Smart Ambulance System with AI-Assisted Predictive Healthcare

[1]Navnath Gaikwad, [2]Aishwarya Yadav

[1,2]Researcher, Rayat Institute of Research & Development, Y C Institute of Science, Satara, Maharashtra, India

Abstract: The increasing demand for rapid and efficient emergency medical services has necessitated the integration of intelligent technologies into ambulance systems. This research proposes a Smart Ambulance System with AI-Assisted Predictive Healthcare, designed to enhance pre-hospital care through real-time data analysis, predictive modeling, and seamless human-machine collaboration. The system integrates biomedical sensors to continuously monitor vital parameters such as heart rate, oxygen saturation, blood pressure, and body temperature during patient transport. These data are processed using artificial intelligence algorithms to predict potential health deterioration and recommend immediate medical interventions. A cloud-connected platform enables real-time communication between ambulance personnel and hospital emergency departments, facilitating early diagnosis and preparation for treatment before patient arrival. The AI module supports decision-making by identifying critical patterns in patient data, estimating severity levels, and optimizing route selection based on traffic conditions. Additionally, an intuitive human interface ensures that paramedics can easily interpret AI-generated insights and maintain control over medical decisions. Simulation and prototype evaluations demonstrate improved response time, enhanced patient monitoring accuracy, and better coordination between emergency teams and healthcare facilities. The proposed system highlights the potential of AI-driven predictive analytics in transforming traditional ambulance services into intelligent, responsive, and life-saving healthcare platforms.

Keywords: Smart Ambulance System, Artificial Intelligence (AI), Predictive Healthcare, Emergency Medical Services (EMS), Real-Time Patient Monitoring, Internet of Things (IoT) in Healthcare, Biomedical Sensors.

I. INTRODUCTION

Emergency medical services (EMS) play a critical role in reducing mortality and improving patient outcomes during life-threatening situations. However, conventional ambulance systems primarily function as transportation units with limited diagnostic and predictive capabilities. Delays in identifying critical conditions during transit can significantly impact survival rates. To address these limitations, the proposed Smart Ambulance System integrates Artificial Intelligence (AI) with real-time health monitoring to transform ambulances into intelligent mobile healthcare units capable of predictive decision-making. Emergency Medical Services (EMS) are a cornerstone of pre-hospital care, particularly in time-sensitive conditions such as stroke and cardiac arrest, where rapid and appropriate response is essential for favorable clinical outcomes.

Timely and effective Emergency Medical Services (EMS) are critical for improving outcomes in life-threatening conditions such as cardiac arrest and stroke. However, traditional dispatch methods—typically assigning the nearest ambulance—are often inefficient, especially when resources are limited. Accurate triage is essential for prioritizing cases and optimizing response

Globally, EMS systems use either the protocol-driven Medical Priority Dispatch System or the symptom-based Criteria-Based Dispatch System. While widely adopted, these methods often lack accuracy, resulting in significant over-triage and under-triage rates. In Singapore, the Singapore Civil Defence Force (SCDF) manages over 190,000 emergency calls annually using a rule-based triage system based on the Patient Acuity Category Scale (PACS). Despite structured protocols, recent data show a 47% over-triage and 6% under-triage rate, indicating room for improvement.

In Singapore, the national EMS provider—the Singapore Civil Defence Force (SCDF)—responds to over 190,000 emergency calls annually with a limited fleet of 84 ambulances. SCDF employs a rule-based dispatch model guided by the Patient Acuity Category Scale (PACS), a five-tier system ranging from P1+ (critical emergencies) to P4 (non-urgent cases). Triage decisions are made by call center specialists based

on caller-reported information and 30 predefined protocols.

These specialists, while trained, are not clinically certified, and operate under strict time constraints that limit the depth of patient assessment.

This study proposes a machine learning-based triage model that leverages call data to enhance dispatch accuracy. By providing data-driven decision support, the model aims to reduce over-triage while maintaining low under-triage rates, ultimatelyimproving EMS efficiency and patient care outcomes.

