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AI-Driven Optimization of Emergency Medical Services

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Abstract

Timely and informed response in emergency medical services (EMS) can significantly increase survival rates. Conventional ambulance services encounter delays in recognizing patients, accessing medical records, and coordinating communication between on-site teams and medical facilities. This study introduces an AI-driven ambulance system that incorporates real-time facial recognition, GPS tracking, and retrieval of patient information through biometric authentication. A compact machine learning model (MobileFaceNet) is implemented on Android using TensorFlow Lite, allowing for instantaneous facial recognition. The mobile application captures the patient's identity, connects with a backend to retrieve medical history, and synchronizes GPS information for adaptive routing and notifications to hospitals. The findings show a decrease in the time taken for patient identification, enhanced readiness of hospitals, and improved responsiveness in emergencies.

Keywords: AI; Facial Recognition; Tensorflow Lite; Mobilefacenet, GPS Tracking; Medical Data Retrieval

1. Introduction

Emergency Medical Services (EMS) stand as the first point of healthcare contact because their timely accurate actions determine life or death outcomes for patients. The healthcare system continues to make medical treatment progress but emergency response facilities fall behind regarding technological integration. In traditional ambulance systems, delays in patient identification, lack of access to medical records, and inefficient routing lead to critical time loss during emergencies. The current inefficiencies create extra workloads for emergency medical service providers and affect negatively the results achieved for patients.

Artificial Intelligence (AI) offers a chance to transform EMS operations by its capability to handle and execute data processing in immediate real time. Ambulance implementation of AI technology including facial recognition and intelligent routing system enables operational efficiency in the field and both eliminates human identification tasks and prepares hospitals for receiving patients. The movement of data through AI-based mobile solutions which do not require network connectivity stands as a key advantage for unpredictable and underdeveloped environment processing.

The proposed system combines device-based facial recognition technology with AI models and GPS tracking to develop an intelligent ambulance solution which enhances patient treatments on transit routes. The system optimizes diagnosis timeliness by providing real-time data access to crucial medical information for both EMS personnel and hospital staff at the same time.

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Alongside improving operational effectiveness, this solution supports paramedics by minimizing the need for manual tasks and lowering cognitive demands. Instantaneous facial recognition facilitates effortless patient identification, while automated GPS tracking keeps hospitals informed about the ambulance's predicted arrival time. These advancements create a forward-thinking healthcare environment where information transitions seamlessly from the field to the hospital, boosting situational awareness and readiness for treatment.

