International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Intruder Detection System Using Machine Learning

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ABSTRACT

With the increasing need for intelligent surveillance systems, our web application integrates three essential modules: motion detection, face recognition, and face mask detection. These features work together to monitor environments, identify individuals, and ensure compliance with health guidelines. The system aims to enhance security and safety across various settings by offering real-time monitoring, recognition, and alerting capabilities. This application leverages advanced algorithms such as deep learning and computer vision to improve accuracy and efficiency. It provides a scalable solution adaptable to a range of environments, from public spaces to enterprises, addressing modern challenges like identity verification and pandemic management.

Keywords: Motion Detection, Face Recognition, Face Mask Detection, Real-time Surveillance, Deep Learning, Flask Web Application, Security System, Health Compliance

1. Introduction

Security and safety have become significant concerns in today's world, especially with increasing threats to physical spaces and public health. Conventional surveillance systems often rely on manual monitoring, which is prone to human error and delayed responses. There is a growing demand for automated solutions that can monitor spaces, identify individuals, and enforce safety protocols efficiently.

Facial recognition has emerged as a key technology for security, helping organizations manage access control and monitor critical areas. However, many systems still struggle with environmental challenges like varying lighting and dynamic backgrounds. Integrating face recognition with advanced motion detection can significantly improve the efficiency of surveillance systems.

The COVID-19 pandemic has also introduced new health safety requirements, such as wearing masks in public spaces. Existing surveillance systems are not equipped to monitor compliance with these rules. Incorporating mask detection alongside other security features can ensure better public health management and compliance monitoring.

This project aims to build a web application that combines motion detection, face recognition, and face mask detection to deliver a comprehensive, intelligent surveillance system. With real-time alerts and analysis, this solution can help businesses, governments, and individuals manage security and health protocols more effectively.

2. Literature Survey

Amit, Y. (2002) – 2D Object Detection and Recognition: Models, Algorithms, and Networks research explores various models, algorithms, and network architectures used in 2D object detection and recognition. The study focuses on feature extraction techniques, classification methodologies, and the application of neural networks in visual recognition tasks. It provides insights into probabilistic modeling, learning strategies, and performance optimization for object detection systems.

Yoshida, T. (2004) – Background Differencing Technique for Image Segmentation Based on the Status of Reference Pixels paper introduces an advanced background differencing technique for image segmentation that relies on the status of reference pixels. The method enhances accuracy by dynamically adjusting to changes in lighting conditions and environmental variations.

Experimental results demonstrate its effectiveness in improving segmentation quality for applications in computer vision and surveillance systems.
Yong, Ching, Sudirman, Rubita & Chew, Kim Mey (2011) – Motion Detection and Analysis with Four Different Detectors compares four distinct motion detection algorithms and evaluates their efficiency in tracking and analyzing movement. The research assesses each method's accuracy, computational

efficiency, and suitability for real-time applications. Results indicate the strengths and limitations of each detector, offering insights into selecting the optimal approach for specific motion detection tasks.

Linetal. (2019) – Face Mask Identification Using a Machine Learning Approach presents a machine learning-based framework for face mask detection. By leveraging deep learning techniques, the study develops a model capable of accurately distinguishing between masked and unmasked faces. Experimental results demonstrate the system's robustness, making it suitable for public health monitoring and security applications.

Kumar, Ashu, Kaur, Amandeep & Kumar, Munish (2019) – Face Detection Techniques: A Review paper explores various face detection techniques, including traditional image processing methods and deep learning-based approaches. It discusses key advancements in face detection algorithms, highlighting their performance in terms of accuracy, efficiency, and robustness against variations in lighting, occlusion, and pose.

Kaihan Lin et al. (2020) – Face Detection and Segmentation Based on Improved Mask R-CNN proposes an enhanced Mask R-CNN model for face detection and segmentation. The improvements focus on refining feature extraction and mask generation processes to increase detection accuracy. The proposed approach is evaluated on benchmark datasets, demonstrating its effectiveness in real-world applications.

