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Smart Home Anti -Theft Detection using IoT and AI

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***Abstract*— In today's fast-paced world, where security and convenience go hand in hand, smart automation has become more of a necessity than a luxury. This study proposes a smart home security system that utilizes the combined strengths of Internet of Things (IoT) and Artificial Intelligence (AI) to deliver advanced safety through a dual-factor authentication approach.**
This system has been developed to recognize and allow entry solely to authorized personnel can access the premises by combining facial recognition with a password-based verification method. What truly makes this solution stand out is its ability to be monitored and controlled remotely, giving homeowners peace of mind even when they're away.
AI plays a vital role by enabling real-time face detection and recognition guaranteeing rapid and accurate identification. upon identifying a breach, the system goes a step further—capturing a short video of the suspected intruder and instantly emailing it to the homeowner. If the system senses any tampering, such as attempts to break the lock or damage the setup, it immediately triggers an alarm to alert nearby residents.
This intelligent, responsive approach brings together technology and practicality to redefine the way we secure our homes.

***Index Terms*— Smart Home Security; IoT Integration; AI-Powered Surveillance; Home Automation Systems; Intelligent Energy Use.**

I. INTRODUCTION

The rise in thefts and break-ins, often driven by poverty and other underlying social issues, has made home security more essential than ever. It's no longer just about protecting material possessions—it's about safeguarding peace of mind. Beyond monetary loss, victims of theft often grapple with emotional distress caused by the breach of their private sanctuary. With crime becoming more unpredictable, it's natural to worry: "Could I be next?"

This growing concern has made surveillance systems a vital part of home security. CCTV installations, specifically, have gained significant traction and proven their efficiency. Modern CCTV systems use video cameras to monitor property and stream live footage to a screen for review [4][9]. However, most thefts happen during the day when residents are away at work—making it impractical for someone to constantly monitor the footage. Hiring a person just to watch video feeds 24/7 is expensive and often inefficient.

That's why smart, automated surveillance systems are gaining traction. These systems offer real-time monitoring, intelligent detection, and immediate alerts—eliminating the need for human oversight.

With built-in theft detection, they can quickly recognize unusual activity and notify the homeowner or security personnel before the situation escalates.

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Advanced systems also work in coordination with police databases. When someone enters the premises, their face is captured and analysed. Key facial features—such as eyes, nose, lips, and hair—are segmented from the image and compared with existing criminal records. If the person matches a known criminal, alerts are instantly sent to both the homeowner and the local police station. If the person is identified as a family member or trusted visitor, no action is taken. For unknown individuals, the system collects and stores footage while notifying the homeowner for further review.

The primary objective of this system is to foster a safer, more connected home—giving individuals the confidence that their space is secure, even when they're away.

II. Literature Survey

The work by M.T. Bhatti and colleagues introduces an innovative approach for weapon detection in surveillance systems. By leveraging advanced deep learning methods, particularly Convolutional Neural Networks (CNNs), their system enables real-time identification of threats in CCTV feeds, thereby making surveillance more intelligent and proactive [1]. Similarly, M. Grega et al. proposed a smart and hands-free system capable of detecting dangerous objects such as knives and firearms through live video streams. Their contribution lies not only in identifying these objects but also in generating immediate alerts, which significantly enhances preventive measures [2].

In another related study, L. Mary Glad Ence and her team focused on designing a comprehensive solution to proactively detect criminal activities in real time, aiming to strengthen the security of smart home environments [3]. Extending this line of research, A.B.K.H and colleagues developed an advanced CCTV surveillance framework that goes beyond passive observation.

Their system integrates automatic intrusion detection and live video streaming. Whenever an unfamiliar face is detected, the user is instantly notified via SMS or email with the intruder's image, while also having the option to observe the situation live [4].

N. Micheli et al. presented a unique solution targeting theft prevention through a hidden monitoring system embedded in electric meters. This system automatically issues real-time alerts when current levels exceed a predefined threshold, providing authorities with both the location and an image of the detected threat [5]. Complementing this, Mada Albany and co-researchers highlighted how the growth of smart homes is being powered by IoT integration, enabling devices to interconnect, share data, and improve automation within everyday life [6].

