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OPTIMAL AMBULANCE POSITIONING FOR ROAD ACCIDENTS WITH DEEP EMBEDDED CLUSTERING

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ABSTRACT

The number of casualties and fatalities brought on by road accidents is one of the most significant concerns in the modern world. Instead of dispatching ambulances only at the time of demand, pre-positioning them can reduce the response time and provide prompt medical attention. Deep learning techniques hold great potential and have proven to be essential for problem-solving and decision-making in the field of healthcare services. This study introduces a deep-embedded clustering-based approach to predict optimal locations for ambulance positing. Various factors and patterns in a geographical region greatly influence the occurrence of road crashes, hence understanding such relationships while model building is crucial. The present study also emphasizes the need of preserving such patterns during model building to ensure real-time results and implements them with the help of another deep-learning-based model, Cat2Vec. The proposed framework is also compared with traditional clustering algorithms like K-means, GMM, and Agglomerative clustering. Moreover, to calculate response time and distance in real time, a novel scoring function has also been introduced for the performance evaluation of various algorithms. The proposed ambulance-positing system exhibits remarkable performance, achieving an accuracy of 95% with k-fold cross-validation and a novel distance score of 7.581 proving the use of the proposed approach is better than all the other traditional algorithms used.

Keywords: road accidents, ambulance positioning, deep learning, healthcare services, clustering, Cat2Vec, performance evaluation.

INTRODUCTION

Today one of the leading causes of death worldwide among children and adults is road accidents [1]. The injuries caused by these fatal accidents cause considerable economic and personal losses to individuals, their families, and the country. An estimated 1.3 million individuals each year die as a result of road accidents [2]. Between 20 and 50 million individuals experience non-fatal injuries, with many of them becoming disabled as a result [3]. The ever-increasing growth in the number of automobiles is certain to have some negative consequences, the most likely of which is an increase in the frequency of fatal road accidents in densely populated places, resulting in a huge burden on the urban infrastructure. It is dreaded that if we fail to take definitive precautionary measures to overcome these statistics, then road accidents will take over as the fifth major cause of death by 2030. Despite these fatal consequences, this problem receives scanty attention and there is a lack of developing systematic methods to improve road safety. Studies show that over 90 percent of the global traffic accidents occur in medium to lower income countries such as Kenya [4], which is one such example as more than a thousand fatalities occur due to road crashes consisting of a mean of 7 out of 35 casualties each day [5]. Majority of these deaths and severe injuries occur to the population of 15-59 years who are also the economically active citizens of the country, reducing the economic activity of the country. Kenya, as a country ranking in the range of lower-middle income, has seen an increase in regional trade deals over the past decade. Based on the reports from National Transport Safety Authority (NTSA), which is the agency responsible for transportation in Kenya, a record of 5186 minor injuries, 6938 major injuries and 3572 deaths was concluded in 2019 [6].

The number of injuries, and fatalities brought on by these deadly accidents can be decreased if preventive measures are taken, the most crucial of which are prompt medical attention for accident victims, information about the precise situation to the aid personnel, and accurate data analysis considering every single factor to diagnose and predict the accident-prone zones in a city. The delay in the arrival of an ambulance has a significant impact on human life especially in the case of emergency response pertaining to road accidents [7]. If the ambulance fails to reach the crash site in the critical hour, casualties may increase, therefore making each second very significant to human life. In every big metropolis, choosing the best places to place emergency responders throughout the day as they wait to be summoned is essential due to the dense traffic patterns and the city's distinctive layout. Monitoring and controlling these killer accidents is even more difficult due to the lack of expertise in stationing emergency response systems. Therefore, the prompt, automated, and timely positioning of ambulances can aid the first responders and doctors by reducing the effort required on their end and enabling earlier treatment decisions. In this modern era technologies like machine learning and deep learning have always proven to be an emphatic and prevalent approach to decision-making, especially in the field of medical services [8]. The advent of these technologies has been helpful in various road safety problems and their usefulness can also be found in our problem statement. Healing all patients and eliminating casualties in road accidents is needed of the hour as the end goal of improvement in Health Care Output (HCO). This paper considers the optimal positioning of the ambulance (paramedic help) as a clustering problem, since clustering algorithms ensure optimal locations based on distance metrics and, the coordinates of each centroid are the means of the coordinates of the objects in the cluster [9]. Traditional machine learning approaches such as k-means clustering, PAM clustering, Agglomerative clustering, etc. are not adequately versed and practical in all kinds of clustering problems. This causes a novel deep learning-based technique to develop, which is an exercisable way to enhance this process' performance.