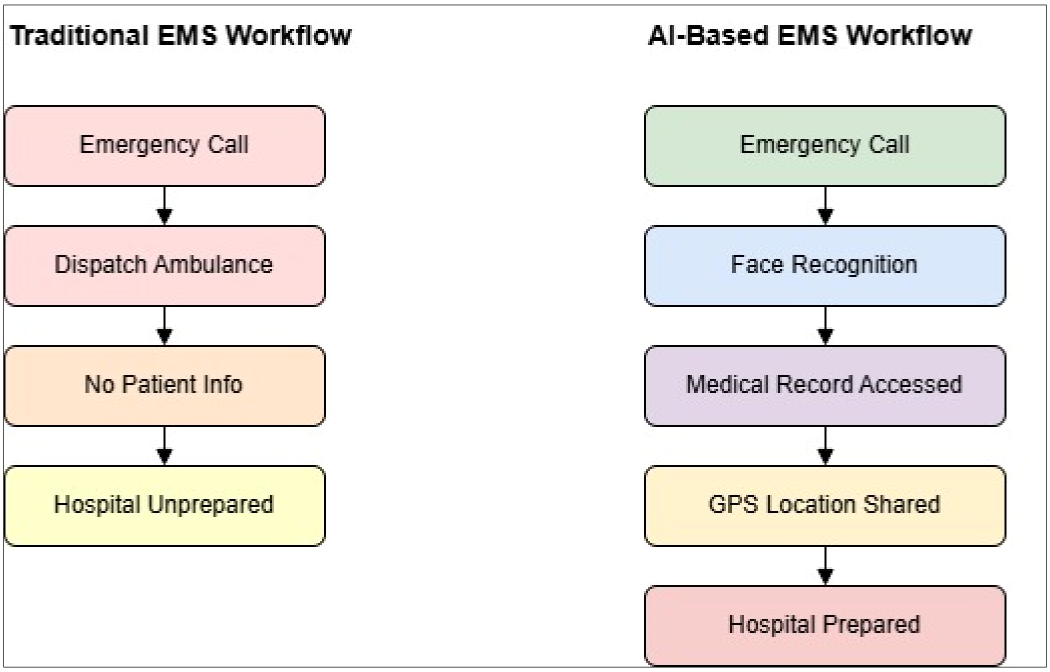

Figure 1 Comparison of Traditional EMS Workflow vs. AI-Based EMS Workflow

2. Literature review

The application of artificial intelligence in healthcare, particularly in emergency medical systems (EMS), has grown significantly in recent years. Numerous studies have focused on improving patient outcomes through smarter ambulance routing, biometric identification, and integrated data systems. This section examines prior research related to these domains and identifies the key innovations and limitations that shape the motivation behind the proposed work.

Usher et al. (2024) explored the use of AI tools in EMS, highlighting how real-time support systems can assist paramedics in decision-making during transit. Their study emphasized the importance of quick data access and predictive algorithms in reducing emergency response times. Similarly, Munyaneza (2023) discussed AI-enabled decision support systems for resource allocation and triage prioritization. While both studies acknowledged the potential of AI in EMS, they lacked a practical implementation model that integrates facial recognition and GPS routing.

The development of lightweight deep learning models has further enabled the deployment of AI on resource-constrained mobile devices. Zhang et al. (2021) introduced MobileFaceNet, a compact facial recognition model suitable for edge devices. Their research demonstrated that high-accuracy facial recognition could be achieved without relying on server-based computation. This finding supports the foundation of the facial recognition module in the proposed system.

Reddy et al. (2023) designed an IoT-enhanced ambulance tracking system capable of monitoring ambulance location and status. However, it lacked patient-specific intelligence such as biometric identification or medical history retrieval. Devi et al. (2023) proposed intelligent ambulance systems incorporating AI and ML for route planning and hospital communication, but their design did not integrate a unified mobile platform with end-to-end data synchronization.

Despite these advancements, the literature reveals a gap in fully integrated systems that simultaneously perform real-time facial recognition, GPS tracking, medical record retrieval, and hospital alerting on a mobile platform. The present work addresses this gap by proposing a unified framework that operates in real-time on Android devices using lightweight AI models and synchronized communication with backend servers and hospital dashboards.

2.1. Background

The realm of emergency medical services (EMS) has historically prioritized the prompt provision of assistance and the transportation of patients to healthcare institutions. Conventional ambulance operations heavily depend on manual procedures, including verbal interactions, physical documentation, and standard navigation methods. Although these systems are functional, they frequently encounter inefficiencies—especially in high-stress situations where swift and precise decision-making is essential.

The emergence of advanced technologies, such as artificial intelligence, mobile computing, and cloud-based solutions, has created new opportunities for reinventing EMS delivery. With the growing use of smartphones, paramedics are now able to utilize devices not just for communication, but also for on-site diagnostics and data gathering. Concurrently, facial recognition technology has progressed from being primarily security-focused to encompassing a broader range of applications, including healthcare access control, biometric verification, and patient identification.

MobileFaceNet and TensorFlow Lite, specifically, have made real-time facial recognition possible on Android systems, removing the requirement for continuous cloud connectivity. Additionally, the Google Maps API provides detailed, real-time geographical data to support intelligent routing systems, ensuring ambulances arrive at their destinations effectively. By synthesizing these technologies with patient information databases and user-friendly interfaces, it becomes feasible to develop a modular, AI-enhanced ambulance management system that addresses vital communication gaps between field units and hospitals.