II. RELATED WORK

Recent research has increasingly focused on enhancing emergency medical services (EMS) through the integration of intelligent technologies such as artificial intelligence (AI), the Internet of Things (IoT), and cloud computing. For example, Ayesha and Komalavalli proposed a comprehensive IoT- and cloud-based Smart Ambulance system that integrates medical sensors and patient identification techniques to enable real-time monitoring of vital signs during transit, improving emergency care delivery and communication with hospitals. This work underscores the importance of continuous data transmission and cloud analytics in EMS applications.

Similarly, Shujaat et al. presented a Smart Ambulance Response System that uses IoT and AI to monitor patient health and provide predictive analytics during the critical "golden hour," addressing delays in data sharing and preparation at hospital emergency departments. This system emphasizes the potential of AI to forecast medical conditions and bridge communication gaps between ambulances and healthcare facilities.

In addition to real-time monitoring, research has explored predictive analytics and optimization strategies. Thiagarajan et al. demonstrated that predictive modeling using deep learning and clustering approaches could identify high-risk accident zones and optimize ambulance placement to reduce response times, highlighting the value of data analytics in improving EMS efficiency.

Academic reviews also reveal growing interest in AI applications within prehospital care. A systematic review by Elfahim et al. found that AI models and machine learning algorithms have been widely applied to EMS to support tasks such as patient trajectory prediction, triage, resource allocation, and operational efficiency across the emergency care continuum,

underscoring the potential of AI to enhance clinical decision-making in ambulatory settings.

Other works emphasize the broader ecosystem of smart emergency services. Research into adaptive ambulance monitoring systems using IoT shows that vehicular communication with traffic controls can further reduce transit delays by dynamically managing obstacles such as traffic signals.

Collectively, these studies highlight the growing adoption of AI and IoT in EMS for real-time health monitoring, predictive analytics, and improved data exchange between ambulances and hospitals. The present work builds on these foundations by proposing an integrated framework that emphasizes AI-assisted predictive healthcare, intelligent decision support, and seamless human–machine collaboration to enhance ambulance effectiveness and patient outcomes.

Blomberg SN, Folke F, Ersbøll AK, Christensen HC, Torp-Pedersen C, Sayre MR, Counts CR, Lippert FK. Machine learning as a supportive tool to recognize cardiac arrest in emergency calls. Resuscitation. 2019;138:322–329.

This study explores the use of machine learning algorithms to aid in recognizing cardiac arrest situations during emergency calls. The researchers investigate the potential of machine learning as a supportive tool for identifying cardiac arrest cases based on information provided during emergency calls.

Blomberg SN, Christensen HC, Lippert F, Ersbøll AK, Torp-Petersen C, Sayre MR, Kudenchuk PJ, Folke F. Effect of machine learning on dispatcher recognition of out-of- hospital cardiac arrest during calls to emergency medical services: A randomized clinical trial. JAMA Netw Open. 2021;4(1):e2032320.

This paper presents the results of a randomized clinical trial that examines the impact of machine learning on dispatcher recognition of out-of-hospital cardiac arrest cases. The study assesses how machine learning algorithms affect the ability of emergency medical service dispatchers to recognize cardiac arrest situations during calls, providing valuable insights into the effectiveness of these technologies in real-world scenarios.

Tollinton L, Metcalf AM, Velupillai S. Enhancing predictions of patient conveyance using emergency call handler free text notes for unconscious and fainting incidents reported to the London Ambulance Service. Int J Med Inform.

2020;141:104179.

This research focuses on improving predictions related to patient conveyance by analyzing free text notes provided by emergency call handlers. Specifically, the study concentrates on incidents involving unconsciousness and fainting reported to the London Ambulance Service. By leveraging natural language processing techniques, the researchers enhance the accuracy of predictions, highlighting the importance of textual information in emergency medical services.