Tasie, Nicholas, Risi, Ikechi & Robert, Judah (2020) – Design and Implementation of Intruder Detector System with SMS Alert details the development of an intruder detection system equipped with an SMS alert feature. The system integrates motion sensors and microcontrollers to detect unauthorized entry and send real-time notifications. The study discusses system architecture, implementation, and testing, highlighting its effectiveness for home and office security.

Sahlan, F., Feizal, F. Z., & Mansor, H. (2022) – Home Intruder Detection System Using Machine Learning and IoT presents a smart home security system that utilizes machine learning and IoT technologies for intruder detection. The system employs image processing and sensor-based monitoring to identify unusual activities and send alerts. The study evaluates its performance under different conditions, demonstrating its reliability for real- time security applications.

Mohammed Ali, F. & Al-Tamimi, M. (2022) – Face Mask Detection Methods and Techniques: A Review paper examines various face mask detection methodologies, including conventional computer vision techniques and deep learning- based approaches. The study highlights the effectiveness of different models, discusses their limitations, and provides recommendations for future improvements in face mask recognition systems.

David Lee (2022) – Federated Learning for Posture Classification explores the application of federated learning in posture classification. The study proposes a decentralized model that allows multiple devices to collaboratively train a posture recognition algorithm while maintaining data privacy. The results indicate that federated learning enhances model accuracy while ensuring security and scalability in real-world implementations.

3. Methodology and Discussion

The web application integrates three core modules: motion detection, face recognition, and face mask detection. For motion detection, we employ frame-differencing algorithms enhanced by background subtraction to identify movement accurately. Face recognition uses a pre-trained convolutional neural network (CNN) model to detect and identify individuals. Mask detection is implemented using a deep learning model like Mobile Net, trained on datasets containing images of people with and without masks.

Each module is deployed using a Flask backend, with a responsive web interface built using HTML, CSS, and JavaScript. The system captures video streams in real-time, processes the data, and provides alerts when motion is detected, a face is recognized, or an individual is found without a mask. This modular approach ensures scalability and allows seamless integration of additional security features in the future.

4. System Architecture

The system architecture depicted in **Figure 4.1** represents the comprehensive workflow of a face mask detection model, detailing the various stages the classification model transitions through and the events that trigger these transitions. This architecture encapsulates the model's behavior, from data preprocessing to model training, and finally, its application for real-time detection.

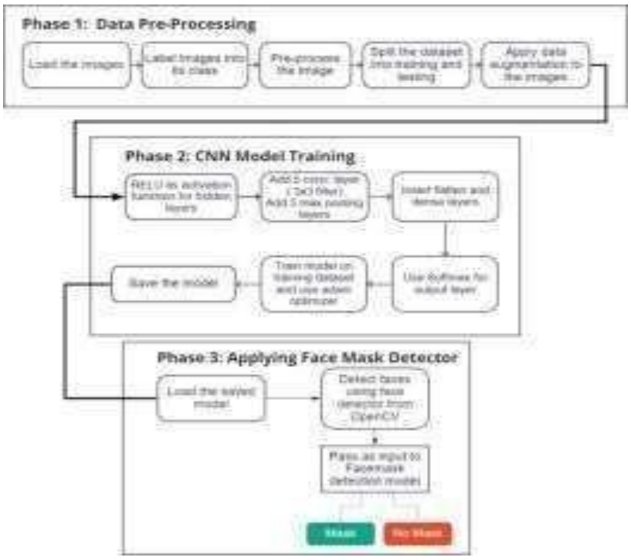

Figure 4.1 System Architecture

It provides critical insights into how the system dynamically interacts with external inputs, such as user data and real-time images, and how it processes these inputs through various stages of computation. The architecture is divided into three primary phases. In Phase 1: Data Pre-Processing, the system begins by loading raw image data, which is essential for training the model. This data is labeled into respective classes— "Mask" and "No Mask"—and undergoes pre-processing to standardize the input through techniques like resizing, normalization, and augmentation. The dataset is split into training and testing subsets to evaluate the model's accuracy and generalization capability. Data augmentation is applied to increase variability, which improves model robustness and reduces overfitting.