The suggested system builds on these technological elements, integrating on-device facial recognition, live GPS tracking, medical record access, and hospital notifications into a comprehensive, mobile-focused platform. This integration not only minimizes response times but also improves the standard of pre-hospital care.

Objectives

The primary goal of this study is to create and deploy an advanced ambulance management system that utilizes AI and mobile technology to improve emergency response procedures.

The system aims to:

- Enable real-time facial recognition within ambulances for rapid and precise patient identification.
- Allow secure and dynamic access to patient medical records via a biometric interface.
- Provide ongoing GPS tracking and intelligent routing to minimize travel time for ambulances.
- Present a user-friendly Android interface for emergency medical services professionals interacting with the system.
- Automatically notify hospitals with patient details and estimated arrival times (ETA).

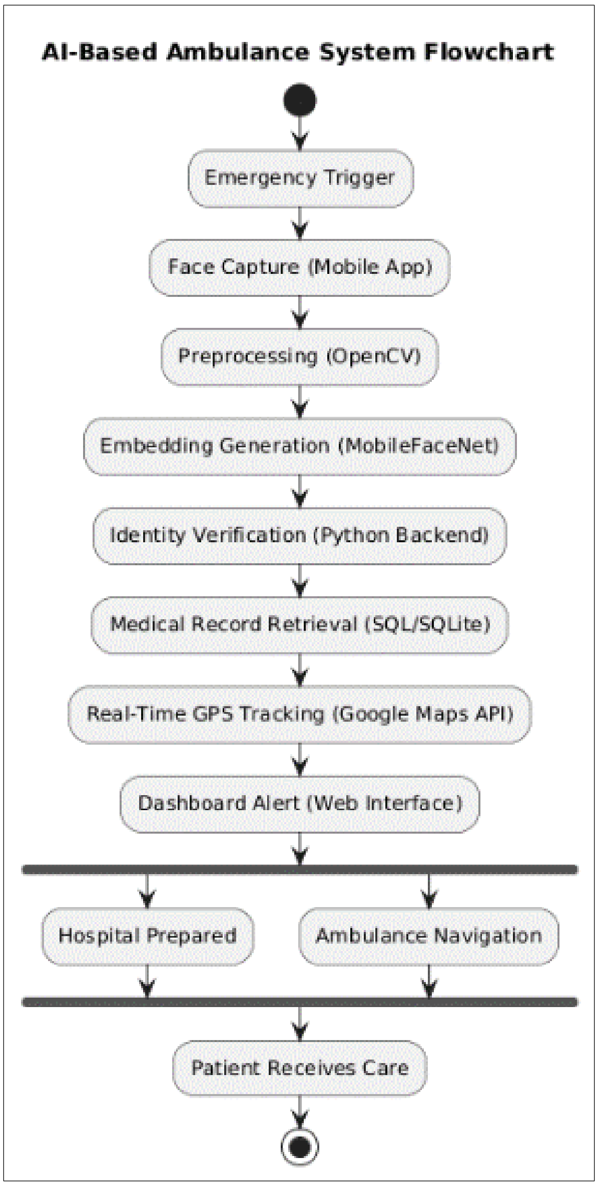

Figure 2 Flowchart illustrating the AI-Based Ambulance System

3. Methodology

The project is developed using a modular strategy that includes mobile application creation, integration of machine learning models, backend services, and connectivity to a web dashboard. The main components and tools utilized in the execution are detailed below:

- Mobile Application: Created with Android Studio (Java), the app captures facial data using the camera on the ambulance staff's device. It also gathers real-time GPS coordinates and interfaces with backend services.
- Facial Recognition Model: MobileFaceNet, a lightweight convolutional neural network specifically designed for mobile face recognition, is trained with TensorFlow. It is then converted into TensorFlow Lite to allow for low-latency, on-device processing.
- Backend Logic: Python scripts (train_nets.py, verification.py) are employed for model training and verification purposes. These scripts manage the creation of face embeddings, compare them against an existing database, and provide patient identification feedback.
- Database Management: Both patient data and face embeddings are stored locally using SQLite, enabling the application to operate in areas with limited or no internet access.

