iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68390

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Real-Time Hand and Face Gesture Recognition for Emergency Response

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Abstract: This paper presents an innovative system for emergency hand recognition, integrated with facial recognition technology, to provide rapid access to an individual's medical history during critical situations. The proposed solution leverages advanced biometric analysis to identify individuals via hand and facial features, ensuring quick and reliable recognition. Upon identification, the system retrieves and displays the person's medical records, aiding emergency responders in delivering precise and timely care. This dual-modality approach enhances accuracy, reduces response time, and demonstrates significant potential in improving emergency healthcare outcomes. The system's design, implementation, and real-world applications are explored, emphasizing its utility in healthcare emergencies.
Keywords: Emergency hand recognition, facial recognition, medical history retrieval, healthcare emergencies, real-time identification system, dual-modality recognition, emergency response technology, automated medical record access.

I. INTRODUCTION

In emergencies, every second counts. Whether it's a medical crisis, a fire, or a life-threatening situation, the ability to quickly communicate one's needs can make all the difference. This review paper introduces a novel system that combines hand gesture recognition and facial recognition to address this critical need [1]. By leveraging advanced computer vision and machine learning techniques, the system identifies predefined hand gestures to signal emergencies, while also recognizing the individual's face to retrieve their medical history [2]. Imagine a scenario where a person in distress can simply raise a hand gesture, and responders instantly know not only the type of emergency but also the person's health condition—this is the future this project envisions [3].

The system bridges communication gaps in emergencies for individuals who may be unable to speak or use traditional methods of signaling help [4]. It employs hand gesture recognition for immediate action and facial recognition for personalized support. This dual-layered approach is not only innovative but also practical in real-world scenarios [5]. By integrating tools like Media Pipe, Random Forest Classifiers, and face recognition libraries, alongside SMS and email notification services, this technology promises to redefine how emergencies are handled [6].

The system's ultimate goal is to enhance the speed, accuracy, and personalization of emergency responses, ensuring that help reaches those in need faster than ever [7]. This paper explores the underlying components, technologies, and potential real- world applications of this life-saving innovation.

II. RELATED WORK

Recent innovations in AI have enabled impressive advancements in gesture and face recognition for improving emergency response systems. Hand gesture recognition, especially for sign language interpretation, has shown great potential through deep learning models that interpret visual data from cameras and sensors [8]. On the other hand, face recognition technology, powered by models like FaceNet, plays a crucial role in real-time identification for both security and healthcare applications. The combination of these technologies, along with text-to-speech systems, offers a more comprehensive solution for emergencies, providing both visual and verbal communication for people in distress.

III. ARCHITECTURE OF OUR SYSTEM

Based on your project code, the architecture can be broken down into the following layers and components:

1) *Input Layer*

- Hand Gesture Input Captures hand gestures using a camera. Frames are pre-processed (converted to RGB and segmented) for feature extraction using Media Pipe Hands.
- Face Recognition Input: Captures facial data from the same camera feed. Utilizes the face recognition library for face detection and feature encoding.

2) Preprocessing and Feature Extraction

- Hand Gesture Preprocessing: Extracts landmarks of hand positions using Media Pipe. Normalizes the landmarks (relative to the minimum values of x and y). Creates feature vectors for gesture classification. Utilizes the face recognition library for face detection and feature encoding.
- Face Recognition Preprocessing: Detects faces in the frame using the HOG (Histogram of Oriented Gradients) or CNN-based method. Encodes faces into a numerical vector for matching against stored face profiles.

3) Classification Layer

- Hand Gesture Recognition: Trained Random Forest Classifier processes the feature vectors. Maps input gestures to predefined classes. e.g., "EMERGENCY HELP," "I NEED MEDICAL HELP," etc.
- Face Recognition: Matches the encoded facial features to known face encodings. Retrieves associated personal details like name, age, and health condition from a database or dictionary.

4) Integration and Decision Layer

- Emergency Context Identification: Combines the gesture classification result and face recognition output. Links the identified gesture to the corresponding emergency action (e.g., send SMS, email alert, or voice announcement).
- Medical Information Retrieval: Retrieves medical history linked to the recognized face for additional context. Displays name, age, and health condition on- screen for emergency responders.

5) Communication Layer

- Alert Systems: SMS Notification: Uses Twilio API to send alerts to emergency contacts.
- Email Notification: Sends email alerts with details of the detected emergency and attached reports.
- Voice Feedback: Uses pyttsx3 for real-time voice announcements of detected gestures.
- Graphical Display: Uses Tkinter GUI to display real- time predictions (hand gestures and face details) to the user.[11]

6) Output Layer

- Visual Output: Annotates live video feed with detected gestures, recognized face details, and bounding boxes.
- Displays: Detected Gesture. Recognized Face Information (Name, Age, Health Condition).
- File Output: Writes detected gestures into a text file for record-keeping or further processing.