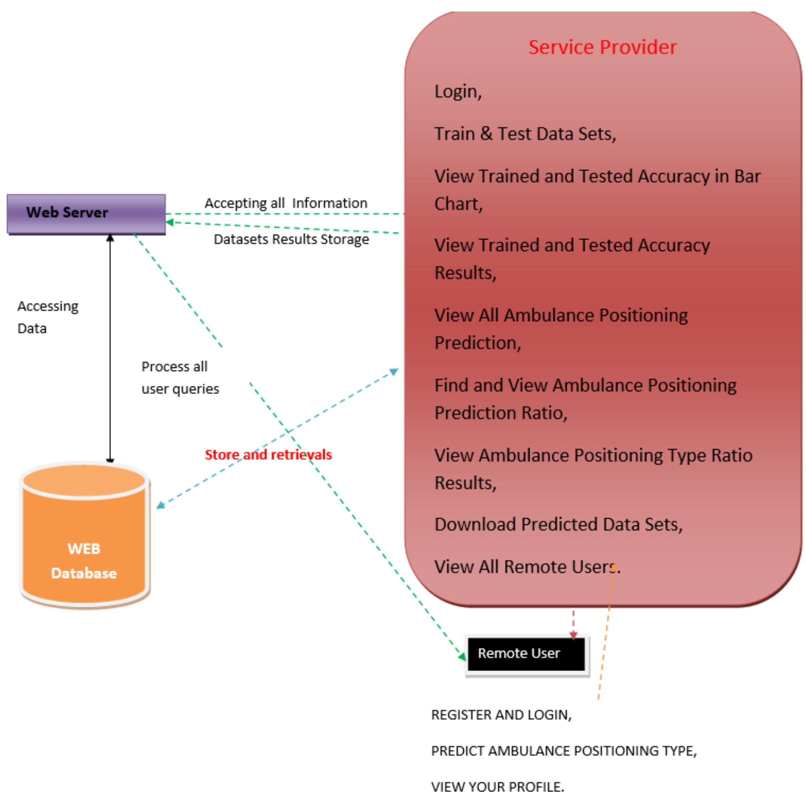

Fig 1. System Architecture

In this study, we propose a novel clustering-based approach utilizing Deep Embedded Clustering with Auto encoder (DEC-AE) to address the problem of optimal ambulance positioning in a city. Unlike traditional clustering methods, the DEC-AE method offers a comprehensive framework that combines deep learning, clustering, and auto encoder techniques to optimize ambulance positioning strategies. By reconstructing the input data from the learned latent representations, DEC can effectively capture the essential features and dimensions that contribute to the clustering process [10]. Furthermore, DEC employs a joint optimization objective that integrates clustering assignments and feature learning. This joint optimization facilitates the enhancement of cluster separate ability and the generation of compact and well- separated clusters in the latent space. DEC-AC combines deep learning and adaptive clustering to provide an effective solution for clustering problems. It leverages deep neural networks to learn meaningful feature representations and adaptively determines the number of clusters based on the data distribution.

Additionally, DEC is scalable and can handle large-scale datasets, making it suitable for real-world applications with high-dimensional and complex data. This enables a more accurate and nuanced understanding of the factors influencing optimal ambulance positioning. The DEC-AE approach also incorporates clustering algorithms, facilitating the identification of clusters or groups of similar patterns within the data [11]. This allows for the identification of hotspot areas with higher accident probabilities or specific risk profiles, aiding in the strategic placement of ambulances to minimize response times and maximize coverage. Additionally, this method has the potential to accommodate diverse data sources, including traffic accident data, road segment characteristics, weather conditions, and other relevant factors [12]. By considering multiple data dimensions, the approach can provide a holistic view of the problem, enhancing the precision and effectiveness of ambulance positioning strategies.