H. Turtiainen et al. contributed a novel perspective by applying computer vision techniques to identify CCTV cameras themselves in images and videos. Unlike traditional approaches that only analyse what cameras capture, their framework shifts focus to the detection of surveillance devices, marking a new research direction [7].

Focusing on visitor management and personal privacy, A. Karthikeyan and his team emphasized the growing importance of real-time identity verification.

They advocated for facial recognition technology as a more reliable and secure alternative to manual checks, noting that cost-effectiveness and scalability must be considered depending on residential, commercial, or industrial settings [8].

Meanwhile, S. Shammi et al. addressed vehicle theft prevention in parking areas. Their method utilized Canny edge detection to classify objects in complex CCTV video inputs, enabling real-time vehicle monitoring [9]. Finally, Vir Singhender and colleagues introduced a neural network–based anomaly detection system for CCTV streams. By modelling both normal and abnormal behaviours, their framework improved detection accuracy and proved effective in diverse and complex surveillance environments [10].

III. Methodology

In many current surveillance systems, the process begins by capturing images of anyone who enters the premises. These systems are designed to automatically extract key facial features—like the eyes, nose, and mouth—to analyse and compare against a stored database.

If the captured face doesn't match any known profiles, such as those of family members or trusted individuals, the system sends a smart, real-time notification to the homeowner. This proactive approach is intended to enhance residential safety by automating the process of intrusion detection and quick response—minimizing delays and reducing the need for constant human monitoring.

At their core, these systems strive to establish a protected living atmosphere, allowing residents to feel secure no matter where they are.

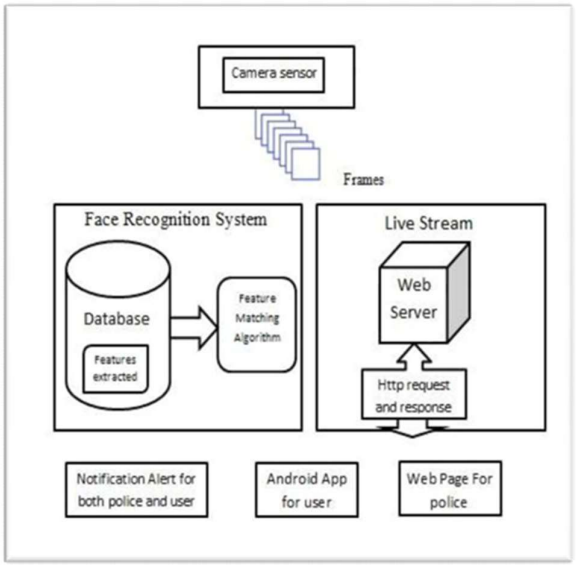

Figure 1: System Architecture

As illustrated in Figure 1, the system architecture is centred around a CCTV camera sensor that continuously captures video footage, breaking it down into individual frames for analysis. Once a face is detected in the frame, this system incorporates advanced facial analysis technology for accurate user identification to draw meaningful comparisons between features—such as the unique outline and structure of the eyes, nose, and mouth—against a database of known individuals. If the face matches a record associated with a criminal, the system instantly triggers an alert.

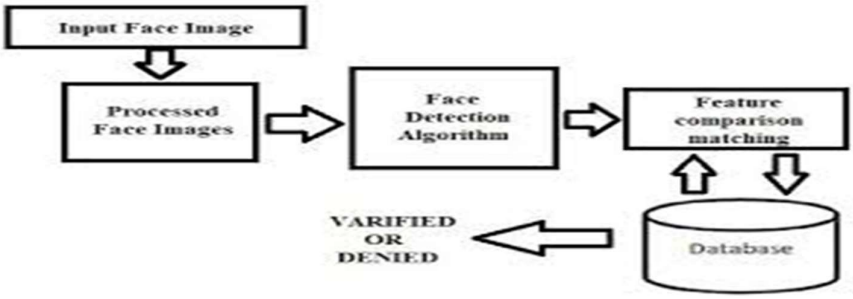

Figure 2: Face Identification Structure

The face identification system, as illustrated in Figure 2, is designed to intelligently detect and identify individuals captured on CCTV footage. At its core, the system leverages the Histogram of Oriented Gradients (HOG) algorithm to extract facial features, and utilizes a Random Forest–powered machine learning solution to recognize and classify those features accurately.