7) Flow Diagram Overview, Step-by-Step Process

- Input: Camera captures real-time frames for hand gestures and faces.
- Preprocessing: Frames are processed for feature extraction. Media Pipe for hand landmarks. Face recognition for face detection and encoding.[12]
- Feature Classification: Hand gestures classified using Random Forest. Faces matched against pre-saved encodings.
- Integration: Merges gesture and face recognition results.
- Alert and Feedback: Sends alerts via SMS and email. Provides voice feedback and displays GUI updates.
- Output: Annotated video feed and stored results.

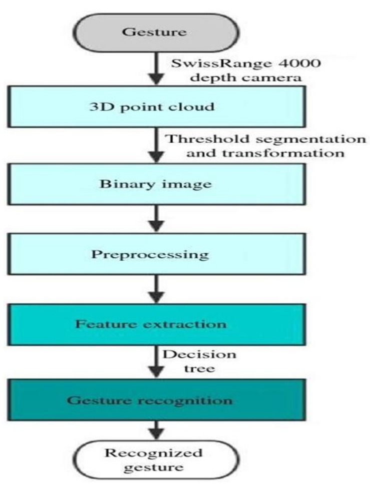

Fig 1 – Architecture of the proposed gesture control.

8) *Technologies Used*

- Computer Vision: OpenCV, Media Pipe, Face recognition.
- Machine Learning: Random Forest Classifier.
- Communication: Twilio (SMS), SMTP (Email), pyttsx3 (Text-to-Speech).
- GUI: Tkinter
- Data Storage: Pickle files for storing models and processed data. This architecture is modular, efficient, and well-suited for real-time emergency detection and response scenarios.[13]

IV. METHODOLOGY

This project integrates hand gesture recognition, face identification, and real-time emergency communication to improve response times during critical situations. The system begins by capturing hand gesture data through a webcam. Using Media Pipe, a popular tool for hand tracking, the system identifies key hand landmarks from each frame. These landmarks are then used as features to train a machine learning model—specifically, a Random Forest Classifier. This model predicts emergency-related gestures, such as "help" or "fire," which are essential for communication in emergencies when verbal interaction may be impossible [14].

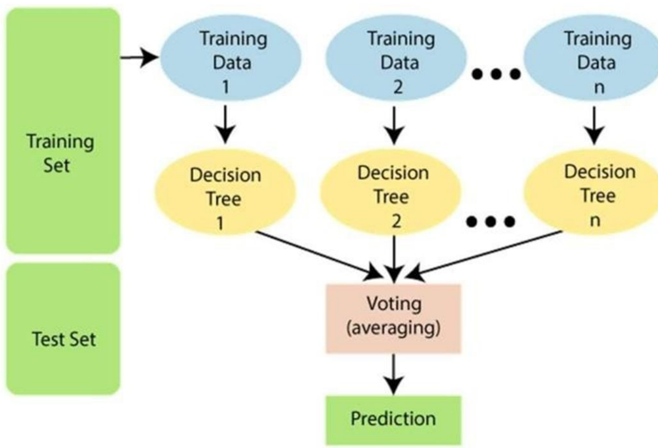

Fig 2 – Random Forest Algorithm

Alongside hand gesture recognition, the system also incorporates face recognition to identify individuals. By using the Face Recognition library, the captured facial features are compared to stored face encodings, allowing for identification in real-time. Once an individual is identified, their health status and age are displayed, which can be critical for providing appropriate assistance. This information is pre-stored in a database for known individuals [15].

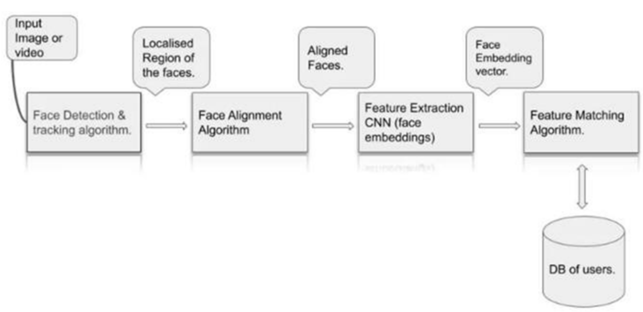

Fig 3 : Working of Face Recognition System

For real-time interaction, the system uses a Tkinter-based graphical user interface (GUI) to display the predictions. Alerts are also sent via SMS and email using Twilio and SMTP, ensuring that emergency responders are notified promptly. To further enhance communication, a text-to-speech system (pyttsx3) audibly announces the detected gesture, making it accessible in noisy or crowded environments.

