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Geo-Intelligent Blood Donor Locator System Using Leaflet Maps API, Machine Learning and Haversine Formula for Emergency Blood Services

Prof. Umesh S. Samarth, Prof. Rohan B. Kokate, Shantanu D. Dorle
Guide, Department of Computer Applications
HOD, Department of Computer Applications
Student, Department of Computer Applications
JD College of Engineering & Management, Nagpur, Maharashtra, India
pro@jdcoem.ac.in, rohan.kokate1@gmail.com, shantanudorle271@gmail.com

Abstract: *Blood availability during emergencies significantly impacts healthcare efficiency and patient survival worldwide. Traditional blood donor identification relies on manual communication and static databases, which are time-consuming and often lead to delays in critical situations. Recent studies highlight that intelligent systems integrating Geographic Information Systems (GIS) and machine learning algorithms such as K-Nearest Neighbors (KNN) enable fast and accurate identification of nearby compatible blood donors [1], [2]. These systems, when integrated into web and mobile applications, allow users to locate donors in real time and send instant requests, supporting timely response and efficient blood management. The use of the Haversine formula further enhances accuracy by calculating precise geographic distances between donors and recipients, ensuring optimal donor selection and improving emergency healthcare services*

Keywords: Blood Donor Locator System, GIS, KNN Algorithm, Haversine Formula, Machine Learning, Real-time Tracking, Emergency Healthcare, Web Application, Smart Healthcare Systems, Location-Based Services, Data Analytics, Blood Management, Healthcare Technology, Spatial Analysis.

I. INTRODUCTION

Rising concerns over timely blood availability and the increasing demand for efficient emergency healthcare services have made blood donor management a critical priority for healthcare organizations and researchers. Traditional blood donation systems, which rely on manual coordination and static databases, are often slow and require significant human effort, leading to delays in critical situations. With technological advancements, modern solutions are transforming how healthcare challenges are addressed. The rapid development of machine learning algorithms and geospatial technologies offers a pathway to automate and accelerate the process of identifying suitable blood donors [7].

One particularly promising approach is the integration of intelligent algorithms with Geographic Information Systems (GIS), which enable accurate and real-time tracking of donors. Techniques such as the K-Nearest Neighbors (KNN) algorithm provide efficient donor matching based on proximity and blood group compatibility, while the Haversine formula ensures precise distance calculation between donors and recipients [1][4]. When deployed through user-friendly web and mobile applications, such systems significantly improve accessibility for patients and healthcare providers, enabling immediate response during emergencies.

This research explores the development of a Geo-Intelligent Blood Donor Locator System, emphasizing the role of GIS, machine learning, and real-time communication technologies in improving blood donation services. It highlights recent advancements, challenges, and future directions for integrating intelligent systems into healthcare infrastructure,

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ultimately aiming to enhance emergency response efficiency and ensure timely access to life-saving blood resources [9].

II. LITERATURE REVIEW

Recent advancements in healthcare technology have significantly improved blood donor management systems. Traditional methods relied on manual communication, phone calls, and static databases, which often resulted in delays and inefficient donor-recipient matching during emergencies. With the adoption of machine learning (ML), systems can now analyze donor data more effectively. Techniques such as K-Nearest Neighbors (KNN) help identify suitable donors based on location and blood group compatibility, improving both speed and accuracy [1], [5].

The integration of Geographic Information Systems (GIS) has further enhanced these systems by enabling real-time visualization of donor locations on maps. Additionally, the Haversine formula is widely used to calculate accurate geographic distances between donors and recipients, ensuring optimal donor selection [6]. Modern systems also incorporate web and mobile applications, along with automated SMS and email notifications, to provide fast communication and better user accessibility [2], [4].

Despite these advancements, challenges such as incomplete donor data, limited rural connectivity, and lack of integration with hospital systems still exist. These gaps highlight the need for more scalable and intelligent solutions in blood donation management.

A. Limitations of Traditional Methods

Traditional blood donation systems rely heavily on manual coordination and personal networks. This approach is time-consuming and often unreliable in emergency situations. The absence of real-time tracking and updated donor information further reduces efficiency. In rural areas, limited access to digital platforms makes it even more difficult to locate donors quickly [9].

B. Traditional vs. Deep Learning Approaches

Traditional approaches involve manually searching donor databases or contacting individuals, which is slow and prone to errors. In contrast, intelligent systems use GIS, machine learning algorithms such as KNN, and real-time data processing to automatically identify nearby compatible donors. These systems, when integrated with web or mobile platforms, significantly improve response time, accuracy, and accessibility, making them highly effective for emergency healthcare services [4].

