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Blood donation management system using K-Nearest Neighbor

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Abstract

Blood donation management plays a critical role in ensuring a constant supply of safe and compatible blood for transfusion purposes. This research paper proposes a Blood Donation Management System that employs the K-Nearest Neighbor (KNN) algorithm to optimize the process of matching blood donors with recipients. The system aims to enhance the efficiency, accuracy, and accessibility of blood donation operations, ultimately saving more lives. The research includes an implementation of the system, and a comparison with alternative algorithms.

Keywords: Blood Donation, Management System, K-Nearest Neighbor, Donor-Recipient Matching, Transfusion.

1. Introduction

Blood transfusion is a life-saving medical procedure that involves the transfer of blood or blood components from a donor to a recipient. It is commonly used to treat various medical conditions such as severe injuries, surgeries, anaemia, and certain diseases. However, ensuring a consistent and adequate supply of compatible blood is a complex task that requires efficient blood donation management systems (Kindful, 2022).

The need for blood is a significant aspect of modern medicine and healthcare. Every second of every day, someone will require blood transfusions in order to survive. Unsafe blood transfusions have caused the Human Immune Virus (HIV) to infect over 4 million individuals. Nigeria failed the WHO's recommendation of (+1.5 million pints/annum) in 2017 and at least 34% of pregnant women die during childbirth from bleeding difficulties and a shortage of blood for transfusions (Obinna, 2017).

Data from Nigerian National Blood Transfusion Service (2021) revealed that since 2017, Nigeria's voluntary unpaid blood donor population has been steadily declining. Unpaid blood donations totaled 42,384 in 2017, 20,420 in 2018, 24,527 in 2019, 22,218 in 2020, and 20,839 in 2021. The number of voluntary blood donations declined to 20,420 in 2018 and rebounded slightly in 2019. Only 500,000 pints of blood are given, tested, and collected nationwide each year (Nigerian National Blood Transfusion Service, 2021). Despite all the research that has been done on BDMS, there still lies a gap in the area of efficiently and effectively matching donors to requesters.

Traditional blood donation management processes often rely on manual record-keeping, phone calls, and paper-based documentation, leading to inefficiencies, delays, and potential errors. Inadequate management of blood donations can result in critical shortages, wastage of resources, and challenges in matching donors with recipients in a timely manner. These challenges become more pronounced in emergency situations or when dealing with rare blood types.

To address these challenges, the use of advanced technologies, such as machine learning algorithms, can significantly enhance the efficiency and effectiveness of blood donation management. This research paper focuses on the utilization of the K-Nearest Neighbor (KNN) algorithm in developing a robust Blood Donation Management System.

The KNN algorithm is a supervised machine learning technique that can be used for classification and regression tasks. It works on the principle of proximity, where it finds the K nearest neighbors to a given data point based on certain features or attributes. In the context of blood donation management, the KNN algorithm can be applied to match donors with recipients by considering their blood types, proximity, and availability.

The proposed Blood Donation Management System aims to automate and streamline the entire blood donation process. It includes features such as donor registration, recipient registration, database management, and donor-recipient matching using the KNN algorithm. By leveraging machine learning capabilities, the system can efficiently identify potential blood donors for a given recipient based on relevant factors, reducing response times and ensuring the timely availability of compatible blood units.

The successful implementation of an optimized Blood Donation Management System offers several benefits. It improves the accuracy and speed of donor-recipient matching, thereby reducing the risk of mismatched blood transfusions and improving patient outcomes. Moreover, it enhances the accessibility of blood donation operations by allowing donors and recipients to register digitally, facilitating a wider reach and more efficient communication.

Overall, this research paper aims to demonstrate the effectiveness and potential of using the KNN algorithm in blood donation management systems. By leveraging the power of machine learning, the proposed system can revolutionize the way blood donations are managed, ensuring a constant supply of safe and compatible blood units, and ultimately saving more lives.

2. Literature review

Several studies have been conducted to explore and improve blood donation management systems, focusing on donor-recipient matching and overall efficiency. This section provides an overview of the related work and highlights the limitations of traditional methods, along with the potential benefits of employing machine learning algorithms, including the K-Nearest Neighbor (KNN) algorithm.

Traditional blood donation management systems have relied on manual processes, including paper-based records and manual matching of donors and recipients. These approaches are time-consuming, prone to errors, and lack scalability. Additionally, they often struggle with efficiently matching donors with recipients, especially when considering factors such as blood type compatibility and proximity.

