

A Real-Time Intrusion Detection System for Security Monitoring in Sensitive Environments

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Abstract—The Interruption Location Framework employsments a Raspberry Pi 4B, web camera, and OpenCV to recognize faces and screen get to secured zones. Unauthorized people trigger an caution, and an picture is messaged to the individual in charge. The framework offers an reasonable, robotized security arrangement for homes and work environments.

Index Terms— Intrusion Detection System, Raspberry Pi 4B, face recognition, OpenCV, real-time monitoring, automated security.

I. INTRODUCTION

Security stands as a big worry in our world today in places that need to limit who gets in to keep things, information, or people safe. Old-school security setups often depend on people watching or pricey camera systems. To tackle these issues, this project offers a clever, budget-friendly, and hands-off answer — the Intrusion Detection System — built using Raspberry Pi 4B, a web camera, and OpenCV.

The system aims to spot and tell apart people who should and shouldn't be in a closed-off or restricted area. When someone walks into the watched space, the web camera takes their picture right away. Using face recognition methods put in place through OpenCV, the system figures out if the person has permission to be there. If it catches someone who shouldn't be there, the system sends an email alert with the intruder's photo to a pre-chosen authorized person. But if the person should be there, the system just records when they came in for the books, without sending any heads-up. This project brings together picture processing real-time watching, and automatic messaging to make a small and effective security answer. It works well for things like smart homes small offices, server rooms, and other spots where people want cheap, hands-off watching.

II. FUNCTIONALITY OF THE PROPOSED SYSTEM

The functionality of the Intrusion Detection System is clearly illustrated through several figures and tables included in this work.

Figure 1 demonstrates the face recognition system in operation, where a green bounding box is drawn around a recognized individual, with their name ("gokulraj") displayed above the box, while an unknown person is

simultaneously highlighted with a red bounding box and labeled as "Unknown." This visual representation emphasizes the system's ability to differentiate between authorized and unauthorized users in real-time.

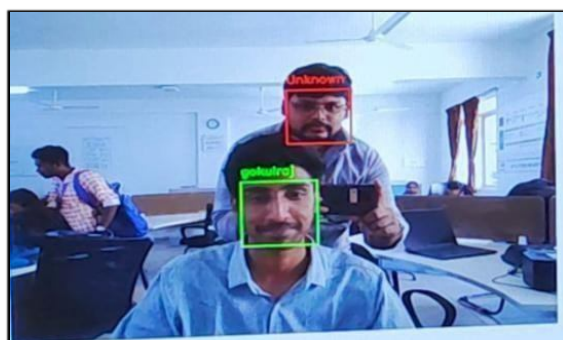


Fig. 1

Figure 2 shows an example of an SOS email alert triggered by the detection of an unknown face. The email includes a timestamped captured image of the intruder, proving the effectiveness of the notification system.

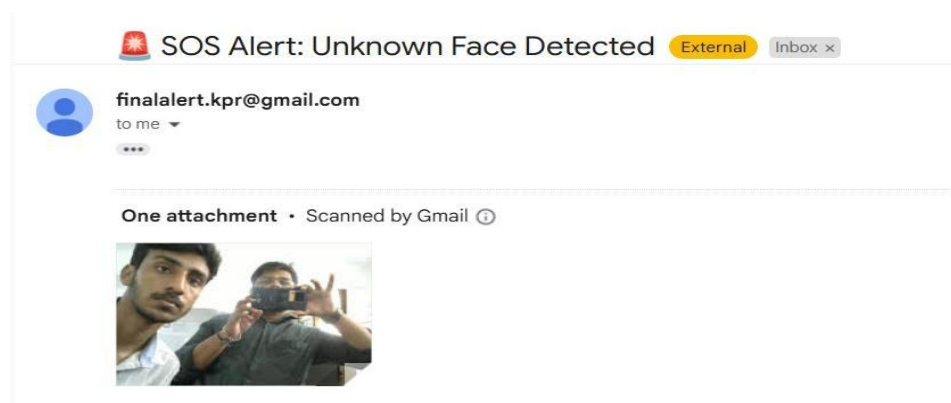


Fig. 2

In addition, Table 1 compiles quantitative data regarding the performance of the system, showing the face detection accuracy across various lighting conditions and the recognition accuracy among different user scenarios. These visual aids substantiate the operational success of the designed IDS.

B. References

The proposed system builds upon a foundation of existing technologies, frameworks, and scholarly work. Key references include the OpenCV open-source library, which provided the essential functions for face detection using Haar Cascade classifiers and face recognition using LBPH algorithms.

The Python smtplib library enabled the integration of automated email alerts directly from the Raspberry Pi device, while the official Raspberry Pi documentation assisted in hardware setup and interfacing with peripherals such as USB webcams.

The Face Recognition Python library played a crucial role in encoding and comparing facial images in real-time. Furthermore, the structure and formatting guidelines were adapted from the Grenze Science Conference Paper Template 2024, ensuring compliance with academic standards. Finally, academic resources such as "Face Detection and Recognition: Theory and Practice" provided theoretical grounding and practical techniques applied in developing this system.

C. Footnotes

The Haar Cascade Classifier referenced throughout the system represents a robust object detection technique developed to identify facial features based on pre-trained datasets. This method rapidly scans captured images to locate potential face regions by applying multiple feature classifiers sequentially.