A. Here's how it works

When a face appears on camera, the system immediately processes the video frames, encoding facial data and comparing it with entries stored in a secure database. If it spots a clear match and the face belongs to a known criminal, the system promptly sends a smart, real-time notification to the user's mobile device and automatically notifies the nearest police station via the integrated web portal.

B. Proposed System

In this system, we introduce an intelligent system powered by machine learning algorithms to detect suspicious individuals—particularly thieves—by analysing faces captured through CCTV or laptop cameras. The process begins as soon as the camera starts recording; the video stream is automatically broken down into individual image frames for analysis.

Once a face is recognized and flagged, the system applies a face recognition algorithm to spot and compare the captured face against a database of stored profiles. The comparison checks whether the newly recorded face matches any known individuals in the system—especially criminal records. If it spots a clear match, an alarm is triggered based on specific criteria outlined in Figure 3.

C. Enhanced Real-Time Face Recognition System with ESP32-CAM Integration

In this proposed system, we are re-engineering the face recognition and surveillance technology with modern patterns, smarter algorithms, and real-time processing capabilities. Our aim is to not just replicate existing solutions, but to enhance each algorithm and component to deliver better, faster, and more reliable output in real-world scenarios.
Here's how we're making it happen:

D. ESP32-CAM Module for Real-Time Processing

At the heart of our system is the ESP32-CAM, a powerful microcontroller with built-in camera capabilities. It allows us to capture and process visual data in real-time, making it ideal for live surveillance and face recognition tasks. This compact yet powerful module is central to delivering accurate, low-latency results.

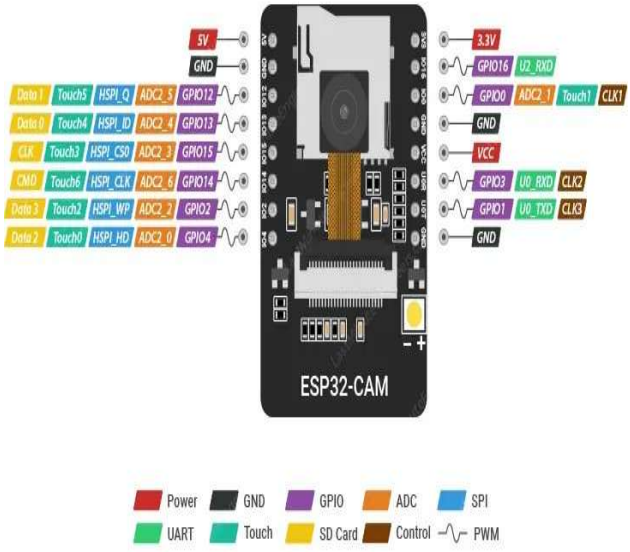

Figure 3: ESP-32 Camera

The ESP32-CAM module lies central to this approach, acting as the brain of the entire face recognition and security system. It seamlessly brings together both hardware components and software intelligence to enable smart surveillance and automation.

E. Comprehensive Sensor and Component Integration

To create a fully functional smart surveillance setup, we've integrated various hardware components:

- Motion detectors to sense movement.
- AI algorithms for facial recognition and classification.
- Wi-Fi for wireless data transmission.
- Sensors to gather environmental data.
- Smart access solution using electronic locking mechanisms.
- Communication interfaces for system interaction and notifications.

F. Display and Ultrasonic Sensing

- We've connected a 16x2 LCD display using the I2C protocol through the ESP32-CAM's GPIO 12 and 13 pins (SDA and SCL), providing clear system feedback to the user.
- For obstacle and proximity sensing, an ultrasonic sensor is integrated via GPIO 14 and 15 (Trig and Echo pins), useful for detecting presence near the door or in a monitored area.