Analysis of the existing systems

The functionalities to be analysed have been abbreviated as follows:

- Funct 1 - User Registration and Authentication
- Funct 2 - Donor Information Management
- Funct 3 - Blood Donation Scheduling
- Funct 4 - Blood Inventory Management
- Funct 5 - Donor-Recipient Matching

Table 1

Analysis of the existing systems

ID	AUTHOR(S)	YEAR	1	2	3	4	5	WEAKNESS
1	Kumar & Tyagi	2021	✓	✗	✓	✗	✗	The risk of inaccurate information or outdated availability of blood can cause delays or complications in urgent care situations.
2	Umar & Ismaila	2019	✓	✗	✓	✗	✗	The study suggests the use of compensated donors, which may raise ethical concerns and lacks information on data confidentiality and security.
3	Hisham et al	2016	✓	✓	✓	✓	✗	Hospitals act as intermediaries between donors and recipients, potentially slowing down the process of finding a suitable match.
4	Casabuena et al	2018	✓	✓	✓	✗	✗	The assumption of sufficient blood supply and lack of efficient matching features may result in inefficiencies in the blood donation process.
5	Domingos et al	2016	✓	✓	✓	✓	✗	The system focuses on incentivizing donors through "gamification" and social rewards rather than addressing effective donor-recipient matching.
6	Ali et al	2017	✓	✓	✓	✓	✗	The system does not effectively address the issue of matching donors to recipients based on blood type, resulting in inefficiencies.
7	Fawaz Alharbi	2020	✓	✓	✓	✓	✗	Technological adoption and resource availability in the region may limit the effectiveness of the system.
8	Maji et al	2018	✓	✗	✗	✗	✗	Philanthropy Score and Philanthropy League incentivize blood donation but may not be effective in motivating donors in the long term. Challenges in recording and updating data may impact the accuracy of analytical results from the data warehouse.
9	Diana et al	2021	✓	✓	✗	✓	✗	Adoption of private Ethereum blockchain is challenging due to its complexity and high cost, which may limit system adoption.
10	Mittal & Snotra	2017	✓	✗	✗	✗	✗	Insufficient information on proposed improvements and potential security and privacy concerns not addressed during the transition to a portable architecture.
11	Manvir et al	2022	✓	✓	✗	✗	✗	HIPAA paradigm may not be sufficient for protecting donor privacy and simplicity of interface may lack advanced

								features for effective donor-recipient matching.
12	Wijayathilaka et al	2020	✓	✓	✓	✓	✗	Linear regression model used for predicting blood demand may not account for complex factors that impact demand.
13	Hegedüs et al	2019	✓	✗	✗	✗	✗	System may not effectively address systemic issues like unequal access to healthcare and blood donation resources.
14	Das et al	2020	✓	✗	✓	✓	✗	System may not be reliable in areas with a shortage of donors or poor network connectivity, reducing its effectiveness in emergency situations.
15	Ghernaout et al	2020	✓	✗	✓	✗	✗	Lack of digitalized blood collection procedure limits informed decisions regarding optimal mobile centre location, resource management, and donor waiting times.
16	Izadeen et al	2021	✗	✓	✗	✗	✗	Basic authentication process leaves the system vulnerable to attacks from unauthorized users.
17	Elakya et al	2020	✗	✓	✓	✓	✗	Reliance on mobile technology may exclude members of the population without access to smartphones, and the authentication process may be vulnerable to attacks if the OTP is not sufficiently secure.

3. Methodology

Object-oriented analysis and design (OOAD) are an approach to software design that emphasizes the use of objects, classes, and other fundamental concepts of object-oriented programming. It is a process of analyzing and designing a software system based on object-oriented principles, which focus on breaking down a system into small, manageable parts, and defining how they interact with each other.

3.1.KNN

The KNN algorithm is a widely used machine learning algorithm for classification and regression tasks. The main idea behind KNN is to find the K-nearest neighbours of a given data point in the feature space, based on a distance metric, and assign a label to the data point based on the majority label of its K nearest neighbours.
When implementing the KNN algorithm for multiclass classification in the context of blood donation management, there are two key things to keep in mind. First, it is important to choose an appropriate distance metric that can capture the similarity between different blood types. Second, it is important to choose an appropriate value of K that can balance the bias-variance trade-off, where small values of K can lead to overfitting, and large values of K can lead to underfitting. The mathematical formula for the KNN algorithm is given as follows:

$$d_E(x^i, x^j) = (\sum_{k=1}^{p}(x_k^i - x_k^j)^2)^{\frac{1}{2}} \quad (1)$$

3.2. KNN Implementation

To implement the KNN algorithm for multiclass classification in the BDMS, several research tools and software were utilized. The programming language used for the implementation was PHP with MySQL for data storage and retrieval, and PHPMyAdmin for data manipulation and analysis.