III. PROPOSED SYSTEM

The proposed system consists of biomedical sensors, embedded processing units, communication modules, and a centralized cloud platform. Sensors continuously capture vital parameters such as heart rate, oxygen saturation (SpO_2), blood pressure, electrocardiogram (ECG), and body temperature. These signals are processed by an onboard microcontroller or edge computing device, which transmits data to a cloud-based AI engine. The AI algorithms analyze trends and detect abnormal patterns, enabling early prediction of potential complications such as cardiac arrest, respiratory distress, or shock.

To implement this initiative, two applications have been designed:

- Hospital Application: This application loads and preprocesses the dataset, trains all algorithms on the processed data, and initiates a cloud server to receive requests from ambulances.
- Ambulance Application: In the absence of IoT sensors, this application uploads test data, representing the patient's vital signs, from a file. The application then transmits this data to the hospital server, where the patient's condition is predicted. The hospital server sends back the response to the ambulance, enabling timely and accurate medical interventions.
- The Smart Ambulance System significantly enhances emergency response efficiency by reducing diagnosis time, improving coordination, and enabling proactive medical intervention. Predictive healthcare analytics reduce the risk of sudden deterioration during transit and support early clinical decision-making. Furthermore, cloud-based data storage enables future analysis for improving EMS strategies and patient care protocols.
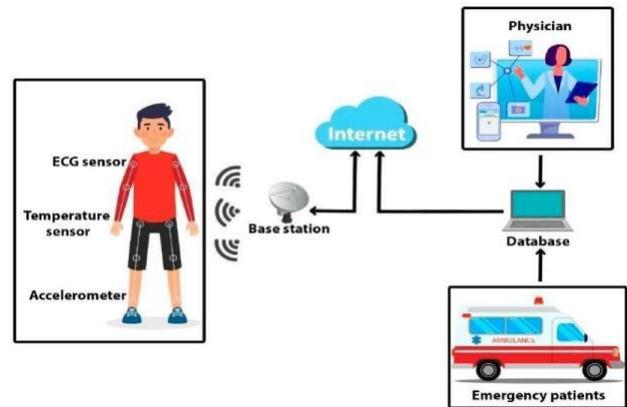
This advanced AI-based Ambulance system not only addresses the challenges posed by the burgeoning population but also significantly enhances the efficiency and effectiveness of emergency medical services, ultimately saving lives in critical situations. Finally, the AI-based Ambulance System represents a significant leap forward in the field of emergency medical services, offering a solution to the challenges posed by the increasing population and urbanization. By leveraging modern technologies, the proposed model ensures that every moment counts in saving lives during medical emergencies.

Advantages of proposed system

The advantages of intelligent ambulance-AI and human interface technology encompass improved efficiency, accuracy, patient care, and decision-making, ultimately leading to better outcomes for patients in emergency situations and creating a more responsive and effective emergency medical services system. The integration of intelligent ambulance-AI and human interface technology in emergency medical services offers several advantages, including:

- Enhanced Efficiency: Automation of tasks and processes leads to quicker response times, streamlined operations, and efficient allocation of resources. AI algorithms can optimize ambulance routes, ensuring the fastest possible response to emergencies.
- Improved Accuracy: AI-driven predictive analytics and decision support systems provide accurate insights based on vast amounts of data. This accuracy can aid paramedics in making informed decisions about patient care, leading to better treatment outcomes.
- Optimized Resource Utilization: By analyzing data and predicting demand, the system can optimize the allocation of ambulances and medical staff.

This ensures that resources are used efficiently, reducing idle time and improving overall service availability.

