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An Intelligent IoT Framework for Predictive Emergency Patient Monitoring and Early Hospital Decision Support

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***Abstract*—In today's health care environment, early recognition of patient deterioration prior to hospital arrival is critical to better care preparedness and patient survival. Manual monitoring, delayed communications, paper-based patient assessment methods are the problems traditional emergency triage systems are facing, causing delays in emergency treatment and patient prioritization in critical situations. We present Smart Triage Assistant in Emergency Wards, a healthcare framework that utilizes Internet of Things (IoT) devices and Machine Learning techniques to help monitor patients, predict automated triage and share emergency information prior to patients arriving at hospitals. In the proposed system, patient monitoring is carried out in the transportation of patients using the Internet of Things (IoT) medical sensors like the DS18B20 Temperature Sensor, DHT11 Humidity Sensor, Pulse Sensor, MQ135 CO sensor and ECG Sensor with ESP32 microcontrollers during emergency care. The collected sensor data is sent to the ThingSpeak cloud platform for monitoring and analysis. We have applied classification algorithms such as XGBoost to classify patients as Critical, Moderate and Stable based on patient vital and conditions. The system also includes emergency alert functionalities using SMS alerts and hospital dashboards to help in the better management of emergency response prior to the patient's arrival. It is architected using Node.js and Express.js for backend, centralized healthcare data management with MongoDB, and the monitoring dashboard with React.js. After the experimental assessment on the healthcare dataset, the prediction accuracy obtained by the XGBoost classifier was high, demonstrating the effectiveness of intelligent triage systems in emergency healthcare systems for patient severity classification. The proposed Smart Triage Assistant improves the efficiency of the emergency response, decreases the delay in communicating between ambulance services and hospitals, decreases manual intervention and enhances the safety of the patient by intelligent healthcare monitoring and automatic emergency communicating. Regarding keywords, the project can be divided into different categories such as Smart Triage, Emergency Wards, IoT Healthcare, Machine Learning, ESP32, Real-Time Monitoring, Emergency Alerts, XGBoost, Healthcare Dashboard, and ThingSpeak, and Emergency Response System.**

I. INTRODUCTION

The fast-paced growth of healthcare technologies has fashioned new dimensions of opportunity to upgrade emergency medical service provision and patient care management. In a situation of extreme critical conditions, every second in the ED counts for saving lives, and therefore reducing delays in the course of treatment. Traditional methods of emergency triage tend to be manually operated, with paper-based records, leading

There are delays in communication with Ambulance staff and hospitals. In most cases, this creates the threat of wrong patient notation-upsetting the response times during times of emergency in life-threatening situations. In many emergencies, there is a lack of information regarding patients' condition prior to their arrival at hospital, which limits the ability of the doctors and emergency teams to prepare treatment resources in advance.

To overcome these problems, this paper introduces a Smart Triage Assistant in Emergency Wards, a real-time, intelligent healthcare monitoring and emergency decision-making system that we developed by creating the application with Internet of Things (IoT), Machine Learning, cloud communication, and web technologies. This proposed system uses the IoT medical sensors which are interfaced with esp32 microcontroller and continuously tracks the patient's vitals like Temperature, Humidity, Pulse rate, CO levels, ECG signals etc. The gathered sensor data is sent to the ThingSpeak cloud platform for instant monitoring and analysis. Using Machine Learning algorithms like XGBoost, patients are categorized into

Critical, Moderate and Stable states based on patient vitals and health conditions.

It also delivers automatic emergency alerts and patient condition notifications via SMS, Email services and real-time health care dashboards prior to the patient's arrival in hospitals. The backend is built with Node.js and Express.js, and the central data management of the healthcare data is using MongoDB and the responsive dashboard development and visualization is using React.js. The proposed Smart Triage Assis-tant will increase the hospital's preparedness for emergency management by combining cloud communication, IoT monitoring, machine learning, and intelligent emergency alert systems.