To pre-process the dataset and prepare it for training the model, multiple feature extraction techniques were utilised, such as data cleaning and data normalization. Finally, a web-based interface developed using PHP, HTML, CSS, and JavaScript was used as the primary research tool for implementing and testing the KNN algorithm for multiclass classification. The use of a web-based interface allowed for access to the system from any device with a web browser, which facilitated the data exploration, model development, and testing processes.

Sample case

Table 2
Sample Dataset

ID	Blood Group	Age	Weight	RH Factor	Zip code
1	A+	28	70 kg	Positive	10001
2	B-	35	80 kg	Negative	10002
3	AB+	42	75 kg	Positive	10003
4	O-	25	60 kg	Negative	10004
5	AB-	31	68 kg	Negative	10005
1	A+	28	70 kg	Positive	10001
2	B-	35	80 kg	Negative	10002

. Here's how the KNN algorithm could be used to achieve this:

Vectorise the inputs. Vectorizing the inputs involves converting each input into a numerical value, such as assigning a numerical value to each blood group and using a binary representation for the RH factor.

Define the number of neighbours (K) to consider as the square root of the total number of rows in the dataset: So

$$K = \sqrt{5} \approx 2. \quad (2)$$

Calculate the distance between the new individual and each data point in the data set. In this case, we can use the Euclidean distance formula:

$$\text{Distance} = \sqrt{((a1-a2)^2+(b1-b2)^2+(x1-x2)^2+(y1-y2)^2+(z1-z2)^2)} \quad (3)$$

where,

a1, b1, x1, y1, z1 are the values of the parameters for the new individual, and a1, b1, x2, y2, z2 are the values of the parameters for each data point in the data set. We can calculate the distance for each data point in the data set and store it in a table:

Table 3
Sample: Dataset with Calculated Euclidean Distances

ID	BLOOD GROUP	AGE	WEIGHT	RH FACTOR	ZIP CODE	DISTANCE
1	A+	28	70 kg	Positive	10001	3.16
2	B-	35	80 kg	Negative	10002	11.22
3	AB+	42	75 kg	Positive	10003	13.08
4	O-	25	60 kg	Negative	10004	11.40
5	AB-	31	68 kg	Negative	10005	3.74

Select the K nearest neighbours: In this case, we have K = 3, so we select the three data points with the smallest distances to the new individual:

Table 4
Sample: Final Result for Sample Dataset

ID	BLOOD GROUP	AGE	WEIGHT	RH FACTOR		ZIP CODE	DISTANCE
1	A+	28	70 kg	Positive		10001	3.16
5	AB-	31	68 kg	Negative		10005	3.74

results and discussion of findings

Implementation is the process of utilizing a system's design document in realizing a system that meets the stated system requirements.

3.3. Technologies used

The technologies employed in building this system include HTML, CSS, JavaScript, PHP, XAMPP, and MySQL. The Integrated Development Environment (IDE) chosen for the development of this system was Visual Studio Code. Visual Studio Code is a free open-source IDE that enables developers build web, desktop and mobile applications. The IDE facilitates the creation of applications in a number of languages, such as Java, HTML5, PHP, and Python. From project creation through debugging, profiling, and deployment, the IDE offers integrated support for the whole development cycle.

XAMPP is short for Cross platform (X), Apache, MYSQL, PHP and PERL. It is a bundle of software used in developing applications locally. It contains Apache, a Linux server, that when installed it converts the developer's machine to a local server which can be used in development.

Structured query language (SQL) is a standardized programming language used to manage relational databases and perform various operations of data on them. As the name implies, it is the language used to query a database to manage data stored on it.

MySQL is a relational database management system that uses SQL to manage relational data stored in the database. All information regarding donors' information, donation information, etc. Will be stored on this database management system.

4. Implementation and results

System Implementation is the process of execution of a plan, method, design or specifications for doing a thing. It is the conversion of a system's conceptual and logical designs into functional actuality. In this case, it is the process of taking the elicited requirements to a state of fruition.

Figure 1

The Login Page.