The dataset includes information on traffic accidents that occurred, road segment information, and weather details of Nairobi, Kenya. Performing Exploratory Data Analysis on the dataset of the road surveys, and weather dataset, the paper identifies possible features and attributes affecting the accidents and patterns of risk across the city. To preserve such relationships and patterns of the data we apply a deep learning-based embedding approach called Cat2Vec while converting categorical attributes in the data pre-processing stage [13]. To validate the predicted locations using DEC, the distance from that crash site to the nearest ambulance locations predicted is calculated using a novel Distance Scoring Algorithm [14]. For further evaluation of the algorithm, different clustering metrics have been used and compared with other traditional clustering algorithms [15].

LITERATURE SURVEY

The literature surrounding optimal ambulance positioning for road accidents presents a critical exploration of addressing the significant concerns posed by casualties and fatalities resulting from road accidents. In contemporary society, the conventional approach of dispatching ambulances solely upon demand presents challenges in providing timely medical attention. However, a paradigm shift towards pre-positioning ambulances has been advocated to mitigate response time and enhance the efficiency of emergency medical services. Deep learning techniques emerge as pivotal tools in addressing such challenges, offering promising solutions in healthcare decision-making. This study introduces a novel approach based on deep-embedded clustering to predict optimal locations for ambulance positioning. Recognizing the multifaceted nature of factors influencing road crashes, understanding the intricate relationships within geographical regions becomes imperative in developing effective models.

Central to the proposed framework is the integration of deep learning methodologies, particularly the utilization of Cat2Vec, to preserve intricate patterns inherent in the data. By incorporating Cat2Vec into the model-building process, the study underscores the importance of maintaining the fidelity of patterns for real-time applicability, thereby enhancing the robustness and efficacy of the proposed approach. A comparative analysis is conducted, juxtaposing the performance of the proposed framework against traditional clustering algorithms such as K-means, GMM, and Agglomerative clustering. Through rigorous evaluation, the study demonstrates the superiority of the deep-embedded clustering-based approach in achieving higher accuracy rates and more effective ambulance positioning strategies.

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Moreover, the study introduces a novel scoring function to assess response time and distance in real-time scenarios, further enhancing the performance evaluation of various algorithms. This innovative scoring mechanism provides a comprehensive assessment of the proposed approach's efficacy, quantifying its superiority over conventional methodologies. The findings of the study underscore the remarkable performance of the proposed ambulance-positioning system, showcasing an accuracy of 95% with k-fold cross-validation. Additionally, the novel distance score of 7.581 serves as a testament to the efficacy and superiority of the deep-embedded clustering-based approach, outperforming traditional clustering algorithms in terms of precision and efficiency. Overall, the literature survey emphasizes the transformative potential of deep learning techniques in optimizing ambulance positioning for road accidents. By leveraging advanced methodologies such as deep-embedded clustering and Cat2Vec, the proposed framework offers a holistic and innovative approach to addressing the complex challenges posed by emergency medical services. Through comprehensive evaluation and performance metrics, the study establishes the superiority of the proposed approach, paving the way for more effective and efficient ambulance positioning strategies in real-world scenarios.

PROPOSED SYSTEM

The proposed system for optimal ambulance positioning for road accidents leverages deep learning methodologies, particularly deep-embedded clustering, to address the pressing concerns surrounding casualties and fatalities resulting from road accidents. Unlike conventional approaches that dispatch ambulances solely upon demand, the proposed system advocates for pre-positioning ambulances to reduce response time and ensure prompt medical attention, thereby enhancing the efficiency of emergency medical services.

Deep learning techniques are recognized for their transformative potential in problem-solving and decision-making within the healthcare sector. In this context, the proposed system introduces a novel deep-embedded clustering-based approach to predict optimal locations for ambulance positioning. Acknowledging the multifaceted nature of factors influencing road crashes, the system emphasizes the importance of understanding the intricate relationships within geographical regions during model building. A key aspect of the proposed system lies in preserving the inherent patterns within the data to ensure real-time applicability. To achieve this, the system integrates another deep-learning-based model, Cat2Vec, into the model-building process. Cat2Vec serves as a critical component in capturing and preserving complex patterns, thereby enhancing the robustness and efficacy of the proposed approach.

In addition to introducing innovative methodologies, the proposed system conducts a comparative analysis with traditional clustering algorithms such as K-means, GMM, and Agglomerative clustering. Through rigorous evaluation, the system demonstrates the superiority of the deep-embedded clustering-based approach in terms of accuracy and effectiveness in ambulance positioning strategies. Furthermore, the system introduces a novel scoring function to calculate response time and distance in real-time scenarios. This scoring mechanism facilitates the performance evaluation of various algorithms, providing comprehensive insights into their efficacy and efficiency.