G. Relay-Controlled Smart Home Integration

The project also includes three active-low relays, connected to GPIO pins 1, 3, and 16, allowing us to control essential home or office appliances:

- Relay 1: Controls the smart door lock system.
- Relay 2: Operates a fan (for environmental comfort or automated ventilation).
- Relay 3: Manages a light (useful for automated lighting based on motion or time).

This platform is designed not just to support, but to advance real-time face detection and recognition, but also functions as a basic home automation and security system, combining AI, IoT, and embedded control in a single project.

H. Histogram of Oriented Gradients (HOG) – Feature Extraction for Face Detection

The Histogram of Oriented Gradients (HOG) is a refined approach to capturing the essence of the data used to identify and analyse the structure and shape of objects within an image—especially useful for detecting human faces. In our system, the Histogram of Oriented Gradients (HOG) technique serves as a critical component, transforming raw image pixels into structured, high-level feature representations that can be effectively interpreted by machine learning algorithms.

Here's how it works:

HOG doesn't just look at pixel intensity—it focuses on the flow it takes and intensity of gradients, which describe how brightness changes across various regions within the image. The entire image is divided into small localized regions, or sectors. Within each sector, the algorithm calculates the gradient orientation and compiles this into a histogram. These histograms effectively describe the contour and structure of the face or object in that region.

This approach allows HOG to recognize facial features even under varying lighting or slight changes in angle—making it ideal for surveillance cameras, including CCTV systems, where lighting and angles can vary significantly.

After capturing these meaningful details, they are transformed into a structured format that can be seamlessly utilized by machine learning models built to understand deeply and predict precisely analysis and prediction, they are fed into classification algorithms. In our case, we use:

- A Support Vector Machine (SVM) is employed to analyse the extracted feature set, enabling precise classification to verify whether the detected face corresponds to any entry within the system's database.
- A Random Forest algorithm to further refine the recognition process and enhance the accuracy of feature calculation.

Together, these methods form a reliable and efficient image recognition framework, capable of identifying known individuals, detecting unknown or suspicious faces, and providing real-time alerts.

This combination of HOG with SVM and Random Forest not only boosts the precision of our system but also enables it to operate effectively in real-time environments, making it a core part of our intelligent face recognition solution.

I. Grassman Algorithm

In the configuration we propose, a key feature is its ability to recognize and differentiate between familiar and unfamiliar faces using advanced facial recognition techniques. The process begins by training the system with facial data of the homeowner and their family members. Simultaneously, live input is gathered from VMS (Video Management System) technology, gathering real-time data from a network of cameras and sensors embedded throughout the smart home infrastructure.

IV. RESULTS AND ANALYSIS

Smart homes are quietly becoming intelligent, with AI now playing a key role in enhancing home security. One of the most impactful applications is in identifying unauthorized intrusions—specifically, potential theft—using advanced AI algorithms and integrated technologies.

This project combines both software and hardware components to deliver real-time, reliable results. When an unknown person attempts to access a private space, The system leverages facial recognition technology to identify them. Simultaneously, motion detectors are triggered to track any suspicious activity or movement.

Once a potential threat is detected, an instant The recipient is immediately notified the homeowner via mobile communication platforms like Telegram, WhatsApp, or similar apps—ensuring the response is immediate, no matter where the user is.

Figure 4: Theft Detected Notification

V. Conclusion

In conclusion, integrating AI into smart home security opens the door to countless possibilities for benefits for protecting our homes and valuables. AI technologies—especially facial recognition—can accurately identify unfamiliar individuals, while motion detectors can detect unusual movements within the premises. What truly defines this system is its ability to send real-time alerts directly to your mobile device through apps like Telegram or WhatsApp. This immediate notification empowers homeowners to respond quickly, potentially preventing theft or damage before it happens. This technology gives people the comfort of knowing their space is protected, even when they're not there to watch over it. It's especially useful in areas where break-ins or thefts are more common, providing an extra layer of security and peace of mind. Moreover, beyond just being a tool, this system also serves as a wake-up call—raising Understanding the significance of smart security and encouraging its adoption in vulnerable or often-targeted locations. In many cases, simply being alerted in time can make all the difference in preventing loss and identifying intruders

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