In **Phase 2: CNN Model Training**, the core of the machine learning model is constructed and trained. A Convolutional Neural Network (CNN) with five convolutional layers, each equipped with a 3x3 filter, is utilized. These layers capture essential features from the input images, followed by max pooling layers that reduce dimensionality while preserving critical information. The model employs the Rectified Linear Unit (RELU) activation function to introduce nonlinearity, enabling the network to learn complex patterns. Flattened feature maps are passed through dense layers, with the final layer using a Softmax activation function to classify the images. The Adam optimizer is applied to train the model efficiently, dynamically adjusting learning rates to accelerate convergence. Once trained, the model is saved for future use, marking a transition from training to realworld application.

Phase 3: Applying Face Mask Detector brings the trained model into real-time environments. Here, the system loads the saved model and uses the OpenCV library for face detection in live images or video streams. Detected faces are then passed as input to the face mask classification model, which determines whether a face is wearing a mask or not. Based on the model's output, visual indicators are displayed (e.g., green for "Mask" and red for "No Mask"), providing an interactive response to real- time data inputs.

The state diagram associated with this architecture showcases the system's dynamic behavior during the training phase and real-time detection. It illustrates how the model responds to input images, transitions between various states such as data pre- processing and model inference, and how external events, like user interaction or real-time video streams, trigger transitions between these states. This holistic visualization emphasizes the model's adaptive functionality, from learning from a static dataset to reacting in real-time environments, making it suitable for deployment in practical scenarios such as public surveillance and health compliance monitoring during pandemics.

5. Use Case Diagram

Figure 5.1 use case diagram provides an overview of the interaction between external actors and the classification model, outlining the various use cases and how users or external systems interact with the system. The diagram provides a visual representation of the system's external interactions guiding the development and understanding of user requirements. It visually represents the interactions between different actors (users or external systems) and the system, showing the functionality the system provides. It is part of UML (Unified Modeling Language) and focuses on what the system does, rather than how it does it.

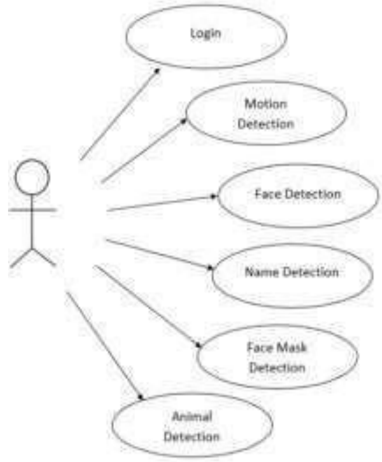

Figure 5.1 Use Case Diagram

6. Flowchart

The surveillance system operates by continuously capturing frames from a video feed using a camera. Each frame is analyzed for motion detection, which serves as the initial trigger for further analysis. If no motion is detected, the system continues monitoring. However, if motion is identified, the system proceeds to perform facial recognition to determine if any individuals are present. If faces are detected, the system attempts to identify them by matching them with stored profiles. Additionally, the system checks for face masks, ensuring compliance in restricted areas where mask-wearing is required. Apart from human identification, the system is also designed to detect animals, which can be useful in scenarios like monitoring wildlife, preventing unauthorized access by pets, or identifying potential threats. Upon meeting any of these conditions—motion detection, recognized or unrecognized individuals, presence of animals, or mask violations—the system generates an alert. This alert can be in the form of a notification to security personnel, an alarm, or even an automated response, such as locking doors or activating additional security measures. This surveillance system enhances security by providing real-time monitoring, detecting potential threats, and ensuring compliance with safety regulations.