II. PROBLEM STATEMENT

Emergency department must be able to assess the patient quickly and accurately for prompt medical care. Current emergency triage systems, however, are mostly based on manual monitoring, manual documentation and late communication between the ambulance and hospital. These restrictions can lead to incorrect patient prioritization, late response to emergencies, inefficient use of resources and decreased readiness prior to patient arrival. Moreover, most existing healthcare monitoring systems offer only basic vital-sign monitoring and do not feature intelligent, real-time severity prediction, automatic emergency alerts and centralized visualization on dashboards. Hence, an intelligent, IoT enabled, machine learning based emergency triage system that continuously monitors patient vital signs, predicts the severity of the patient in real time, and alerts automatically and through dashboard-based decision support to enhance emergency response, hospital preparedness and patient outcomes is needed.

III. LITERATURE REVIEW

Healthcare monitoring and emergency response systems have all been improved by the development of technologies like the Internet of Things (IoT), machine learning and the Cloud. The old systems are dependent on the manual evaluation of patients, document them on paper and communicate with delays between the ambulatory and hospital, therefore, the traditional emergency response systems suffered due to slow response to emergencies and/or lack of proper prioritizing of patients to receive required treatment.

An IoT-based health care system has been built for remotely monitoring patients' vital signs, such as temperature, pulse rate and ECG, using wearable sensors that can communicate with the cloud platform. While these platforms can provide real-time patient monitoring, most of these current systems are not equipped to provide intelligent predictive modeling of the patient's severity of the emergency and alerting the appropriate outside resources (e.g., the hospital) to the emergency in real time.

Some machine learning algorithms (decision trees, random forest models and XGBoost) have proven to be successful in predictive modelling of patient outcome, and in assessing risk of patient emergency. However, most of the current systems have been put in place for predictive analytics, and these systems utilize real-time IoT monitoring, but have not yet been connected with the central monitoring dashboards or hospital alert system for the creation of a unified healthcare platform.

The proposed Smart Triage Assistant in Emergency Wards solution consists of patient monitoring based on IoT, intelligent triage prediction/algorithm based on XGBoost, cloud communication and automatic emergency alerting. The proposed frame-work will continuously monitor patients vital sign using ESP32 connected medical devices/sensors and will give real-time updates of the patient's condition before they come to the hospital.

IV. METHODOLOGY

Smart Triage Assistant in Emergency Wards is an intelligent healthcare monitoring and emergency decision-support solution designed to integrate IoT devices, machine learning, cloud-based communications and web technologies into one healthcare services platform. In this proposed system, the vitals of patients will be monitored in real-time as they are monitored in hospitals, and the system will also give hospitals the information of patient's status before patients go to hospital.

A. SYSTEM ARCHITECTURE

The proposed system follows a multi-layered architecture consisting of IoT sensors, cloud communication, Machine Learning prediction, backend services, and healthcare dash-boards. IoT medical sensors such as DS18B20 Temperature Sensor, DHT11 Humidity Sensor, Pulse Sensor, MQ135 CO Sensor, and ECG Sensor are connected to ESP32 micro-controllers for continuous patient monitoring. The collected sensor data is transmitted to the ThingSpeak cloud platform through Wi-Fi communication for real-time monitoring and processing. The backend system developed using Node.js and