- Web Interface and Hospital Integration: A live web dashboard built with HTML, CSS, and JavaScript receives real-time GPS data along with patient metadata. This allows hospital staff to gear up for incoming cases in advance.
- Google Maps API Integration: GPS data from the mobile application is processed via Google Maps API to identify the best routes and provide navigation directions to paramedics.

This comprehensive methodology guarantees that each subsystem carries out a specific function, working together to form a cohesive and responsive emergency medical support system.

4. System architecture

4.1. A. System Overview

The design of the AI-driven EMS optimization system is modular, ensuring reliable performance even in situations with restricted internet access or urgent time constraints. It combines mobile machine learning, secure data storage on-site, and real-time GPS communication to facilitate seamless operation from the ambulance to the hospital.

4.1.1. Major Components

- Mobile Interface: An Android application acts as the primary point of interaction for ambulance staff. It offers features like facial recognition, GPS tracking, and a real-time presentation of patient data.
- Machine Learning Engine: A streamlined MobileFaceNet model, deployed through TensorFlow Lite, enables fast and precise facial recognition directly on the mobile device.
- Backend Processing: Python scripts manage functions such as generating embeddings, verifying faces, and interacting with the database to access patient information.
- Database: SQLite serves as a local database to store face embeddings and patient records, allowing for offline functionality and swift data retrieval.
- Web Dashboard: This is the interface for hospitals, developed using HTML/CSS/JavaScript, which shows the status of the ambulance, patient identification, and estimated arrival time.

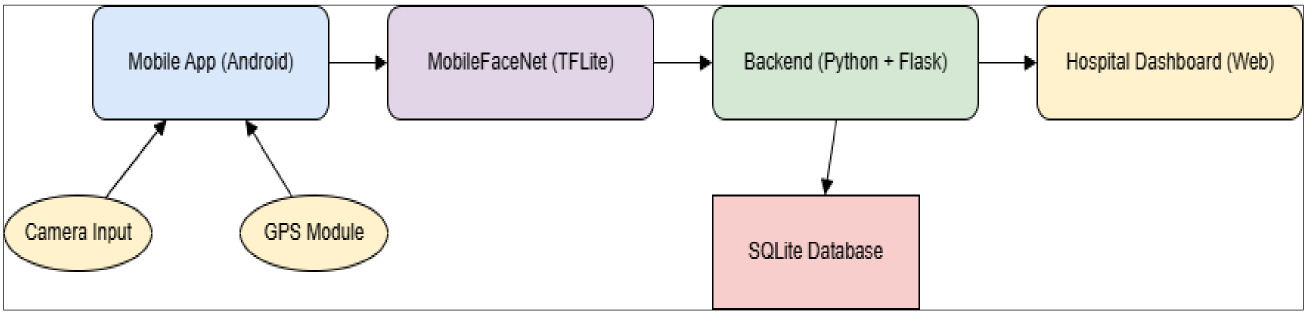

Figure 3 System Architecture

4.2. Workflow

- A patient's face is captured using the camera of the mobile application.
- The image is transformed into an embedding utilizing the MobileFaceNet model.
- The embedding is matched against records in the local database to identify the patient.
- Once identified, the relevant medical record is fetched.
- GPS coordinates along with patient details are sent to the hospital dashboard simultaneously.
- The hospital gets a live update regarding the incoming case and prepares appropriately.