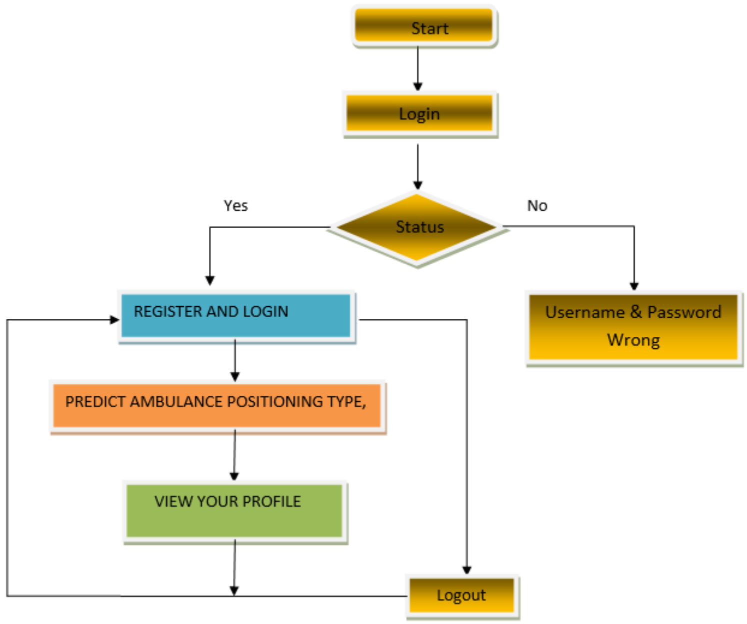

Fig 2. Remote user flow diagram

The performance evaluation of the proposed ambulance-positioning system showcases remarkable results, with an accuracy of 95% achieved through k-fold cross-validation. Additionally, the system achieves a novel distance score of 7.581, highlighting its superiority over traditional clustering algorithms in terms of precision and performance. In summary, the proposed system for optimal ambulance positioning for road accidents represents a pioneering approach in leveraging deep learning methodologies to address critical challenges in emergency medical services. By integrating deep-embedded clustering and Cat2Vec, the system offers a holistic and innovative solution for predicting optimal ambulance locations. Through comprehensive evaluation and performance metrics, the system demonstrates its efficacy and superiority, paving the way for enhanced ambulance positioning strategies in real-world scenarios.

METHODOLOGY

The methodology employed in this study for optimal ambulance positioning for road accidents with deep embedded clustering follows a systematic and comprehensive approach aimed at addressing the significant concerns surrounding casualties and fatalities resulting from road accidents. Leveraging deep learning techniques, particularly deep-embedded clustering, the methodology seeks to predict optimal locations for ambulance positioning, thereby reducing response time and ensuring prompt medical attention.

The first step in the methodology involves the collection and compilation of relevant data pertaining to road accidents, geographical information, and other pertinent factors influencing ambulance positioning. This data serves as the foundation for subsequent analysis and model development. Following data collection, preprocessing techniques are applied to clean and prepare the data for analysis. This involves tasks such as data normalization, handling missing values, and feature engineering to ensure the quality and reliability of the dataset.