- Enhanced Patient Care: Access to real-time data and historical patient information allows paramedics to provide personalized and targeted care. They can arrive at the scene better prepared, with insights into the patient's medical history and specific conditions, leading to more effective treatments.
- Faster Decision-Making: AI algorithms can process information rapidly and provide instant recommendations. This speed is crucial in emergency situations, where swift decision- making can significantly impact patient outcomes.
- Improved Communication: Advanced human-machine interfaces facilitate seamless communication between paramedics, emergency operators, and hospitals. Clear and instant communication ensures that vital information is relayed promptly, enabling more coordinated and effective care.
- Reduction in Errors: Automation reduces the likelihood of human errors, ensuring that critical information is not overlooked. This leads to safer medical practices and minimizes the risk of mistakes in emergency situations.
- Data-Driven Insights: The system generates valuable data that can be analyzed to identify patterns, trends, and areas for improvement. These insights can be used to enhance protocols, training programs, and overall emergency medical service strategies.
- Resource Conservation: By optimizing routes and resources, the system contributes to the conservation of fuel and other valuable resources, making emergency medical services more environmentally friendly and sustainable.
- Cost Efficiency: While initial implementation might require investment, the long-term benefits, including reduced hospitalization costs due to better initial care, streamlined operations, and optimized resource usage, can lead to significant cost savings for healthcare providers and organizations.

AI-Assisted Predictive Healthcare Module:

The core innovation of the system lies in its predictive analytics capability. Machine learning models are trained using historical patient data and emergency case datasets to classify severity levels and forecast possible deterioration during transport. The AI module generates alerts and recommends preliminary interventions, assisting paramedics in making informed decisions. Unlike traditional monitoring systems that provide only raw data, this approach delivers actionable insights in real time, enhancing the quality of pre-hospital care.

Human–Machine Interface and Communication:

A user-friendly Human–Machine Interface (HMI) ensures that paramedics can easily interpret AI-generated insights without cognitive overload. Visual dashboards display patient status, risk levels, and recommended actions in an intuitive format. Additionally, the system enables live data transmission to hospital emergency departments, allowing medical staff to prepare appropriate treatment facilities before the patient arrives. This collaborative AI-human interaction ensures that technology supports rather than replaces medical professionals.

Route Optimization and Emergency Coordination:

Beyond patient monitoring, the system incorporates intelligent route optimization using real-time traffic data. AI algorithms calculate the fastest and safest path to the nearest suitable healthcare facility, minimizing response and transport time. The integration of GPS and cloud connectivity ensures seamless coordination between ambulance units, hospitals, and emergency response centers.

Advantages and Impact:

The proposed Smart Ambulance System with AI-Assisted Predictive Healthcare represents a transformative advancement in emergency medical services. By integrating real-time monitoring, predictive analytics, and human-machine collaboration, the system bridges the gap between on-site emergency response and hospital-based care. This approach has the potential to improve survival rates, optimize emergency resource utilization, and redefine the future of intelligent healthcare transportation.

The proposed Smart Ambulance System with AI-Assisted Predictive Healthcare is designed using a multi-layered architecture that integrates biomedical sensing, edge processing, cloud computing, and artificial intelligence. The system begins with a data acquisition layer, where various biomedical sensors are deployed inside the ambulance to continuously monitor patient vital parameters such as heart rate, oxygen saturation (SpO_2), blood pressure, electrocardiogram (ECG), and body temperature. These physiological signals are captured in real time and transmitted to an embedded processing unit installed within the ambulance.

The embedded controller performs preliminary data processing, including signal conditioning, noise filtering, and

threshold-based anomaly detection. This edge-processing capability ensures that abnormal conditions can be identified immediately, even if network connectivity is temporarily unavailable. The processed data is then securely transmitted via wireless communication technologies such as Wi-Fi, 4G, or 5G to a cloud-based platform for advanced analysis.

Within the cloud environment, artificial intelligence algorithms analyze incoming patient data using machine learning models trained on historical emergency datasets. These algorithms perform pattern recognition, risk classification, and predictive modeling to estimate the likelihood of health deterioration during transport. The AI engine generates real-time alerts and provides recommendations for preliminary medical interventions, assisting paramedics in making faster and more informed decisions.