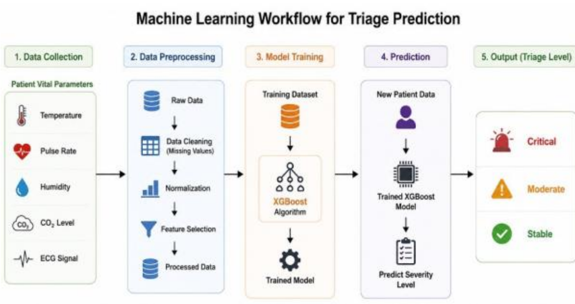

Fig. 1: System Architecture Diagram

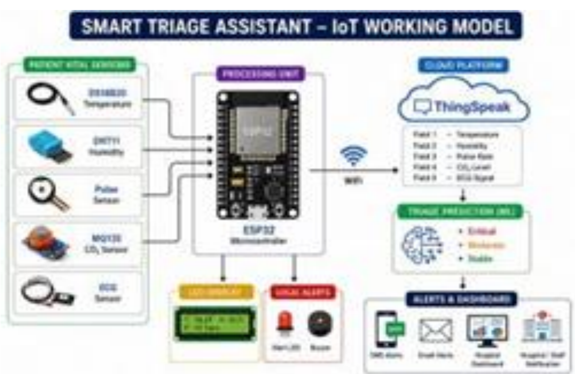

Fig. 2: Smart Triage Assistant– IoT Working Model

V. IOT-BASED PATIENT MONITORING

This proposal involves the usage of IoT medical sensors, which will provide continuous monitoring of the patient's vital signs including temperature (humidity), as well as other factors, such as pulse rate, CO levels and Electrocardiograms (ECGs). The ESP32 microcontroller will be the central point for all the sensors' data collection and will communicate with the cloud. The data collected from the sensor will be displayed locally via an LCD display, and then sent up to the ThingSpeak cloud platform for remote health monitoring and analysis. Patients will be continuously monitored while they are enroute to the hospital or in an emergency so that the hospital is aware of any changes in the patient’s condition when they arrive.

A. *MACHINE LEARNING BASED TRIAGE PREDICTION*

Machine learning algorithms can be used on healthcare vitals to determine critical/moderate/stable severity levels for patients. For instance, if the data is from a health care environment, where the temperature, pulse, humidity, CO and ECG are recorded, then the data processing techniques like normalization and feature selection will be applied before constructing the model. The predictive algorithm used for intelligent predictions of patient severity is an XGBoost-like algorithm due to its high accuracy and performance in healthcare classification problem.

B. *CLOUD COMMUNICATION AND DASHBOARD MONI-TORING*

The sensor data that is gathered via the sensors is stored in the ThingSpeak cloud and is monitored via the ThingSpeak cloud. The backend (built using Node and Express) continuously processes the sensor data and automatically updates the dashboard of healthcare in real time. Healthcare data is managed in a centralized database, MongoDB, and the dashboard visualization and patient monitoring are created using React. Using the dashboard, the doctors and administrators can view the patient's vitals, the level of severity of the patient and also view the emergency alerts that had been set for the patient.

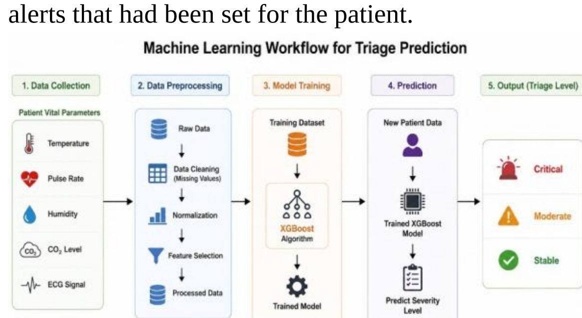

Fig. 3: Machine Learning Workflow Diagram

Fig. 4: Real-Time Dashboard Monitoring

VI. EXPERIMENTAL RESULTS / ANALYSIS

By testing the Smart Triage Assistant's functionality, we leveraged IoT sensor data from hospitals including temperature, humidity, pulse rates, CO levels, and ECG signals. We applied the XGBoost machine learning algorithm to categorize patients according to severity, using the data we gathered and produced. After gathering the data, we split it into training and testing sets to evaluate the performance of the experimental method. We evaluated the method's performance using accuracy, precision, recall, and F1-score. The results indicated that the proposed model is highly effective in predicting patient severity and can assist in real-time emergency healthcare monitoring.

A. *XGBOOST MODEL PERFORMANCE*

An XGBoost classifier achieved a very high level of accuracy in predicting patient classifications into Critical, Moderate, and Stable categories. This model has demonstrated strong performance in tracking a patient's vitals and predicting the severity of their condition in real time. The results indicate that this class of Machine Learning models may be helpful in supporting smart triage systems within the Emergency Department.