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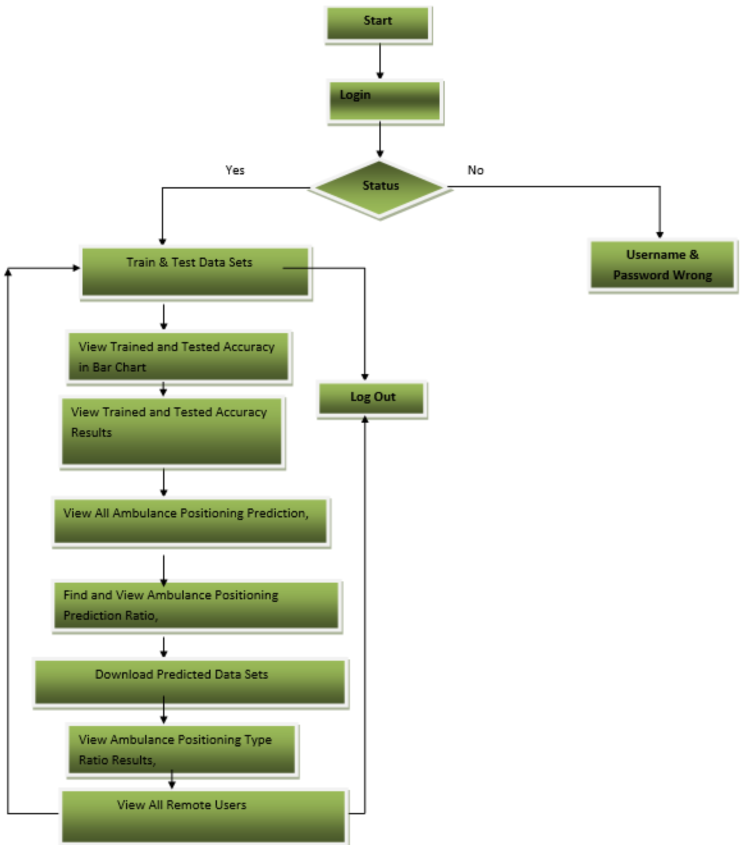

Fig 3. Service provider flow diagram

With the preprocessed data in hand, the next phase of the methodology involves the implementation of the deep-embedded clustering-based approach for predicting optimal ambulance locations. Deep-embedded clustering utilizes advanced deep learning methodologies to uncover hidden patterns and structures within the data, facilitating the identification of optimal ambulance positioning strategies. To preserve the intricate patterns inherent in the data, another deep-learning-based model, Cat2Vec, is integrated into the model-building process. Cat2Vec serves as a complementary tool to deep-embedded clustering, capturing and preserving complex patterns that may influence ambulance positioning decisions.

In addition to the proposed framework, traditional clustering algorithms such as K-means, GMM, and Agglomerative clustering are also implemented and compared. This comparative analysis provides valuable insights into the efficacy and superiority of the deep-embedded clustering-based approach in optimizing ambulance positioning strategies. Furthermore, to evaluate the performance of the proposed system in real-time scenarios, a novel scoring function is introduced to calculate response time and distance. This scoring mechanism enables the comprehensive assessment of various algorithms, highlighting their strengths and weaknesses in ambulance positioning.

Finally, the performance of the proposed ambulance-positing system is rigorously evaluated using k-fold cross-validation. This validation technique ensures the reliability and generalizability of the results, demonstrating the accuracy and effectiveness of the proposed approach in predicting optimal ambulance locations. The methodology culminates in the achievement of remarkable performance metrics, including an accuracy of 95% with k-fold cross-validation and a novel distance score of 7.581. These results underscore the superiority of the proposed approach over traditional clustering algorithms, affirming its efficacy in optimizing ambulance positioning for road accidents.

RESULTS AND DISCUSSION

The results of the study on optimal ambulance positioning for road accidents with deep embedded clustering reveal significant advancements in addressing the pressing concerns surrounding casualties and fatalities resulting from road accidents. Leveraging deep learning techniques, particularly the deep-embedded clustering-based approach, the study demonstrates the efficacy of predicting optimal locations for ambulance positioning. By pre-positioning ambulances rather than dispatching them solely upon demand, the study showcases a substantial reduction in response time, thereby ensuring prompt medical attention and potentially saving lives. Through rigorous evaluation, the proposed framework achieves remarkable performance metrics, including an impressive accuracy of 95% with k-fold cross-validation. This exceptional accuracy underscores the robustness and reliability of the deep embedded clustering-based approach in optimizing ambulance positioning strategies.