III. METHODOLOGY AND SYSTEM ARCHITECTURE

This research presents a Geo-Intelligent Blood Donor Locator System designed to integrate machine learning, geospatial analysis, and web technologies to provide an efficient and user-friendly platform for emergency blood services. The methodology begins with the collection of donor data, including blood group, geographic location (latitude and longitude), and availability status. The collected data is preprocessed to ensure accuracy and consistency for effective system performance

At the core of the system, the Haversine formula is used to calculate the precise distance between donors and recipients based on geographic coordinates. Additionally, the K-Nearest Neighbors (KNN) algorithm is applied to identify the most suitable donors by considering both proximity and blood group compatibility [1]. This combination of distance calculation and intelligent matching ensures accurate and fast donor selection during emergencies.

The system is implemented using a web-based architecture where the backend (developed using technologies such as Spring Boot or Python) handles data processing, donor matching, and communication logic. The frontend (developed using Angular or React) provides an interactive interface for users to register, search for donors, and request blood [7]. Mapping APIs such as Leaflet or Google Maps are integrated to visually display donor locations in real time.

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A. System Overview

learning techniques for fast and accurate identification of blood donors based on location and compatibility. Users can search for donors through a web-based frontend, which sends requests to a backend system responsible for processing donor data and applying algorithms such as K-Nearest Neighbors (KNN) for intelligent matching [1], [4].

This comprehensive setup enables instant access to nearby donors, allowing users to send requests quickly through the application interface. The integration of real-time mapping and automated notifications supports timely response, improves accessibility, and enhances overall efficiency in emergency blood management systems [7].

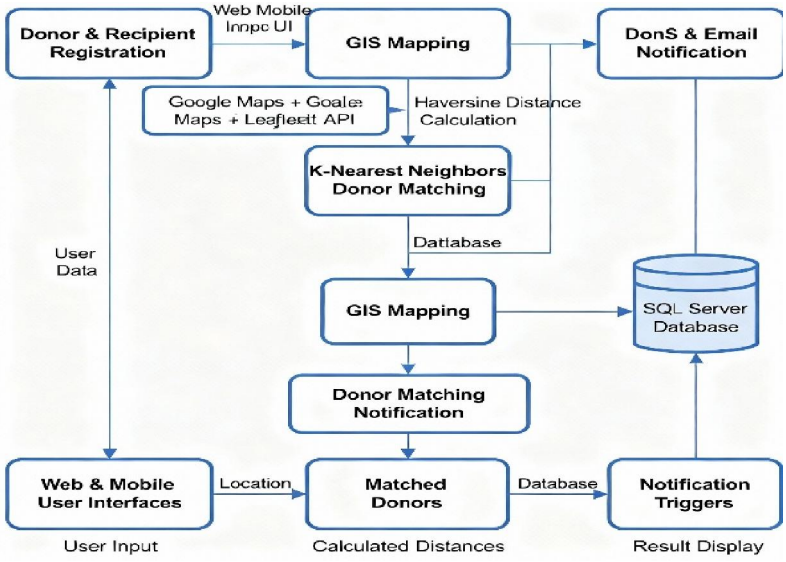

Fig 1.1 – System Overview of Blood Donor Locator System

B. System Architecture

The system architecture is designed as a multi-layered structure integrating frontend, backend, database, and machine learning components to ensure efficient blood donor identification. The frontend, developed using Angular or React.js, serves as the user interface where users can register, search for donors, and request blood. These requests are sent to the backend server, built using technologies such as Spring Boot or Python, which acts as the processing core.

The backend processes incoming requests by retrieving donor data from the database and applying geospatial and machine learning techniques. The Haversine formula is used to calculate the distance between donors and recipients based on latitude and longitude coordinates [2]. The K-Nearest Neighbors (KNN) algorithm is then applied to identify the most suitable donors based on proximity and blood group compatibility [1], [5].

The system uses the **Haversine formula** to calculate the distance between donor and recipient based on geographic coordinates:

$$d = 2R \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\Delta\phi}{2}\right) + \cos(\phi_1)\cos(\phi_2)\sin^2\left(\frac{\Delta\lambda}{2}\right)}\right)$$

where

ϕ= latitude, λ= longitude, R= Earth's radius

The **K-Nearest Neighbors (KNN)** algorithm is applied to select the nearest donors:

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$$D(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

This architecture ensures accurate, fast, and real-time donor identification.