A user-friendly Human–Machine Interface (HMI) is integrated into the ambulance dashboard to display real-time patient vitals, risk levels, AI-generated alerts, and estimated arrival time at the hospital. The interface is designed to minimize cognitive load on emergency personnel through intuitive visualization techniques such as color-coded severity indicators. Simultaneously, patient data is transmitted to the receiving hospital's emergency department, allowing medical staff to prepare necessary treatment facilities prior to the patient's arrival. Additionally, GPS integration enables intelligent route optimization by analyzing real-time traffic conditions, thereby reducing transportation time and improving emergency response efficiency.

The Smart Ambulance System can be further enhanced by integrating advanced communication technologies such as 5G networks to ensure ultra-low latency and seamless real-time data transmission. Future developments may incorporate deep learning models to improve predictive accuracy for complex medical emergencies. Telemedicine integration can allow live video consultations between ambulance personnel and hospital specialists during transit, enhancing collaborative decision-making. Furthermore, blockchain-based frameworks may be implemented to secure patient data and prevent unauthorized access. Integration with smart city infrastructure, such as automated traffic signal control for ambulances, can significantly reduce response time. Wearable health devices connected to the system could provide continuous patient data even before ambulance arrival, enabling a more proactive emergency care model. These advancements would further strengthen the reliability, efficiency, and intelligence of next-generation emergency medical services.
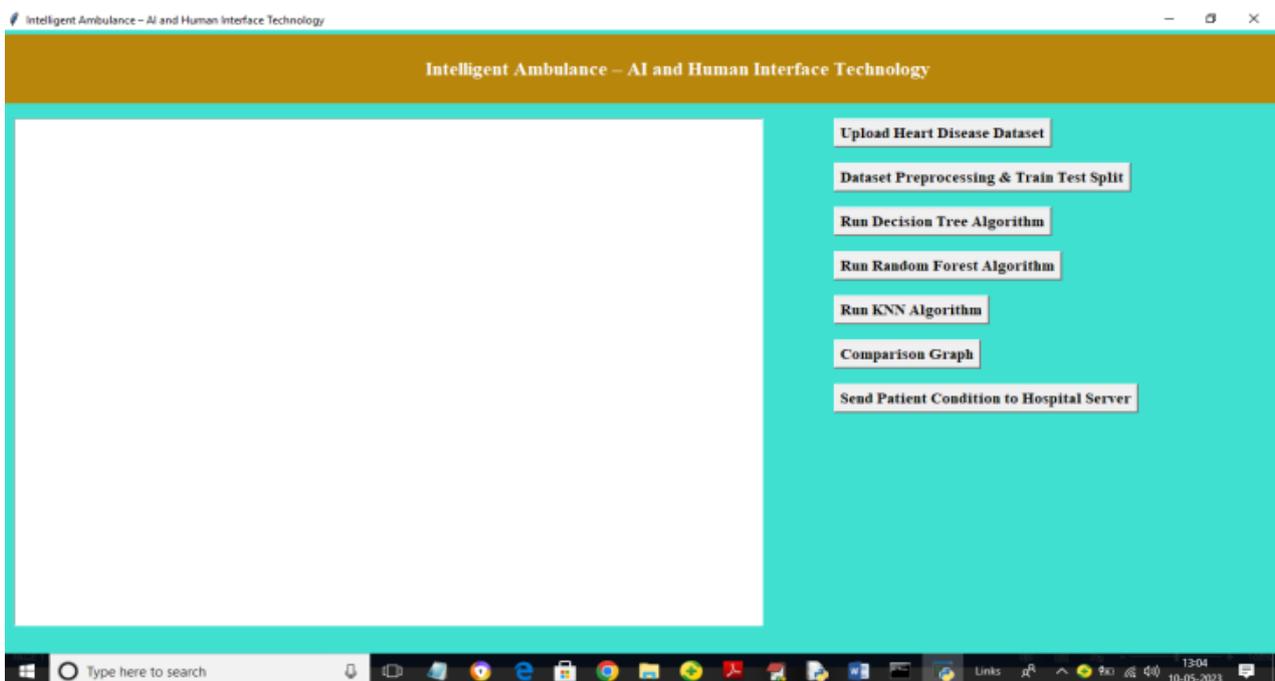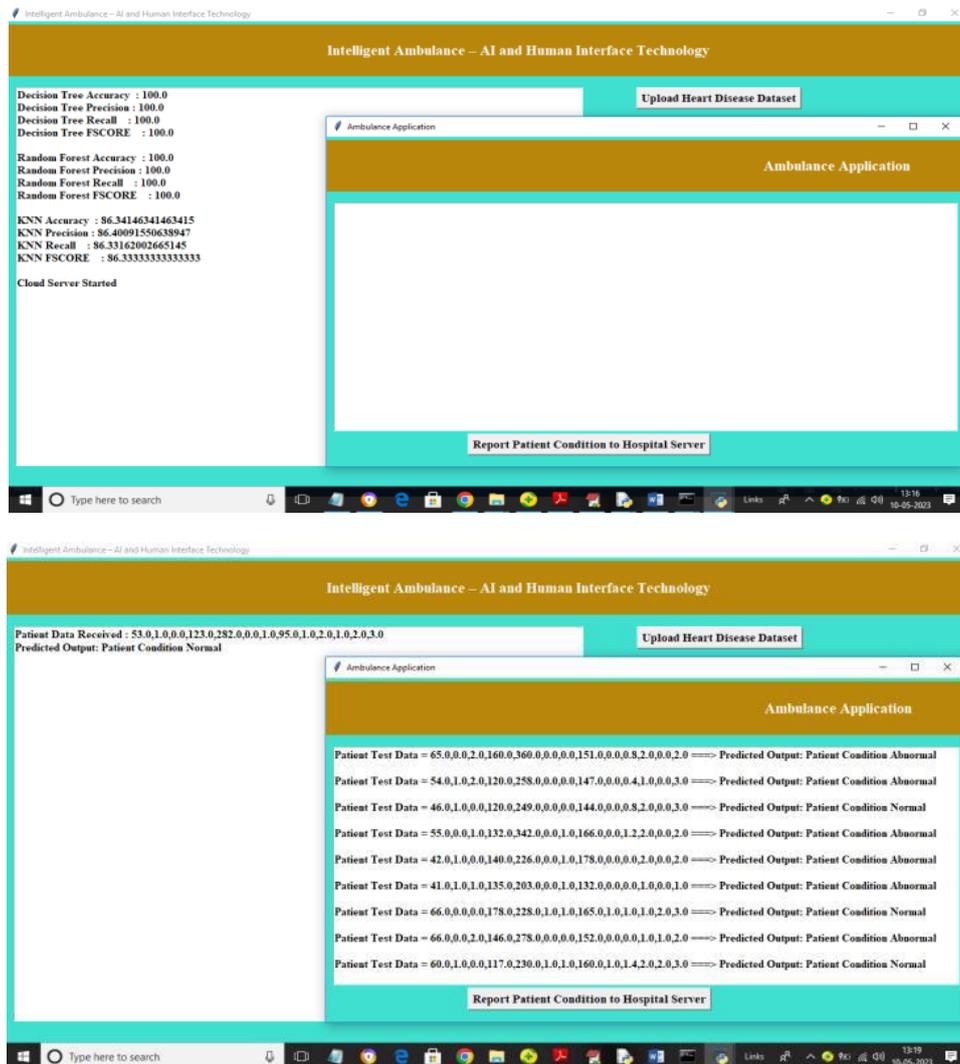
In above screen continuously ambulance will send patient data to server to get predicted condition and based on condition doctors will arrange medications. There have been some studies exploring machine learning on medical emergency calls. In Copenhagen, Blomberg et al.used a machine learning framework to recognize cardiac arrest in emergency calls, but the details of the machine learning framework are proprietary and, hence, was not disclosed. In their randomized clinical trial, no significant improvement in dispatchers' ability to recognize cardiac arrest was found when supported by machine learning. In London, Tollinton et al. used machine learning models to predict whether an unconscious and fainting patient would be conveyed to a hospital using the Medical Priority Dispatch System codes and free text notes as features. However, using conveyance as a binary marker of case severity is neither accurate nor objective.