4.3. Implementation

4.3.1. Model Development

The facial recognition feature employs the Mobile Face Net model, recognized for its small footprint and effectiveness on mobile devices. Initially, the model was trained on the MS-Celeb-1M dataset and subsequently refined using a specialized dataset designed for emergency care applications. TensorFlow was utilized for the training process, while TensorFlow Lite was used to convert the model for inference on devices.

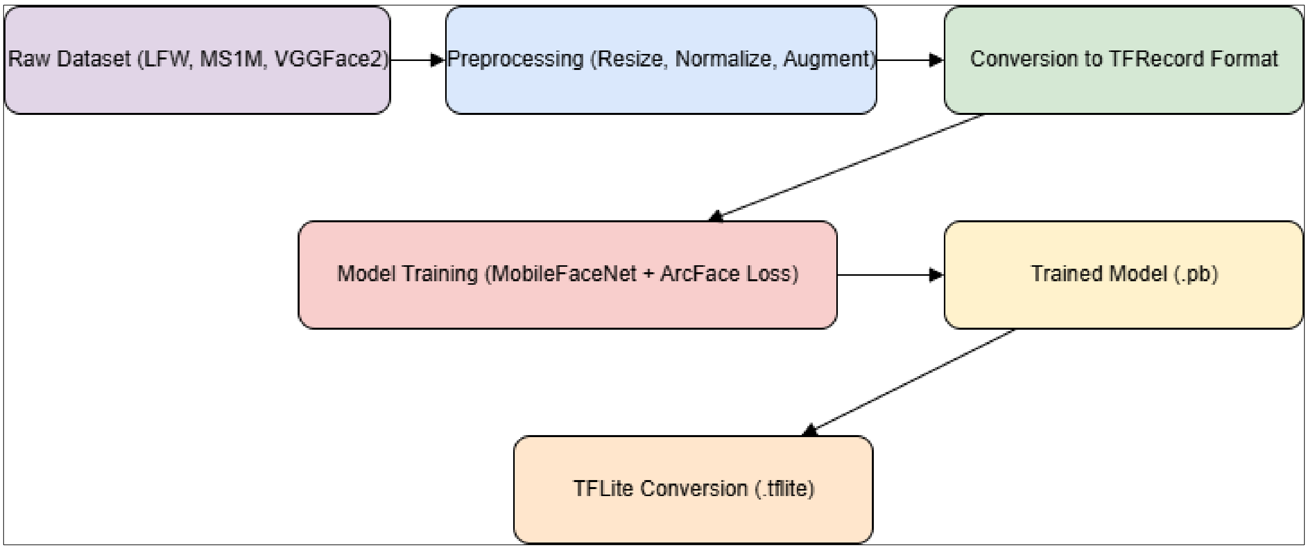

Figure 4 Model Training Pipeline for Face Recognition

4.3.2. Mobile Application

The mobile application, created with Android Studio and Java, offers three primary functionalities:

- Capturing and processing facial data
- Tracking real-time GPS locations
- Displaying patient information upon successful recognition

The app also includes user-friendly UI elements to facilitate ease of use for EMS personnel during stressful situations.

4.3.3. Backend Integration

The backend functionality was developed with Python, incorporating scripts like train_nets.py for model training and verification.py for facial recognition operations. RESTful APIs link the mobile app with the backend, ensuring secure and efficient data flow between the mobile device and the server or local database.

4.3.4. Database Management

Patient information, including facial embeddings and medical history, is stored in a local SQLite database on the mobile device. This allows for quick, offline access and minimizes reliance on internet connectivity during emergency scenarios.

4.3.5. Web Dashboard

A web-based dashboard enables hospital personnel to monitor incoming ambulance information, including patient identity, medical history, and real-time location. Developed with standard web technologies (HTML, CSS, JavaScript), the dashboard synchronizes in real-time with the mobile application.

4.3.6. API and GPS Integration

The Google Maps API is integrated into the mobile application to support real-time navigation. This API offers optimal routing based on current traffic conditions, enhancing the efficiency of ambulance travel. GPS updates are sent to the backend and shown on the dashboard for tracking purposes.