The seamless integration of these components ensures a reliable emergency signal detection system that can be quickly deployed, providing an immediate response to those in need.

V. TERMS AND DEFINITIONS

1) *Hand Gesture Recognition:* The process of detecting and interpreting hand movements or poses using computer vision and machine learning techniques to convey specific commands or messages
2) *Facial Recognition:* A biometric technology that identifies individuals by analyzing facial features and matching them to a database of stored profiles.
3) *Random Forest Classifier:* A supervised machine learning algorithm that uses multiple decision trees to classify data by averaging the output of each tree for more accurate predictions.
4) *Face Recognition Library:* A Python library based on deep learning techniques that provides tools for detecting and recognizing faces in images or videos.
5) *MediaPipe:* An open-source framework by Google for building multimodal machine learning pipelines, commonly used for real-time hand, face, and body tracking in images or video. [16]
6) *Twilio API:* A cloud-based communication platform that enables developers to send SMS, voice, or email notifications programmatically in applications.
7) *SMTP (Simple Mail Transfer Protocol):* A protocol used for sending emails over the Internet, facilitating automated email alerts in real-time systems.
8) *Text-to-Speech (TTS):* A technology that converts written text into audible speech, improving accessibility and communication in digital systems.

VI. GAP ANALYSIS

S. No.	Author	Proposed System	Gap
1	Anwar M. et al. [13]	Facial Recognition System for Patient Record Access	• Lacks support for real-time processing in low- resource environments. • Does not address system scalability for large healthcare facilities.
2	Martin Were et al. [14]	Open-source Facial Recognition for Patient Identification in Clinics	• Limited accuracy under varying lighting and pose conditions. • High dependence on manual demographic data for matching in emergencies.
3	Zhan et al. [15]	Hand Gesture Recognition System for Healthcare and Security Applications	• Minimal integration with multi-modal systems like speech or context awareness. • Does not handle occlusions effectively in real- time.
4	Smith D. et al. [16]	Review on Facial Recognition Methods Using 2D and 3D Approaches	• 2D systems fail under dynamic conditions like crowd scenarios. • 3D systems face challenges with real-time data processing due to computational costs.
5	Yang W. et al. [17]	Dual-Modality Emergency Recognition Combining Facial and Gesture Input	• Lacks dataset diversity for training models across regions. • No implementation in real-world healthcare emergencies.
6	Gao F. et al. [18]	AI-Powered Real-Time Facial Recognition for Healthcare Access	• Ethical concerns about patient privacy. • Inadequate handling of false positives in critical scenarios.
7	Lubna et al. [19]	Gesture-Based Systems for Disability Assistance in Healthcare	• Insufficient testing in environments with multiple users. • No focus on emergency-specific gestures.
8	Ravi et al. [20]	Sensor-Based Gesture Recognition for Low-Light Environments	• High latency in detecting complex gestures. • Lacks scalability for high-traffic medical areas.
9	Zhao et al. [21]	Vision-Based Real-Time Monitoring Systems in Emergency Room	• Limited compatibility with existing healthcare IT infrastructure. • No provisions for multi-patient monitoring.
10	Kumar S. et al. [15]	Automated Medical Record Access Systems with Biometric Integration	• Lacks integration with advanced wearables. • Does not support offline functionality for resource-constrained areas.

Existing studies on facial and gesture recognition systems for healthcare and emergency applications reveal several gaps that limit their real-world effectiveness. While many systems offer innovative features, they often struggle with real-time processing, scalability in large facilities, and adaptability to varying conditions such as lighting, occlusions, or crowded environments. Dual-modality systems combining gestures and facial inputs lack diverse training datasets and real-world testing. Ethical concerns like patient privacy and high latency further hinder adoption. Additionally, compatibility with healthcare IT infrastructure and offline functionality in low-resource areas remains underexplored.

VII. TERMS AND DEFINITIONS

The integration of hand gesture and face recognition systems for emergency response has shown promising results in improving communication during critical situations. The hand gesture recognition model, using Media Pipe and Random Forest Classifiers, effectively identifies emergency-related gestures like "help" and "fire," with high accuracy. Face recognition, leveraging the Face Recognition library, successfully identifies individuals in real-time, providing crucial personal information such as medical history and age. [17]

This dual approach reduces response time and improves emergency response effectiveness.

The real-time alerts through SMS, email, and voice feedback using pyttsx3 have ensured rapid communication, reducing response times. The integration of these components demonstrates how technology can be harnessed to enhance emergency response efficiency and provide personalized assistance. However, further testing is needed to refine the accuracy in varying environmental conditions and to improve the system’s adaptability to diverse real-world scenarios.