The increasing population in developing countries like India has put immense pressure on existing infrastructures, especially in the healthcare sector. The history of emergency medical services dates back to ancient times when communities devised rudimentary methods to transport the injured. Rapid urbanization and population growth have led to challenges in providing timely medical assistance during emergencies. Traffic congestion, lack of resources, and communication gaps have further exacerbated this problem, leading to avoidable loss of lives. Over the centuries, these services have evolved, but the challenges have grown with increasing population and urbanization. With the advent of technology, especially artificial intelligence and the Internet of Things (IoT), new opportunities have emerged to revolutionize emergency medical services. Therefore, AI-based Ambulance System aims to revolutionize emergency medical response by leveraging cutting-edge technologies. By integrating IoT sensors, artificial intelligence algorithms, and real-time communication systems, this project

seeks to provide a seamless and efficient method of predicting, diagnosing, and administering treatment to patients en route to the hospital. This innovative approach ensures that patients in critical conditions receive the necessary medical attention promptly, significantly improving their chances of survival and recovery.

The need for an efficient and timely emergency medical response system is crucial. With the rise in propulation and urban density, traditional methods of ambulance services have become inadequate. There is a pressing need for a system that can bridge the gap between patients in critical conditions and timely medical interventions, ensuring that patients receive appropriate care even before reaching the hospital.

IV. CONCLUSION

The proposed intelligent ambulance system integrating AI and advanced human-machine interfaces aims to revolutionize emergency medical services. By automating processes, utilizing predictive analytics, and improving communication between paramedics and hospitals, this system enhances efficiency, accuracy, and responsiveness. The timely and data-driven support provided ensures optimal patient care during critical situations, ultimately saving lives and reducing the strain on healthcare facilities. This innovative approach addresses the limitations of traditional ambulance systems and underscores the importance of technology in improving emergency response and medical outcomes.

REFERENCES

[1] Advani R, Naess H, Kurz MW. The golden hour of acute ischemic stroke. Scand J Trauma Resusc Emerg Med. 2017;25(1):54.

[2] Heestermans T, van 't Hof AWJ, ten Berg JM, van Werkum JW, Boersma E, Mosterd A, Stella PR, van Zoelen AB, Marcel Gosselink AT, Kochman W, et al. The golden hour of prehospital reperfusion with triple antiplatelet therapy: A subanalysis from the Ongoing Tirofiban in Myocardial Evaluation 2 (On-TIME 2) trial early initiation of triple antiplatelet therapy. Am Heart J. 2010;160(6):1079–1084.

[3] Al-Dury N, Ravn-Fischer A, Hollenberg J, Israelsson J, Nordberg P, Strömsöe A, Axelsson C, Herlitz J, Rawshani A. Identifying the relative importance of predictors of survival in out of hospital cardiac arrest: A machine learning study. Scand J Trauma Resusc Emerg Med. 2020;28(1):60.

[4] Carter GM, Chaiken JM, Ignall E. Response areas for two emergency units. Oper Res. 1972;20(3):571–594.

[5] Jagtenberg CJ, Bhulai S, van der Mei RD. Dynami3c ambulance dispatching: Is the closest-idle policy always optimal? Health Care Manag Sci. 2017;20(4):517–531.

[6] Haghani A, Tian Q, Hu H. Simulation model for real-time emergency vehicle dispatching and routing. Transp Res Rec. 2004;1882(1):176–183.

[7] Bandara D, Mayorga ME, McLay LA. Priority dispatching strategies for EMS systems. J Oper Res Soc. 2014;65(4):572–587.

[8] Jagtenberg CJ, van den Berg PL, van der Mei RD. Benchmarking online dispatch algorithms for Emergency Medical Services. Eur J Oper Res. 2017;258(2):715–725.

[9] Leeies M, Ffrench C, Strome T, Weldon E, Bullard M, Grierson R. Prehospital application of the Canadian triage and acuity scale by emergency medical services. CJEM. 2017;19(1):26–31.