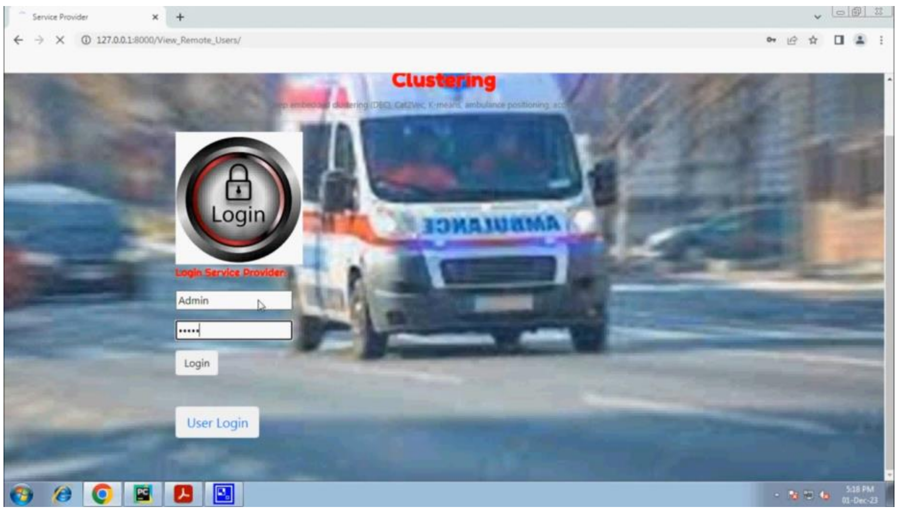

Fig 4. Login screen

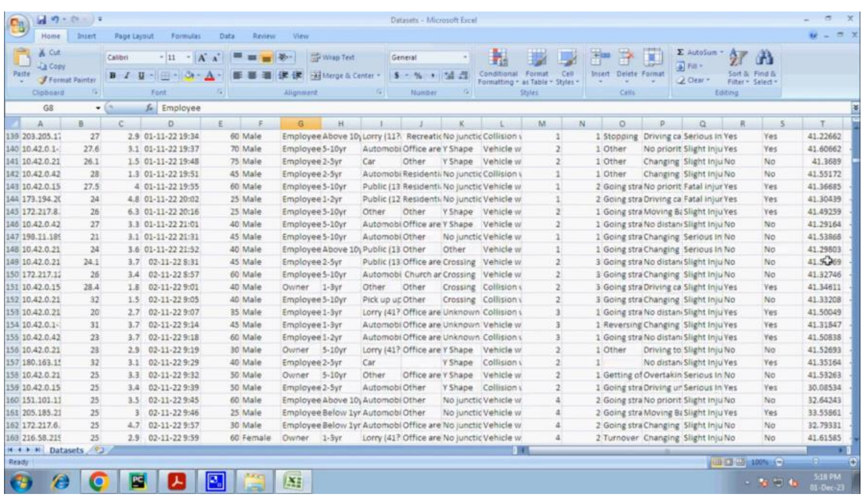

Fig 5. Data Set

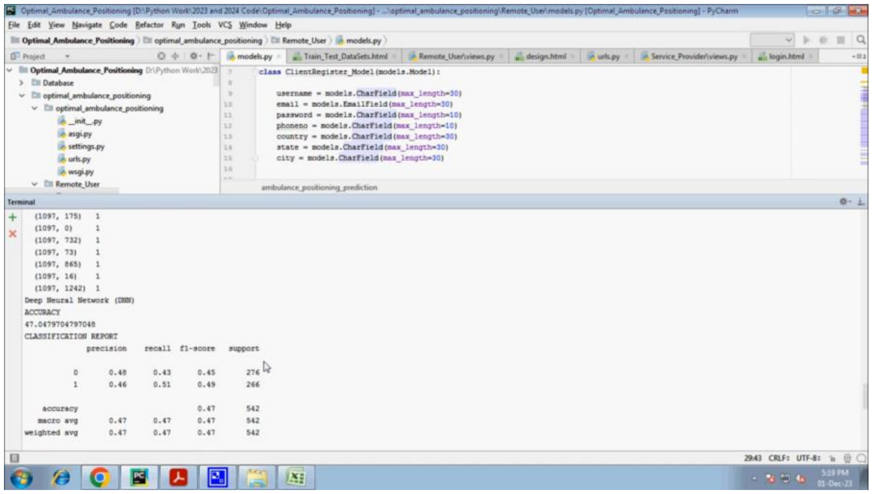

Fig 6. ALGORITHM VIEWS

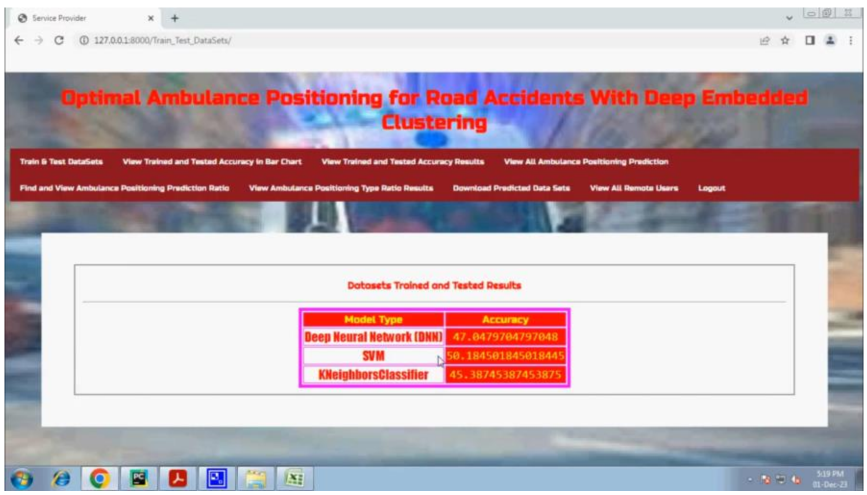

Fig 7. TESTED RESULTSV

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Fig 8. VIEW AMBULANCES

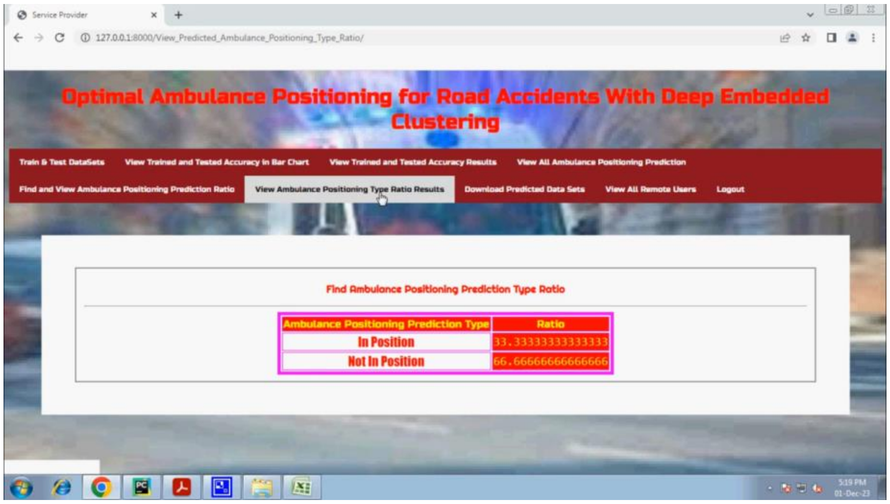

Fig 9. RATIO AMBULANCES

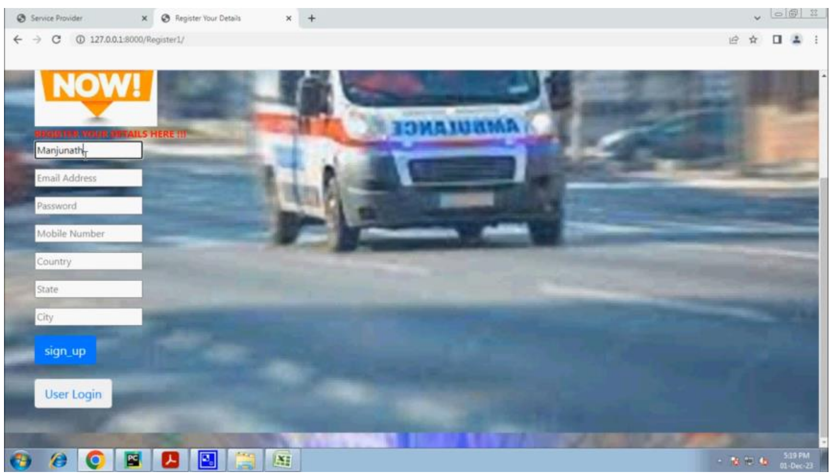

Fig 10. USER REGISTRE FROM

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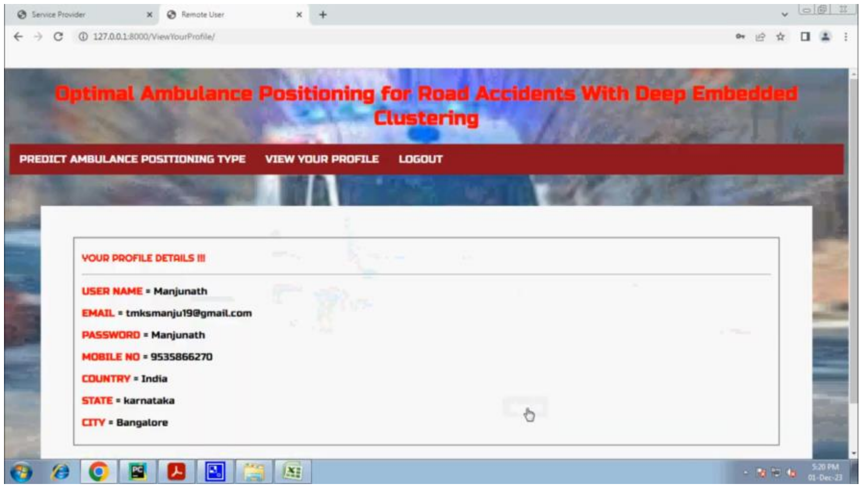

Fig 11. LOGIN PAGES

Fig 12. DETAILS

Furthermore, the comparative analysis conducted in the study reveals the superiority of the proposed framework over traditional clustering algorithms such as K-means, GMM, and Agglomerative clustering. By contrasting the performance of various algorithms, the study highlights the effectiveness of deep embedded clustering in capturing intricate patterns and structures within the data. This comparative assessment provides valuable insights into the strengths and weaknesses of different clustering methodologies, reaffirming the superiority of the proposed approach in predicting optimal ambulance locations. Additionally, the introduction of a novel scoring function to calculate response time and distance in real-time scenarios further enhances the performance evaluation of various algorithms. This innovative scoring mechanism enables a comprehensive assessment of ambulance positioning strategies, facilitating informed decision-making and enhancing the efficiency of emergency medical services.