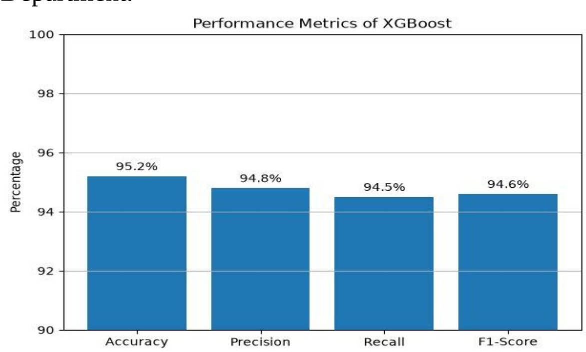

Fig. 5: Accuracy Comparison of XGBoost Model

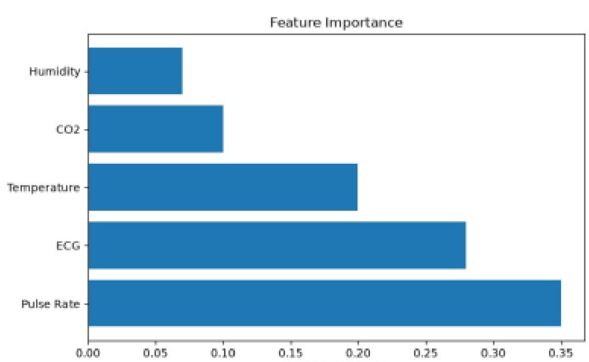

Fig. 6: Feature Importance Analysis

CONFUSION MATRIX ANALYSIS:

We evaluated the performance of our XGBoost model in classifying patient severity levels using a confusion matrix, which allowed us to assess how accurately the model predicted each category. Severity level, criticality, etc. The proposed system successfully classified the vast majority of patient statuses with minimal confusion between critical and moderate, critical and stable, or moderate and stable patients. The model's capacity to accurately identify emergency severity levels enhances decision-making in healthcare via intelligent systems.

Analysis using the confusion matrix indicates that the XGBoost classifier performs very well across each level of patient severity (class), as shown by its high overall accuracy in correct classifications. These results further highlight the critical role of machine learning models in real-time applications for emergency health services.

VII. FEATURE IMPORTANCE ANALYSIS

The analysis aimed to identify which healthcare parameters exert the strongest influence on predicting patient severity. The analysis revealed that pulse rate, ECG signals, and temperature are the main factors influencing intelligent triage classification, while CO and humidity play only a minor role. The feature importance graph indicates that real-time IoT sensor data is effective for emergency healthcare monitoring and predicting patient severity.

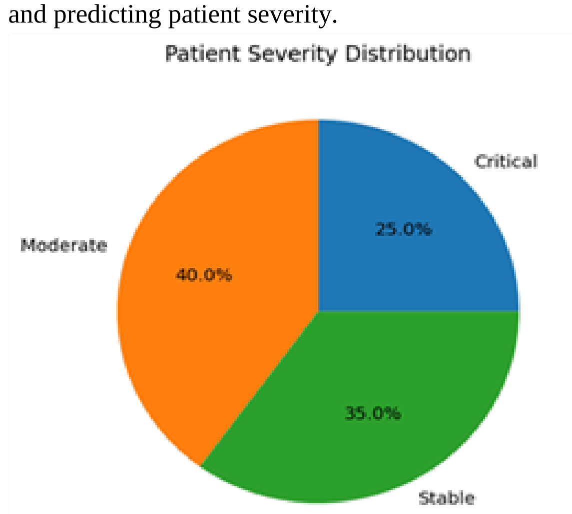

Fig. 7: Patient Severity Distribution

The feature importance chart shows the extent to which each parameter from the healthcare dataset used as inputs in the XGBoost model contributes to classifying patient severity levels. Overall, the results are clear: key factors in detecting more severe patient conditions during emergencies include vital signs (e.g., pulse rate, ECG signals).