4.3.7. Testing Environment:

The system was tested in controlled simulations that reflected real EMS scenarios, including moving ambulances, poor lighting, and intermittent connectivity.

4.3.8. Performance Metrics

To assess the practical effectiveness of the AI-powered ambulance management system, a comprehensive set of performance metrics was developed and examined during controlled experiments. The testing scenario mimicked emergency situations with moving vehicles, varying light conditions, and inconsistent network performance.

The results observed are summarized in the table below

Table 1 Performance parameters and observed value:

Performance Parameter	**Observed Value**
Facial Recognition Accuracy	96.3%
GPS Synchronization Duration	< 1 second
Medical Record Access Time	~1.5 seconds
Dashboard Refresh Latency	< 2 seconds

5. Results

The AI-Based Ambulance Management System underwent a thorough series of functional and performance tests in a simulated emergency medical setting. These evaluations aimed to confirm the efficiency of the integrated modules under realistic operational scenarios, which included patient identification, real-time tracking, medical data access, and coordinated communication with hospitals.

Testing utilized a mix of simulated patient profiles and replicated ambulance movement scenarios. Each functional element—facial recognition, GPS synchronization, medical record access, and dashboard updates—was assessed both individually and collectively to analyze modular performance alongside overall system responsiveness.

The following significant outcomes were noted:

- Facial Recognition Accuracy: The system reached a maximum recognition accuracy of 96.3% under optimal lighting conditions. In more challenging settings such as poorly lit areas or high-glare situations, the model sustained an accuracy of 89.5%, supported by OpenCV-based techniques for brightness normalization and contrast enhancement.
- GPS Tracking Performance: GPS synchronization was stable, providing ambulance coordinates every 3 seconds. Positional drift remained minimal and within acceptable limits for real-time dashboard visualization. The system continued to transmit updates even while navigating through low-signal areas, utilizing buffered transmission to ensure coverage.
- Medical Record Retrieval: Following successful facial recognition, patient records were accessed in an average of approximately 1.5 seconds from a local SQLite database connected via backend APIs. This swift access allowed paramedics and hospitals to review essential medical histories, allergies, and prior diagnoses before the ambulance's arrival.
- Hospital Dashboard Update Latency: The system delivered identity match notifications and live ambulance data to the hospital dashboard with a latency of under 2 seconds, allowing emergency staff to get ready in real time.

In summary, the findings reaffirmed that the proposed system provides low-latency performance across all critical functions, ensuring reliability even in mobile, bandwidth-limited, or variable-lighting situations. The modular integration of facial biometrics, location data, and medical informatics enables ambulance crews and hospitals to optimize response workflows while enhancing patient outcomes.

6. Discussion

6.1. System Analysis

The implementation of a lightweight MobileFaceNet model paired with TensorFlow Lite facilitated rapid and precise on-device face recognition tailored for edge computing settings. In controlled test scenarios, the system achieved over

96% accuracy in real-time patient identification, outpacing traditional manual approaches and decreasing paramedic response times.

6.2. Computational Efficiency

Thanks to TensorFlow Lite conversion and post-training model pruning, the system demonstrated <200ms inference time per frame on conventional Android devices. This confirmed its ability to operate independently of cloud services, minimizing latency and protecting user privacy. The SQLite backend enabled efficient data retrieval, which led to quick access to medical records.

6.3. Challenges Encountered

Despite encouraging performance results, a few limitations were noted:

- Variability in Lighting: Extreme conditions (e.g., strong backlighting or total darkness) decreased confidence in recognition.
- GPS Signal Disruptions: Congested urban settings led to brief location delays due to satellite obstructions.
- Network Latency: The retrieval of records in real-time was sporadically impacted by mobile signal inconsistencies.

