented in Python and OpenCV. This work aims to develop a simple yet effective motion detection system that can be easily implemented using readily available tools.

The proposed system uses OpenCV, an open-source computer vision library, to capture and process video frames in real-time. The system applies background subtraction techniques to detect motion in the video sequence and uses image-processing techniques to refine the detected objects.

The research [4] is on a lightweight passive human motion detection system using Wi-Fi signals. This work aims to develop a system that can detect human motion without requiring any active participation from the user.

The proposed system utilizes Wi-Fi signals and applies signal processing techniques to detect changes in the wireless signal caused by human motion. The system does not require any additional hardware or sensors, making it a cost-effective and easily deployable solution.

The research [5] on an automated motion detection security system notifier using Raspberry Pi with Telegram. This work aims to develop a low-cost and effective security system that can alert users in real-time when motion is detected.

The proposed system utilizes a Raspberry Pi, a low-cost single-board computer, and applies motion detection algorithms to detect any movement in the monitored area. The system then uses Telegram, a popular messaging application, to notify the user in real-time with an alert and a snapshot of the detected motion.

The research [6] is on video summarization based on motion detection for surveillance systems. This work aims to develop a method for summarizing long surveillance videos into shorter, more concise videos while preserving the most important events and activities captured in the original footage.

The proposed method utilizes motion detection algorithms to identify the most important motion regions in the surveillance video. These regions are then used to generate a summary of the video, which contains only the most relevant frames and events. The method also includes a weighting scheme to assign a score to each region based on its relevance and importance.

The research [7] is on the detection, identification, and tracking of objects during motion. This work aims to develop a method for detecting, identifying, and tracking moving objects in video sequences, which can be used for various applications such as surveillance, traffic monitoring, and activity analysis.

The proposed method utilizes a combination of background subtraction, contour extraction, and object recognition algorithms to detect and identify moving objects in video sequences. The method also includes a tracking algorithm, which uses the detected objects' position and motion information to track them over time.

The research [8] is on the use of TensorFlow and OpenCV to detect vehicles. This work aims to develop an efficient method for detecting vehicles in real-time video streams, which can be used for various applications such as traffic monitoring, parking lot management, and security surveillance.

The proposed method utilizes a combination of convolutional neural networks (CNNs) and object detection algorithms to detect and classify vehicles in real-time video streams. The researchers trained their CNN using the TensorFlow deep learning framework and used OpenCV for object detection and tracking.

The research [9] on subject tracking with camera movement using a single-board computer. This work aims to develop an effective method for tracking a moving subject in a video stream, even when the camera is moving.

The proposed method utilizes a combination of object detection and tracking algorithms to track the subject of interest. The researchers implemented their algorithm using a Raspberry Pi single-board computer, which is a low-cost, credit-card-sized computer that is commonly used in embedded systems.

The research [10] on the development of an autonomous face detection system for real-time video streaming to ensure the security of intelligence systems. The proposed system is designed to detect human faces in real-time video streams, which is a critical component of many security and surveillance systems.

The system is based on deep learning algorithms and is trained using a large dataset of facial images. The researchers used the TensorFlow deep learning framework to develop their system and conducted experiments to evaluate its performance using real-time video streams. The results showed that their system was able to accurately detect human faces in real-time video streams with high accuracy and reliability. The system is also capable of recognizing multiple faces in the same video stream simultaneously.

The development of a software system [11] for motion detection and tracking. The system is designed to identify and track different types of motion and objects in real-time video streams. The software utilizes advanced algorithms for object recognition and tracking, which allows it to differentiate between various types of motion and objects.

The system is capable of detecting and tracking multiple objects simultaneously and can respond appropriately based on predefined rules or instructions. It can be used for a variety of applications, including security and surveillance, traffic monitoring, and industrial automation.

III. RELEVANCE OF THE RESEARCH

The research on Motion Detection systems and object recognition is highly relevant in today's security landscape. With the increasing need for advanced security measures, the development of such a system can provide a more effective and reliable way to monitor different locations and identify potential security threats.

The system's ability to constantly process the input image of the video camera module and detect movement can be of immense value in detecting and tracking intruders or suspicious activity in real-time. Additionally, the system's capability to recognize different objects, such as vehicles, people, and animals, can help to distinguish between normal activity and potential threats.