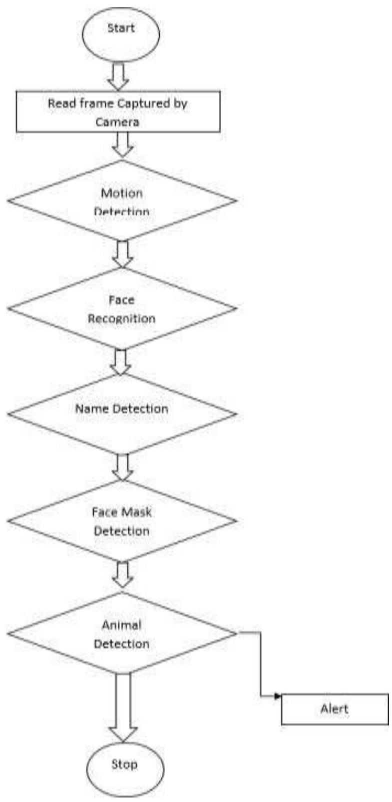

Figure 6.1 Flowchart

7. Objectives

- Develop a real-time **motion detection module** with high accuracy.
- Implement an efficient **face recognition system** for identity verification.
- Integrate **mask detection to** ensure compliance with health regulations.
- Provide a **user-friendly web interface** for seamless interaction.
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- Ensure **real-time alerts** and quick responses to security threats.

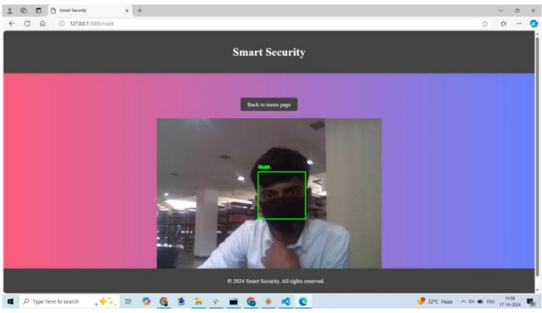
8. Future Scope

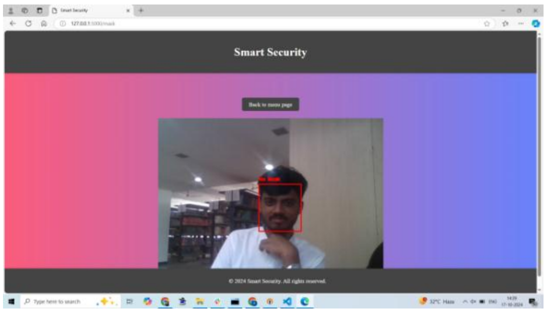
- **Integration with IoT devices** for enhanced automation and remote control.
- **Deployment on cloud platforms** for scalability and storage management.
- **Voice recognition and behavior analysis** for additional security.
- **Multi-camera support** to expand coverage across large areas.
- **Mobile application** to provide remote alerts and controls.

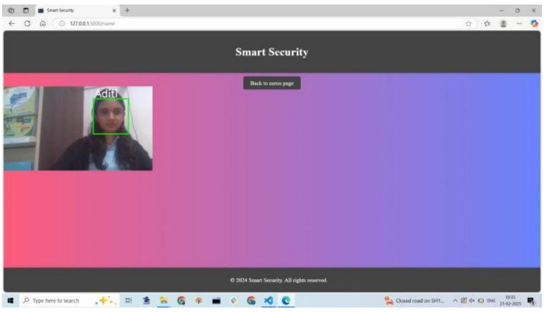
9. Conclusion

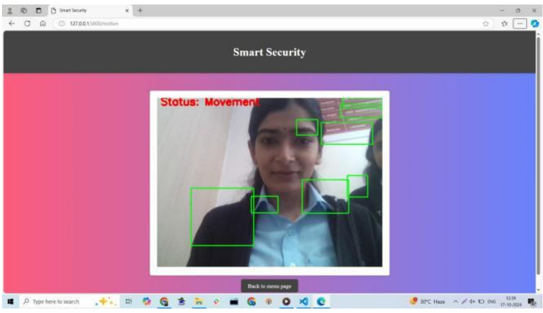
The Smart Surveillance Web Application combines motion detection, face recognition, and mask detection to offer a comprehensive security solution. By addressing the limitations of traditional surveillance systems, it enhances safety, ensures compliance with health regulations, and provides real-time alerts. The modular design ensures that the system can be easily adapted and scaled to different environments. This project represents a significant step toward intelligent surveillance, with the potential for further advancements in the future.

10. Results









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