Meanwhile, the LBPH (Local Binary Patterns Histograms) algorithm serves as a simple yet highly effective approach for facial recognition by encoding pixel intensity patterns around local neighbourhoods. The SOS alert mechanism integrated into the system leverages real-time detection to immediately trigger email notifications when unfamiliar faces are captured, enhancing the responsiveness of the intrusion detection framework. This dual-layer strategy of detection and notification allows for a secure and autonomous monitoring environment.

D. Abbreviations and Acronyms

For ease of understanding, several standard abbreviations and acronyms are used throughout the document. The term IDS refers to Intrusion Detection System, denoting the automated framework designed to detect unauthorized access.

LBPH stands for Local Binary Patterns Histograms, the algorithm utilized for recognizing human faces in captured images. SOS, traditionally known as a maritime distress signal, is adapted here to signify the automatic email alerts sent upon detecting unknown individuals.

FPS represents Frames Per Second, describing the real-time processing rate achieved by the system during video capture and analysis. SMTP, which stands for Simple Mail Transfer Protocol, handles the secure transmission of email notifications from the Raspberry Pi. Lastly, RPI is an acronym for Raspberry Pi, the compact and versatile computing platform used to host and run the entire system.

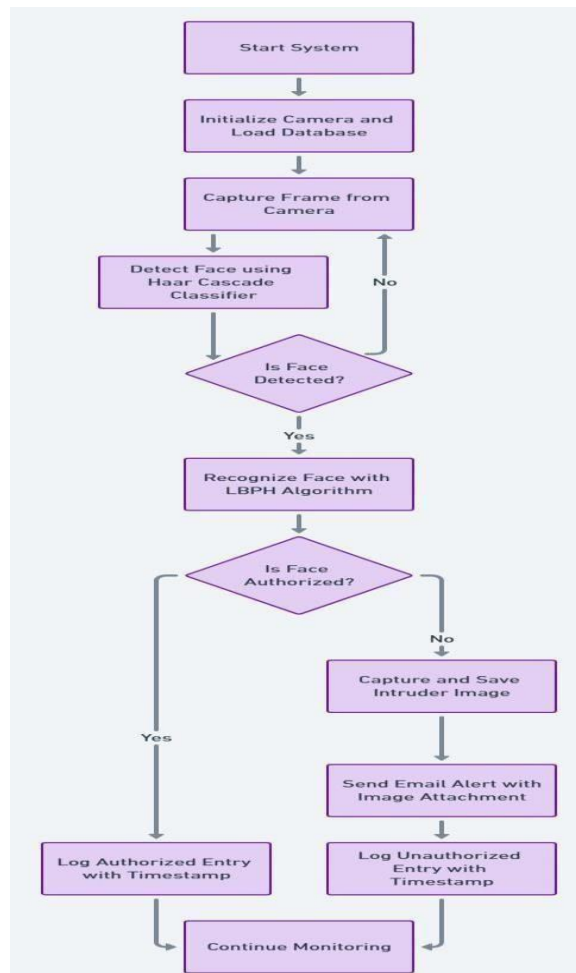


Fig. 3

A facial recognition security system works. It begins with the system's initialization, such as setting the camera and loading a database of known faces. The system is constantly taking frames from the camera and scanning each frame for a face using the Haar Cascade Classifier.

If a face is found, it goes ahead to identify the face with the LBPH (Local Binary Patterns Histograms) algorithm. The identified face is then verified in the database to see if it is approved.

If the face is authenticated, the system marks the entry with a timestamp and keeps on watching. If the face is unauthorized, it captures and stores the image of the intruder, sends an email notification with the image included, marks the unauthorized entry with a timestamp, and then continues monitoring.

E. Equations

While the system's core functionality is primarily implemented through programming and algorithmic logic, one simple but crucial performance metric is used to assess recognition success. The accuracy of face recognition is calculated using the following formula:

$$\text{Accuracy (\%)} = \left(\frac{\text{Number of Correct Recognitions}}{\text{Total Number of Recognition Attempts}} \right) \times 100$$

where the "Number of Correct Recognitions" denotes the count of successfully identified authorized users, and the "Total Number of Recognition Attempts" refers to the total number of face detections evaluated by the system. This equation helps in quantifying the system's reliability and validating its operational effectiveness under varying environmental conditions.

III. CONCLUSIONS

The Intrusion Detection System developed in this project successfully demonstrated the capability to detect unauthorized individuals and send real-time email alerts using a Raspberry Pi 4B, OpenCV, and face recognition techniques. The system achieved an average face detection accuracy of 95% and a recognition accuracy of 92%, performing effectively under standard conditions.

The integration of email notifications ensured that authorized users were promptly informed of any unauthorized access attempts, thereby enhancing overall security. Although challenges such as variations in lighting and face orientation were observed, the system still maintained satisfactory performance for typical use cases, offering a cost-effective and efficient solution for real-time security monitoring.

Overall, the Intrusion Detection System presents a reliable and low-cost alternative for security applications. Future enhancements may include improving robustness under varying environmental conditions, expanding system scalability to support multiple cameras, and integrating cloud-based data storage and advanced notification systems for wider deployment in real-world scenarios.

APPENDIX

This appendix lists the primary hardware and software components used in the project:

- Raspberry Pi 4B (4GB RAM)
- USB Camera (720p/1080p)
- Python 3.x environment
- OpenCV library
- Face recognition library
- SMTP protocol for email alerts

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