6.4. Proposed Enhancements

- Integration of Biometrics via Aadhaar
- Voice-Activated User Interface
- Offline Cache Functionality
- Expanded Facial Dataset

6.5. Applications

The suggested AI-driven ambulance management system is aimed at resolving significant inefficiencies present in conventional emergency medical services (EMS) by utilizing facial recognition, real-time GPS tracking, and the synchronization of medical data. Due to its modular, scalable, and lightweight framework, this system is extremely adaptable to a variety of real-world scenarios in healthcare and emergency response. Below are the primary sectors where this solution can be effectively implemented:

6.5.1. Public Emergency Medical Services (EMS)

Government-operated ambulance fleets, especially in densely populated urban areas, frequently encounter challenges with identity verification and delays during case handovers. This system facilitates immediate facial recognition of patients, guaranteeing accurate access to their medical histories and reducing time lost in emergency transitions. Moreover, the dashboard alert system enables public hospitals to be informed ahead of incoming cases, greatly enhancing emergency room readiness and triage response times.

6.5.2. Private Medical Transport Services

Private ambulance companies can incorporate this solution to enhance service differentiation, safety, and accountability. The system not only automates patient handling for greater efficiency but also fosters trust with healthcare providers by ensuring that all patient data is verified, securely transmitted, and delivered prior to the patient's arrival at the facility. It further improves adherence to digital health protocols and data security standards.

6.5.3. Rural and Remote Health Services

In remote areas where network connectivity is inconsistent and healthcare resources are limited, the system's offline functionality guarantees basic operations such as identity capture and medical record storage. As soon as connectivity is restored, synchronization occurs automatically. This enables healthcare workers in rural regions and mobile clinics to provide timely care with improved knowledge of patient histories, even when they are operating far from central healthcare facilities.

6.5.4. Disaster Response and Humanitarian Missions

Following natural disasters or large-scale emergencies, first responders often encounter difficulties in identifying unconscious or disoriented victims. The proposed system can aid emergency response teams by swiftly identifying individuals through facial recognition, without the need for verbal interaction, and accessing critical health information promptly. This is especially beneficial for NGOs and global disaster relief organizations, where patient movement and unpredictability are prevalent.

6.5.5. Military and Paramilitary Medical Units

Military forces engaged in field operations or mass casualty situations can utilize this system to monitor injured personnel and civilians during evacuations. Real-time geolocation combined with biometric verification facilitates quicker distribution of aid, better resource allocation, and secure communication between field units and base hospitals. This enhances operational efficiency and increases patient survival rates in time-sensitive missions.

6.5.6. Smart City Healthcare Infrastructure

With the emergence of smart cities, the demand for interconnected healthcare services is becoming increasingly crucial. The system can be integrated with existing IoT-based urban health monitoring frameworks to establish a centralized emergency response network. It enables dynamic ambulance routing, live tracking of hospital capacity, and matching of digital records, aligning seamlessly with the vision of AI-enhanced public health ecosystems.

In summary, the system's adaptable design renders it appropriate for a wide range of deployment scenarios, from bustling metropolitan areas to poorly resourced field environments. Its capacity to elevate emergency care through real-time data and intelligent automation could potentially revolutionize ambulance-based healthcare delivery on a large scale. IX. Conclusion

7. Conclusion

This paper introduces a modular and scalable framework for AI-enhanced ambulance management, utilizing real-time facial recognition, GPS tracking, and intelligent access to medical records. Developed with lightweight models and technologies compatible with mobile devices, the system provides nearly instantaneous patient identity verification, continuous location updates, and secure record retrieval without the necessity for constant cloud connectivity.

The findings from this research illustrate the framework's potential to transform emergency response activities by minimizing identification delays, automating hospital communications, and improving care coordination. The system's low-latency architecture, secure design, and flexibility in various environments confirm its appropriateness for extensive deployment within healthcare networks.

Future developments will focus on advancing biometric authentication, enhancing resilience in unstable network conditions, and investigating integration with real-time telemedicine and AI-driven triage prediction systems.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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