This research can be applied in various domains such as public transportation, airports, government buildings, and private organizations to enhance their security measures. By incorporating motion detection and object recognition capabilities into their existing security systems, organizations can increase their preparedness and response to security incidents, providing a safer environment for their employees and the public.

Furthermore, the development of a reliable and efficient motion detection and object recognition system can help to minimize false alarms and improve the accu-

racy of security alerts. This can save valuable time and resources for security personnel, allowing them to focus on more critical tasks and respond to incidents more quickly.

Overall, the research on motion detection and object recognition has significant relevance in today's security landscape and can help organizations to better monitor and secure their premises, ensuring public safety and minimizing potential security threats.

IV. OBJECTIVES

The main objective of developing a video surveillance system for motion detection and object recognition is to enhance the security and surveillance capabilities of a given location. The system that is developed ought to operate using at least 10 % fewer system resources in comparison to its analog counterparts [11], which implies utilizing fewer CPU and RAM resources.

The specific objectives of this project can be outlined as follows:

- Detecting motion: The system should be able to detect any motion within the field of view of the camera. This includes detecting both large and small motions, as well as different types of motion such as walking, running, and crawling.
- Object recognition: The system should be able to identify and recognize different objects that appear within the camera's field of view. This includes both stationary and moving objects, and the system should be able to distinguish between different types of objects, such as people, vehicles, and animals.
- Real-time processing: The system should be able to process the video feed in real-time, with minimal lag between the captured footage and the displayed output.
- Customizability: The system should be customizable, allowing users to adjust the settings and parameters to suit their specific surveillance needs.

By achieving these objectives, the video surveillance system can provide an effective and efficient means of monitoring a given location, enhancing security and safety for both public and private spaces.

V. IMPLEMENTATION OF AN APPLICATION

Let's list the typical functions of computer vision systems:

- identification;
- image search by content;
- recognition;
- assessment of the situation.

To understand the minimum set of functionality necessary to cover all the points listed in the previous section, a kind of unified modeling language will be used, namely, the activity diagram in Fig. 1. It illustrates the moments of interaction between the involved objects: the user and the designed product.

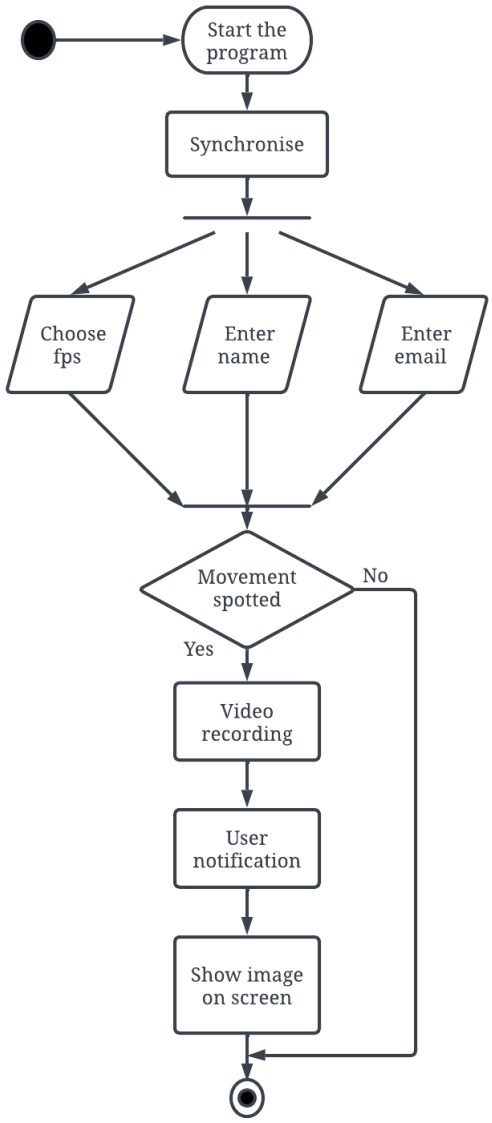

Fig. 1. The monitoring system activity diagram

The block diagram in Fig. 2 shows the life cycle of the flow responsible for maintaining all intermediate states of the timer process, it provides for the collection of statistical data on the operation of the monitoring system.

It should be noted that the life cycles of the threads responsible for maintaining all intermediate states of the monitoring process and subsequent notifications of the video surveillance process, and the thread responsible for maintaining all intermediate states of the timer process, are limited in their work to the active and inactive states of the program that arise as a result of interaction the user with the corresponding elements of the graphical interface.