[10] Medical Priority Dispatch System. IAED. [accessed 8 Feb 2021]. https://www.emergencydispatch.org/what-we-Feb 2021]. https://www.emergencydispatch.org/what-we-do/emergency-priority-dispatch-system/medical- protocol

[11] Sporer KA, Johnson NJ, Yeh CC, Youngblood GM. Can emergency medical dispatch codes predict prehospital interventions for common 9-1-1 call types? Prehosp Emerg Care. 2008;12(4):470–478.

[12] Criteria Based Dispatch—Emergency Medical Dispatch Guidelines. Published online July 2010; http://www.emsonline. net/assets/criteriabaseddispatchguidelines-rev2010.pdf.

[13] Andersen MS, Johnsen SP, Sørensen JN, Jepsen SB, Hansen JB, Christensen EF. Implementing a nationwide criteria-based emergency medical dispatch system: A register- based followup study. Scand J Trauma Resusc Emerg Med. 2013;21:53.

[14] Dami F, Golay C, Pasquier M, Fuchs V, Carron PN, Hugli O. Prehospital triage accuracy in a criteria based dispatch centre. BMC Emerg Med. 2015;15:32.

[15] Bohm K, Kurland L. The accuracy of medical dispatch—A systematic review. Scand J Trauma Resusc Emerg Med. 2018;26:94.

[16] Lidal IB, Holte HH, Vist GE. Triage systems for pre-hospital emergency medical services— A systematic review. Scand J Trauma Resusc Emerg Med. 2013;21:28.

[17] Fong RY, Glen WSS, Mohamed Jamil AK, Tam WWS, Kowitlawakul Y. Comparison of the Emergency Severity Index versus the Patient Acuity Category Scale in an emergency setting. Int Emerg Nurs. 2018;41:13–18.

[18] Blomberg SN, Folke F, Ersbøll AK, Christensen HC, Torp-Pedersen C, Sayre MR, Counts CR, Lippert FK. Machine learning as a supportive tool to recognize cardiac arrest in emergency calls. Resuscitation. 2019;138:322–329.

[19] Blomberg SN, Christensen HC, Lippert F, Ersbøll AK, Torp-Petersen C, Sayre MR, Kudenchuk PJ, Folke F. Effect of machine learning on dispatcher recognition of out-of- hospital cardiac arrest during calls to emergency medical services: A randomized clinical trial. JAMA Netw Open. 2021;4(1):e2032320.

[20] Tollinton L, Metcalf AM, Velupillai S. Enhancing predictions of patient conveyance using emergency call handler free text notes for unconscious and fainting incidents reported to the London Ambulance Service. Int J Med Inform. 2020;141:104179.

[21] Snoek J, Larochelle H, Adams RP. Practical Bayesian optimization of machine learning algorithms. arXiv. 2012. https://doi.org/10.48550/arXiv.1206.2944.

[22] Quinlan JR. Induction of decision trees. Mach Learn. 1986;1(1):81–106.

[23] Chen T, Guestrin C. XGBoost: A scalable tree boosting system. Paper presented at: KDD 2016. Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining; 2016 Aug 13–17; San Francisco, CA.

[24] Breiman L. Random forests. Mach Learn. 2001;45(1):5–32.

[25] Prieto JT, Scott K, McEwen D, Podewils LJ, al-Tayyib A, Robinson J, Edwards D, Foldy S, Shlay JC, Davidson AJ. The detection of opioid misuse and heroin use from paramedic response documentation: Machine learning for improved surveillance. J Med Internet Res. 2020;22(1):e15645. https://doi. org/10.2196/15645.

Citation of this Article:

Navnath Gaikwad, & Aishwarya Yadav. (2025). Smart Ambulance System with AI-Assisted Predictive Healthcare. *Journal of Artificial Intelligence and Emerging Technologies.* 2(12), 26-33. Article DOI: https://doi.org/10.47001/JAIET/2025.212004

*** End of the Article ***