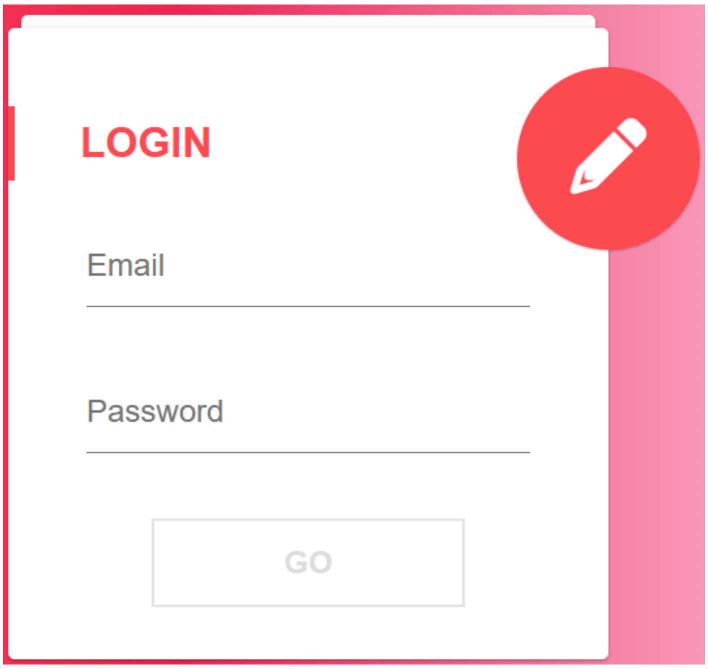


Figure 2

The User profile page

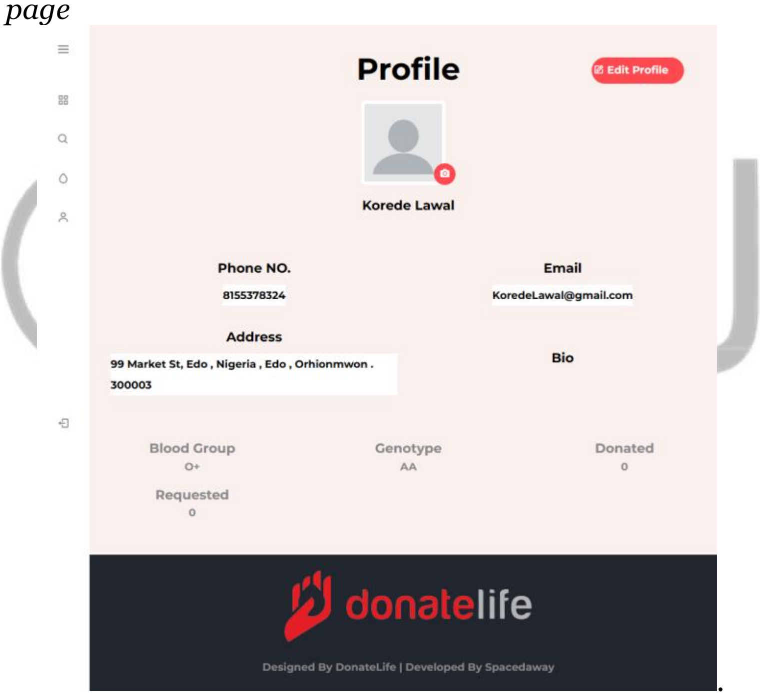


Figure 3

Find Donor using KNN

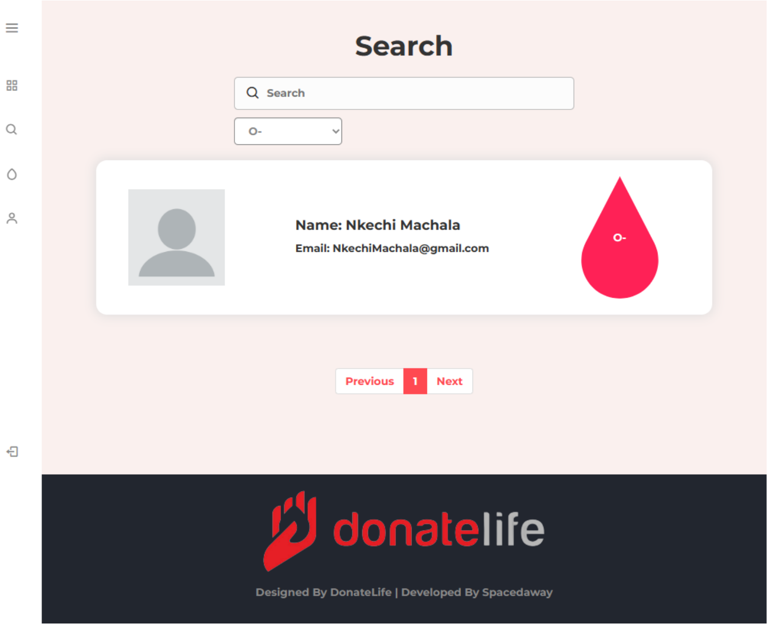
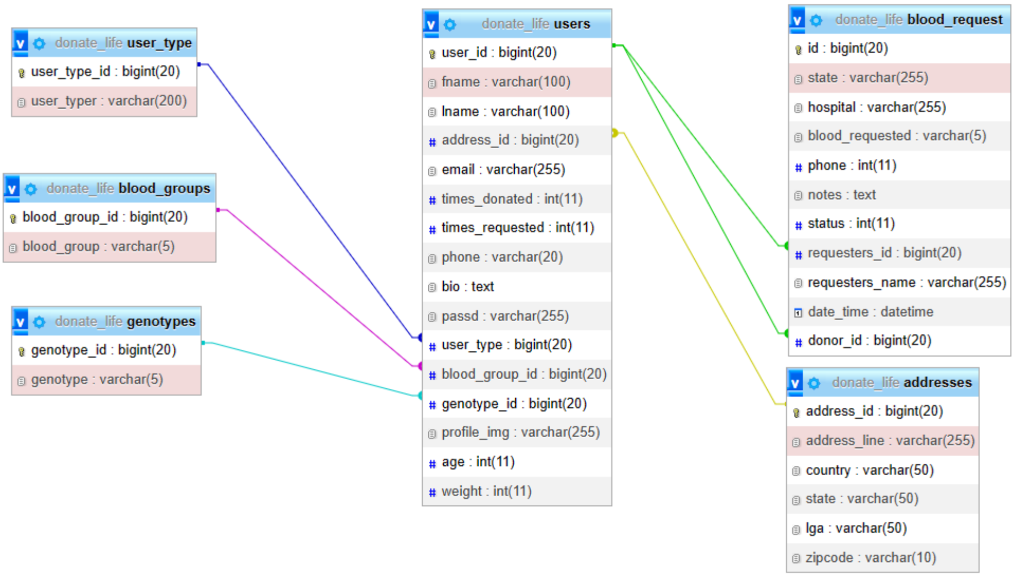


Figure 4
Database Schema



4.1. Discussion of findings

The results show that the KNN algorithm can be effectively applied to the system to match the appropriate donor for the required patient, taking into consideration location, blood type, and other relevant factors. To the best of our knowledge, there is no previous research that has directly applied the KNN algorithm in this manner. Therefore, this study provides novel insights into the potential applications of the KNN algorithm in the context of BDMS.

5.Conclusion

5.1. Summary of key findings

The study examined the application of the KNN algorithm in the BDMS and the design of a well-normalized schema for the system. The results showed that the KNN algorithm can be effectively applied to the system to match the appropriate donor for the required patient, while a well-designed schema can improve the overall efficiency and effectiveness of the system. The findings contribute to the literature by providing specific insights into the application of the KNN algorithm and the design of a schema for BDMS.

5.2. Contribution to literature and industry

The study makes a significant contribution to the literature on the application of machine learning algorithms to medical systems. The results provide valuable insights into the potential applications of the KNN algorithm in the context of BDMS and highlight the importance of a well-designed schema for the success of the system. The findings have significant implications for the industry, as they can inform the design and implementation of effective and efficient BDMS systems.

5.3. Recommendation

Based on the findings of this study, it is recommended that the application of the KNN algorithm and the design of a well-normalized schema should be considered in the development of BDMS systems. Healthcare organizations can also benefit from adopting machine learning algorithms in their operations to improve efficiency and effectiveness. Further research is needed to validate the effectiveness of these approaches in different contexts.

5.4. Limitation of study

The study has some limitations that need to be acknowledged. The research was conducted using a relatively small dataset, which may limit the generalizability of the findings. Additionally, the study focused on a specific context and may not be applicable to other medical systems. Future research should consider larger datasets and explore the effectiveness of these approaches in different contexts.

5.5. Future work for further studies

Future research should consider the application of other machine learning algorithms in the context of BDMS and explore the potential of integrating multiple algorithms for improved efficiency and effectiveness. Additionally, future studies should consider the ethical implications of using machine learning algorithms in medical systems and ensure that appropriate measures are taken to protect patient privacy and confidentiality.

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