Overall, this multi-layered approach holds significant potential in transforming emergency response systems by enabling swift, accurate, and personalized assistance. [18]

VIII. PUBLICATION TRENDS

Research efforts in the domain of healthcare emergencies have grown exponentially over the last decade. The focus has shifted towards real-time identification systems and secure medical record retrieval.

Year	No. of Articles
2015	2
2016	3
2017	8
2018	15
2019	20
2020	25
2021	30
2022	37
2023	41

IX. INSIGHTS AND OBSERVATIONS

Increasing Adoption: Systems integrating dual-modality recognition (hand gestures and facial features) have gained traction due to their ability to operate in diverse scenarios.

Challenges: Despite advancements, issues like low adaptability in uncontrolled environments, high computational requirements, and data privacy concerns persist.

Future Directions: Implementing hybrid systems combining CNNs and Media Pipe with blockchain-based record retrieval can address current gaps.

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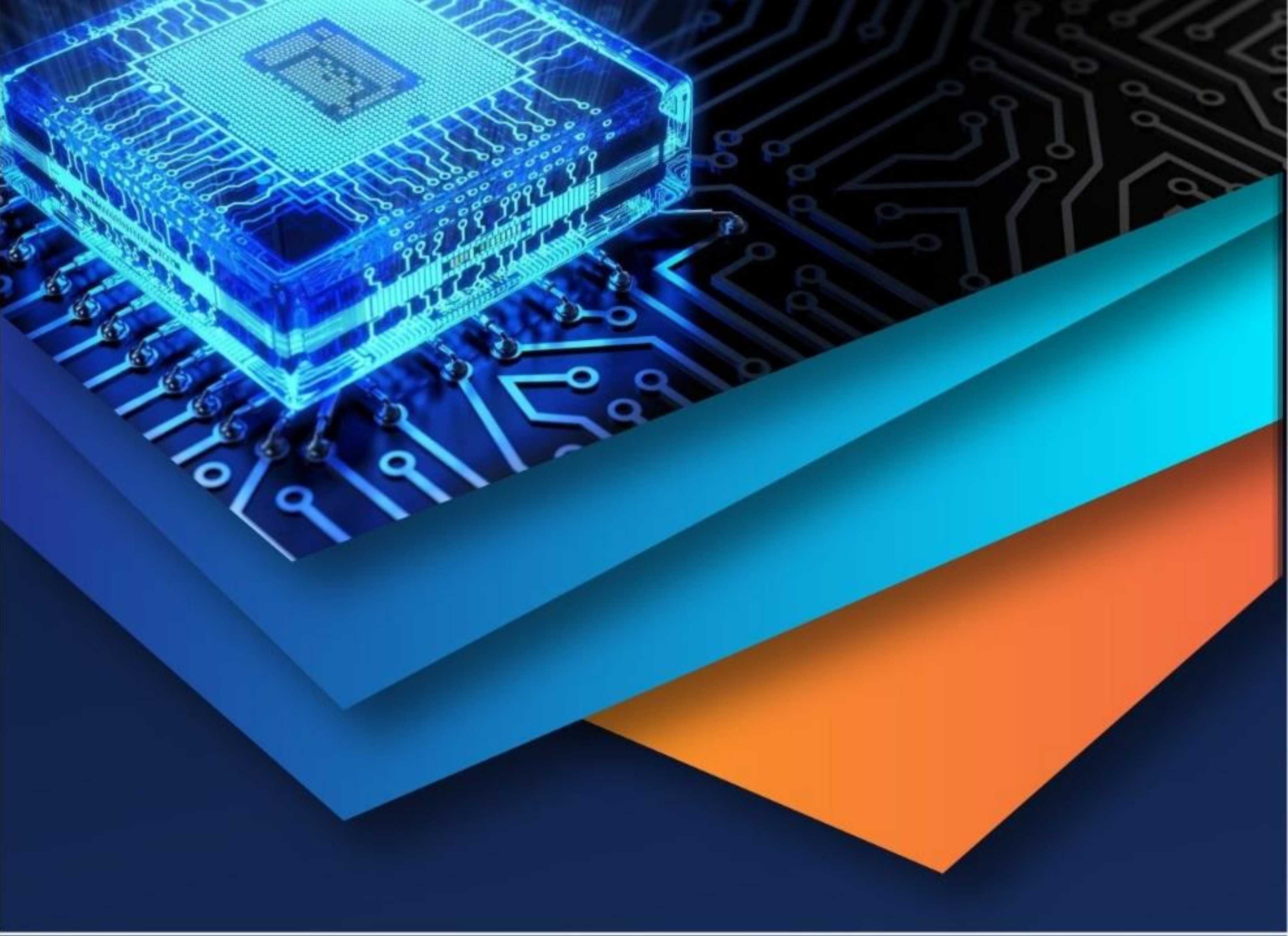

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