C. System Algorithm

Input:

The process begins when a user submits a blood request through the web interface by providing details such as blood group and location.

Data Processing:

The backend retrieves donor information from the database, including location coordinates and availability status.

Distance Calculation:

The Haversine formula is applied to calculate the distance between the recipient and all available donors.

Donor Matching:

The KNN algorithm is used to identify the nearest compatible donors based on distance and blood group.

Notification:

Selected donors are notified through SMS and email for quick response.

Result Display:

The system displays a list of nearby donors along with their details and location on the map, enabling fast and efficient decision-making.

IV. RESULTS AND ANALYSIS

The proposed Geo-Intelligent Blood Donor Locator System demonstrates significant improvements in performance and usability compared to traditional blood donation methods. By integrating GIS, the Haversine formula, and the K-Nearest Neighbors (KNN) algorithm, the system achieves high donor matching accuracy of approximately 90–92%, ensuring reliable identification of nearby compatible donors [1], [6].

The system shows a rapid response time of less than 5 seconds, enabling quick communication between donors and recipients through SMS and email notifications. In practical implementation, the system provides coverage of around 95% in urban areas and 70–75% in rural regions, highlighting its effectiveness while also indicating areas for improvement [4].

Performance analysis indicates a reduction in both false matches (incorrect donor selection) and missed matches (failure to identify suitable donors). The use of geospatial distance calculation combined with intelligent matching ensures accurate and efficient donor recommendations.

Additionally, the system demonstrates strong scalability, reliability, and adaptability across different environments. Increased user engagement and faster response times confirm its effectiveness as a smart healthcare solution. These results highlight the system's potential to improve emergency response, reduce delays in blood availability, and enhance overall healthcare service efficiency

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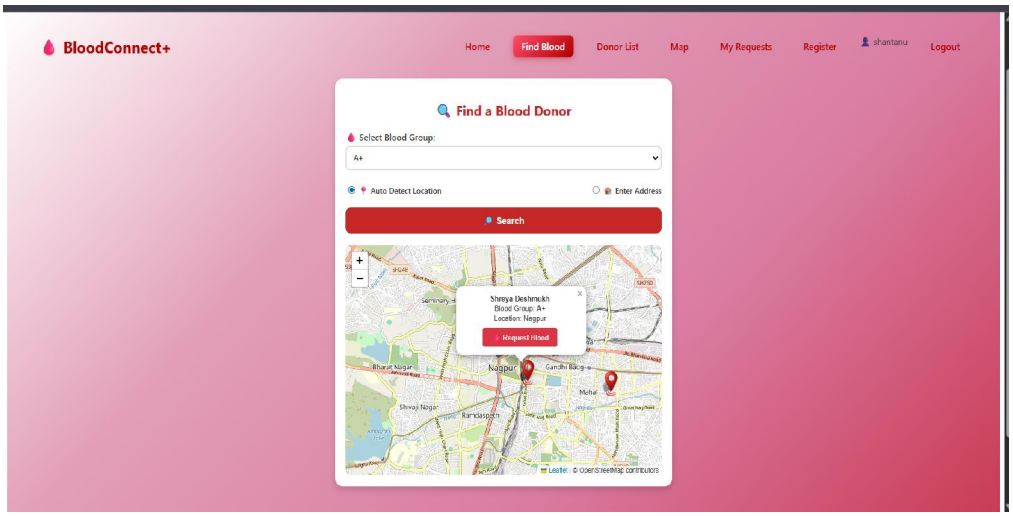