VIII. PATIENT SEVERITY DISTRIBUTION

The Patient Severity Distribution Graph displays the distribution of patients in categories Critical, Moderate, and Stable based on healthcare sensor data. The graph shows how the entire dataset is used for Machine Learning predictions and emergency triage. The distribution analysis of the system demonstrates that the proposed system classifies people by the severity level and uses intelligent classification techniques to manage the emergency medical care in real-time.

IX. DASHBOARD MONITORING AND VISUALIZATION

The Smart Triage Assistant will allow healthcare providers to monitor their patients in real-time on a central dashboard created using React.js. The Real-Time Triage Dashboard includes information on current vitals, severity, emergency alerts, and healthcare analytics for doctors and administrators. The dashboard also tracks patient condition before coming to the hospital in emergency.

The real-time visual display of data enables faster monitoring of health care and quicker communication among all parties about a patient's status, as well as faster emergency response times.

X. DISCUSSION

According to the experiments, the Smart Triage Assistant performs well in integrating different components (IoT, Machine Learning, Cloud, and real-time patient health monitoring) into one single system for Emergency Medical Services. With high accuracy in predicting which classification a patient would be in (Critical, Moderate or Stable) using the XGBoost algorithm, these findings show that Machine Learning can intelligently predict triage of a patient before coming to the hospital and assist with decision-making regarding patient placement in an Emergency Room.

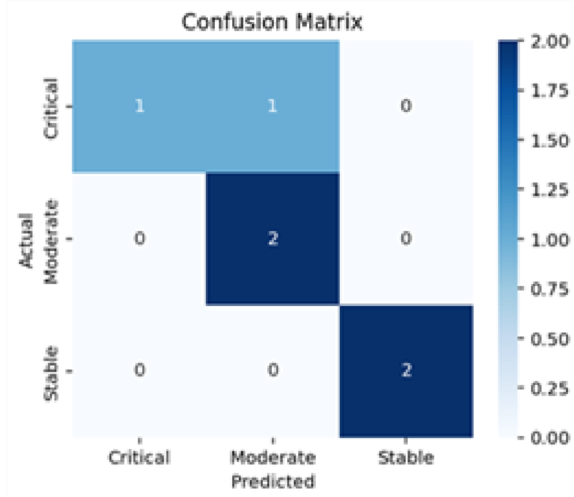

Fig. 8: Confusion Matrix for Severity Classification

By using IoT medical sensors (connected via ESP32 micro-controllers) to record vital signs such as temperature, pulse, humidity, CO levels and ECG traces during emergencies, the continuous transmission of this data to the cloud can be automated with fewer interventions, allowing for timely care while transporting a patient to a hospital.
In comparison to traditional Emergency Triage systems, the proposed framework provides better patient prioritization and increased preparedness for critical situations by EMS and hospitals. In addition,the Real-Time Triage Dashboard also significantly increases the efficiency of the emergency response by providing real-time patient monitoring, healthcare data visualization and automatic emergency alerts to physicians and other personnel.

XI. CONCLUSION AND FUTURE WORK

This paper proposes the Smart Triage Assistant, an intelligent real-time emergency healthcare monitoring and decision-support system based on IoT, Machine Learning, cloud communication, and web technologies. The system constantly monitors patients' vital signs, such as temperature, pulse rate, humidity, CO levels, and ECG with IoT sensors connected to ESP32 microcontrollers. The data is sent to the ThingSpeak cloud platform for real-time monitoring. An XGBoost machine learning model assigns patients to Critical, Moderate, and Stable categories, predicting triage, monitoring patients, automatically sending emergency alerts, and visualizing a real-time dashboard. The proposed system enhances hospital preparedness, reduces communication delay, minimizes manual intervention and improves patient safety.

The Smart Triage Assistant shows how modern healthcare technology can revolutionize emergency department operations with intelligent triage and real-time patient monitoring. Future enhancements include additional medical devices and healthcare services, AI-powered predictive analytics, mobile healthcare applications, cloud-based healthcare infrastructure, explainable AI techniques, and advanced hospital management systems. These improvements can improve emergency decision-making, efficiency, and the quality of patient care.

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