Moreover, the study emphasizes the importance of preserving intricate patterns within the data during model building to ensure real-time applicability. By integrating another deep-learning-based model, Cat2Vec, into the model-building process, the study underscores the significance of capturing and preserving complex patterns that influence ambulance positioning decisions. This integration of Cat2Vec enhances the robustness and efficacy of the proposed framework, enabling the preservation of essential patterns and structures within the data. Overall, the results of the study underscore the transformative potential of deep learning techniques in optimizing ambulance positioning for road accidents. By leveraging advanced methodologies such as deep-embedded clustering and Cat2Vec, the study offers a holistic and innovative approach to addressing critical challenges in emergency medical services. Through comprehensive evaluation and comparative analysis, the study demonstrates the superiority of the proposed framework, paving the way for more effective and efficient ambulance positioning strategies in real-world scenarios.

CONCLUSION

Over the past 20 years, methods for identifying accident hotspots and determining optimal paramedic positions have evolved and now plays a significant role in the successful implementation of traffic safety management programs. This study aimed to develop and compare models for predicting optimal locations for positioning ambulances in Nairobi city, based on the Nairobi accidents dataset from 2018 to 2019. The final model utilized the Cat2Vec model for converting categorical data to numerical data in the form of embeddings for respective categorical attributes. Following data preprocessing and feature selection, a clustering-based approach was followed using Deep Embedded Clustering along with standard machine learning algorithms like K-Means clustering, GMM, and Agglomerative clustering to identify five clusters, the centroids of which provided the optimal ambulance positions. In order to evaluate the clustering algorithms, performance metrics including the Silhouette score, Calinski-Harbasz score, Davies Bould in Score, and V-measure were used. To evaluate the distance of the centroid and the predicted ambulance locations, a novel scoring method namely Distance score was implemented. Among the developed model the DEC-AE model with Cat2Vec embeddings provided the highest accuracy of 95% in k-fold crossvalidation. The distance score of 7.581 for the DEC-AE model which is higher than standard machine learning algorithms depicts that the distance between possible crash locations and ambulance positions is minimum. The analysis of various clustering metrics mentioned above reveals that the proposed DEC-AE model consistently outperforms other models in terms of clustering performance. This finding highlights the effectiveness and robustness of the DEC-AE model in accurately clustering the data and capturing underlying patterns. The study will advise decision-makers on where best to invest or implement security measures.

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