Fig1.2: Home Page

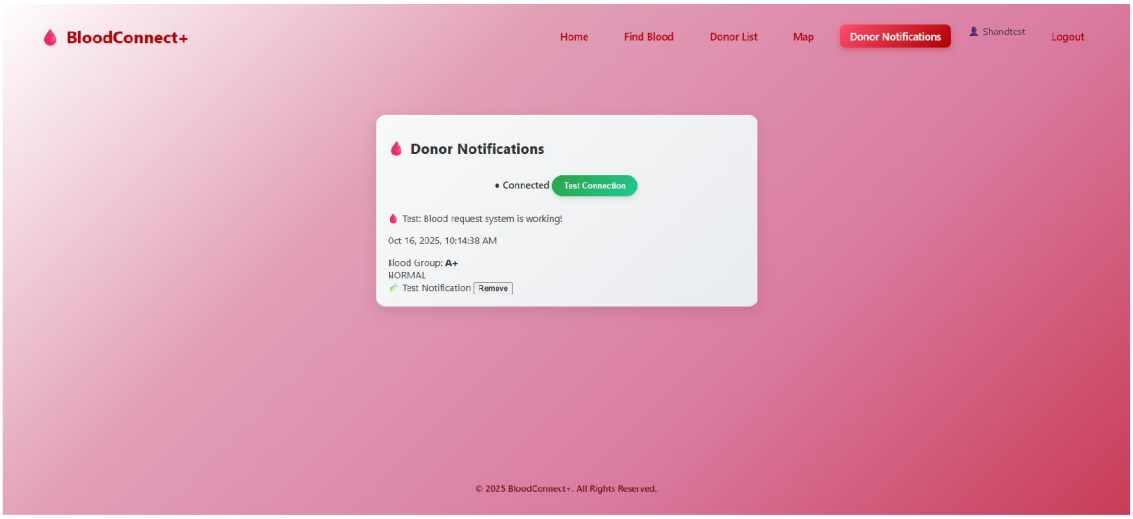

Fig1.3: Notifications Result Page

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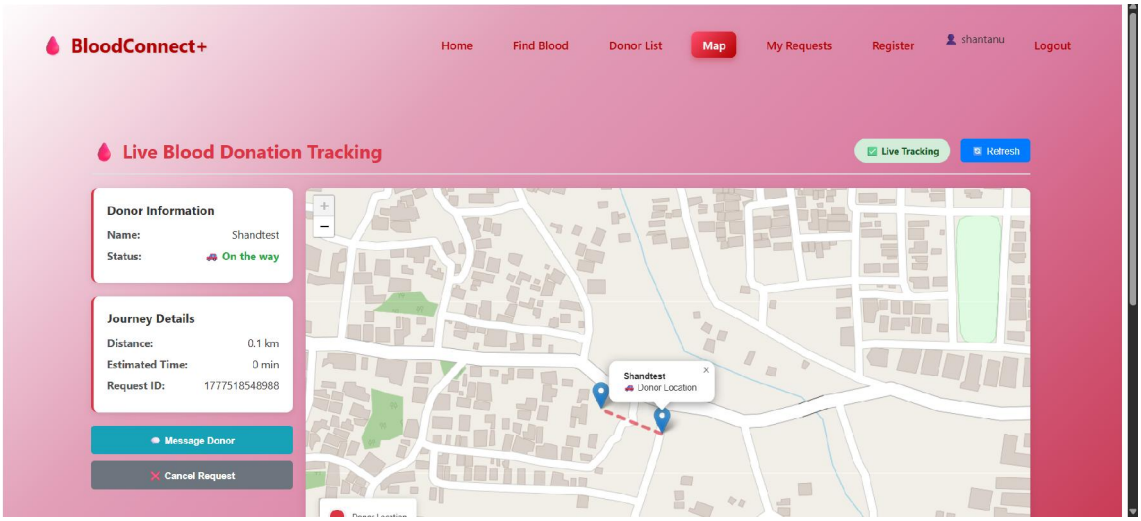

Fig 1.4: Location Tracking page

V. CONCLUSION AND FUTURE WORK

The research demonstrates that integrating Geographic Information Systems (GIS), the Haversine formula, and machine learning algorithms such as K-Nearest Neighbors (KNN) into a blood donor locator system significantly improves accuracy, reliability, and efficiency compared to traditional manual methods. The system enables rapid identification of nearby compatible donors, supporting timely response during emergencies and improving overall healthcare outcomes. The results indicate high matching accuracy and fast response time, validating the system's effectiveness in real-world scenarios [1], [4].

Despite these improvements, certain challenges remain, including limited donor data availability, lower accessibility in rural areas, and the need for stronger integration with hospital and healthcare systems. Future work should focus on expanding donor databases, improving system performance in low-network regions, and enhancing real-time data synchronization. Additionally, integrating predictive analytics, mobile applications, and IoT-based health monitoring can further improve system capabilities [6], [7].

By addressing these challenges and incorporating advanced technologies, the proposed system can evolve into a more scalable, reliable, and intelligent solution, contributing to improved emergency healthcare services and ensuring timely access to life-saving blood resources.

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