The implementation of the computer vision system depends very much on the area of their application, it will be sufficient to answer the questions: Can certain objects be and are studied in the process of operation? Can the knowledge base of the system be gradually improved, or is its awareness determined in advance?

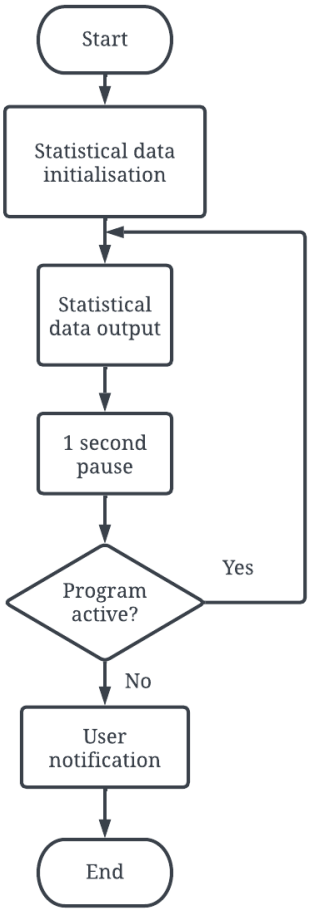

Fig. 2. Timer flow block diagram

Looking at publicly available sources, the third-party library with open source code OpenCV will be used to implement the backbone of the video surveillance system for motion detection and object recognition.

This library is widely used in various applications such as robotics, medical image analysis, and augmented reality. It provides a large number of functions for image and video processing, making it a powerful tool for computer vision applications.

OpenCV is compatible with many programming languages, including C++, Python, and Java, making it accessible to a wide range of developers. Its open-source code also allows developers to customize and extend its functionality to meet specific project requirements.

Overall, the use of OpenCV in the development of video surveillance systems for motion detection and object recognition has become a standard practice due to its reliability and versatility. Its continued popularity and active development community ensure that it will remain a fundamental tool for researchers and practitioners in the field of computer vision.

The program allows users to adjust the settings and parameters to suit their specific surveillance needs in Fig. 3. User interface contains a group of flags that set the desired value of the number of separate frames of the saved video sequence. The phrase "saved video sequence" refers to the value of the separate number of frames of both the image, which will be processed by the third-party OpenCV library algorithm, and the video sequence saved in a file of a known extension. At the same time, this functionality does not limit the user in the saved video series of cumulative and competitive quality and also regulates the use of large volumes of external media memory.

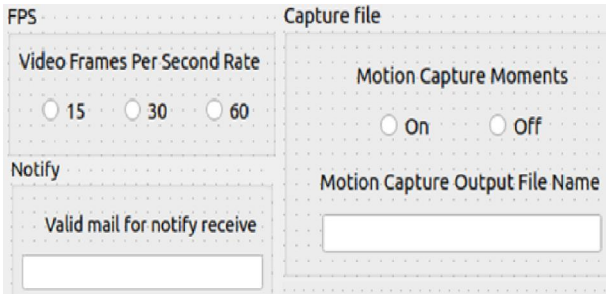

Fig. 3. Custom settings panel

This configuration panel is responsible for specifying the desired e-mail box of the user, or anyone else. The mandatory component of a specialized monitoring system. The electronic box to which the user wishes to receive notifications about potential crimes is indicated in a specially selected text block. There is also a warning message that informs the user that the desired email account must be able to receive emails from third-party applications (this protection mechanism prevents receiving unwanted messages from third-party applications) to successfully receive notifications of a potential crime.

The motion capture configuration panel corresponds to a function such as "Motion capture", which records the entire stream of captured video, which shows the moments of selected crimes and their minimal continuation, which will be a powerful tool for protecting personal belongings, but at the same time slightly increases the required amount of free space on carriers. This functionality can be removed by installing the corresponding flag, for example, by using a small volume of media. Additionally, there is a text block where the user can specify the desired final name of the saved video sequence.

Users of the Qt library are not limited in the use of tools directly involved in working with the graphical interface, if necessary, the user can always switch to the mode of operation without a graphical interface, for this, to avoid unnecessary resource costs necessary to build a full-fledged graphical interface, it will be sufficient to create only object of class QcoreApplication.

VI. APPLICATION TESTING

Video surveillance systems rely on advanced technologies, including computer vision algorithms, to detect and analyze motion and objects in real-time. While these systems are crucial for enhancing security, they can also put a strain on the resources of the computer hardware that runs them, especially the central processing unit

(CPU) and random-access memory (RAM). As a result, it is essential to test these systems' performance to ensure that they operate efficiently and effectively.

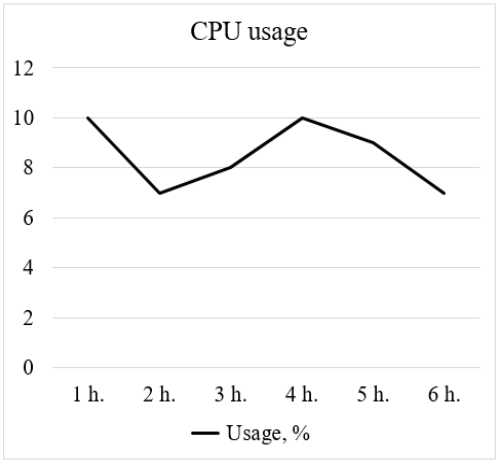

Fig. 4. Graph of CPU usage

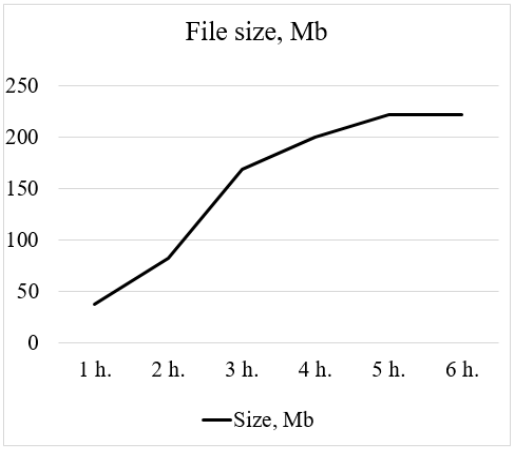

Fig. 5. Graph of file size changes per hour

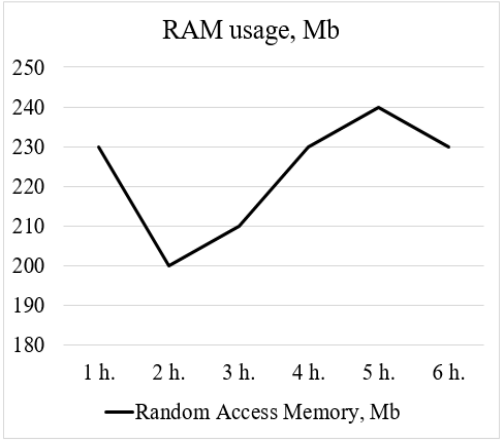

Fig. 6. Graph of RAM usage

The diagram in Fig. 4 shows the tendency of increasing the load on the central processor core during a six-hour monitoring session in a percentage ratio. The peak load is 10 %, and the average indicator fluctuates at the level of 8.5 %.

The diagram in Fig. 5 shows the tendency of increasing the size of the saved video sequence. The size of the video file did not exceed 300 Mb – which is acceptable for a specialized video surveillance system.

The graph in Fig. 6 shows the RAM usage changes per hour during a six-hour session in megabytes. The peak load is 240 Mb, and the average indicator fluctuates at the level of 223 Mb.

VII. CONCLUSION

As a result of this work, a video surveillance system for motion detection and object recognition was developed. Auxiliary technologies related to Computer Vision, which can extend the functionality of the video surveillance system, were also investigated, including their potential implementation of accessible open-source libraries.

One of the key advantages of this system is its efficient use of CPU and RAM resources. Compared to analog surveillance systems, this system shows better results in terms of resource usage, allowing for smoother and more effective performance without overburdening the system.

The created system uses 8.5 % CPU and 240 Mb RAM which is lower than the analog one [11] with 12 % CPU and 450 Mb RAM usage. CPU usage decreased by 29.2 % compared to the analog, and RAM usage decreased by 46.7 %, indicating that the created system is more efficient than the analog one.

The use of OpenCV and other advanced technologies also contributes to the accuracy and reliability of the system, allowing for more precise detection and recognition of objects and reducing the risk of false positives and false negatives.

Overall, the development of a video surveillance system for motion detection and object recognition represents an important advancement in the field of surveillance technology, offering a powerful and effective tool for enhancing security and surveillance capabilities in a wide range of settings. With its efficient resource usage and advanced features, this system is poised to become an essential tool for ensuring safety and security in a variety of applications.

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