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Development of LifeLink: A Smart Community Platform for Blood Donation, Organ Matching and Blood Expiry Alerts

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Abstract

Blood donation and organ transplantation require efficient coordination among the healthcare stakeholders. The existing systems involve the use of separate applications leading to delays in processing of requests for blood emergencies, inefficient donor-recipient pairing and ineffective blood stock monitoring. To address such problems, LifeLink, a web-based healthcare management system was designed to coordinate blood donor registration, organ compatibility-based matching, emergency blood requests coordination and blood expiration monitoring within a single integrated platform. This application was built through the use of Python Flask framework together with HTML, CSS, Bootstrap, Jinja2 and MySQL relational database which will facilitate the management of healthcare records, blood stock and coordination. The evaluation of this web-based application was done using operational healthcare records obtained from the participating hospitals, blood banks and verified volunteers to evaluate the ability to perform donor search, blood record search, organ compatibility check, emergency blood request coordination and blood expiration monitoring functions.

Keywords: Healthcare Resource Management, Compatibility-based Organ Matching, Blood Inventory Monitoring, Emergency Blood Request Coordination, Role-based Access Control (RBAC), Flask-based Healthcare Platform.

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1. Introduction

Emergency medical treatment depends mainly on the availability of compatible blood and organs. While developments in digital technology have helped improve the efficiency of various healthcare services, blood donations and organ distribution still remain regulated by separate information systems within many healthcare facilities. This results in slower donor recognition, limited usage of blood stocks, and increased wastage caused by their expiration. Furthermore, there is no integrated operating environment that could help coordinate the work of all parties involved.

To overcome these challenges, LifeLink becomes a community-oriented web application that combines all these functionalities including blood donation management, organ matching based on compatibility, emergency blood request coordination, and expiry tracking of the blood in one system. This system manages donor information, handles emergency blood requests, performs organ matching based on compatibility, and creates alerts when the blood approaches its expiry date.

The application works through a web-based structure including user authentication, MySQL database management, and automatic alerts creation. The functionalities include donor registration, blood inventory management, matching organs based on compatibility, emergency requests, and tracking of blood expiration. This system will help in reducing delays, minimizing wastage of blood, coordination between the donor and the recipient, and create a strong framework for management of healthcare resources in healthcare communities.

2. Related Works

The increasing need to quickly acquire access to blood transfusions and organ allocations has caused the quick adaptation of digital healthcare systems that increase the availability of resources and the preparation for emergencies. According to global health policies, there is an emphasis on the importance of maintaining an adequate stock of blood supply by organizing inventory and active donors [1]. National health policy states the same information about interoperable digital infrastructure [2].

The recent research on web-based healthcare applications, automation, and data analysis have proven to be beneficial in resource management in medicine [3]. The application of artificial intelligence has helped with organ compatibility and recipient prioritization in order

to increase the efficiency of transplant operations [4]. Machine learning has also been used to make predictions about health data and to process it for better decision-making [5]. However, despite all of these achievements, the main problem is that most of them solve one task but not the set of tasks mentioned above.

Some studies have focused on improving emergency blood donations during emergencies through automatic donor alerts and health records [6], [7]. This system helps in fast communications and makes it easier to access the data of donors in an emergency situation [8]. However, such type of approach generally works on the level of one service only without providing support for blood donation management and organ matching among others.

The current web-based blood bank management systems have improved by donor registration, blood inventory management, and digital record maintenance [9], [10]. Although these software applications provide an effective support for blood bank operations, they do not integrate organ matching, blood expiry monitoring, emergency blood request processing, and coordinated information sharing within a single operational environment.

3. Methodology

LifeLink application is developed as a community-based web application to support the blood donation management, compatibility-based organ matching, emergency blood request coordination, and blood expiry monitoring within a single operational environment. This application connects donors, recipients, hospitals, blood banks, and administrative staff in a shared web environment for coordinated access to healthcare services. The donor information, recipient information, blood stock database, organ requests, emergency blood requests, and blood expiration are managed within the MySQL database. User authentication, role-based access control (RBAC), and alerting are key components of secure access and information distribution.

3.1 System Architecture

The LifeLink architecture follows a layering of web-based workflow to ensure efficient handling of blood donations, organ matching, emergency blood requests and blood expiration tracking. The diagram shown in Figure 1 indicates that all users, including donors, recipients, hospitals, blood banks and administrators, access the software using a web portal and go through authentication process before performing any function.

After successful authentication process, users' requests are handled by the Flask application server that manages the running of the functional modules. The application server runs the donor management module, the blood stock management module, the organ compatibility test, or emergency blood requisition depending on the requested healthcare service. Each of the functional modules interacts with the MySQL database for accessing, modifying, and maintaining the operational records.

The MySQL database serves as the main source of donor information, recipients' details, hospitals' details, blood stock, organ requests, emergencies, and blood expiry dates. When any change occurs in records, the system sends notification. Such an arrangement helps in ensuring the process of information sharing among various participants becomes easy at the same time ensuring data consistency within the application.

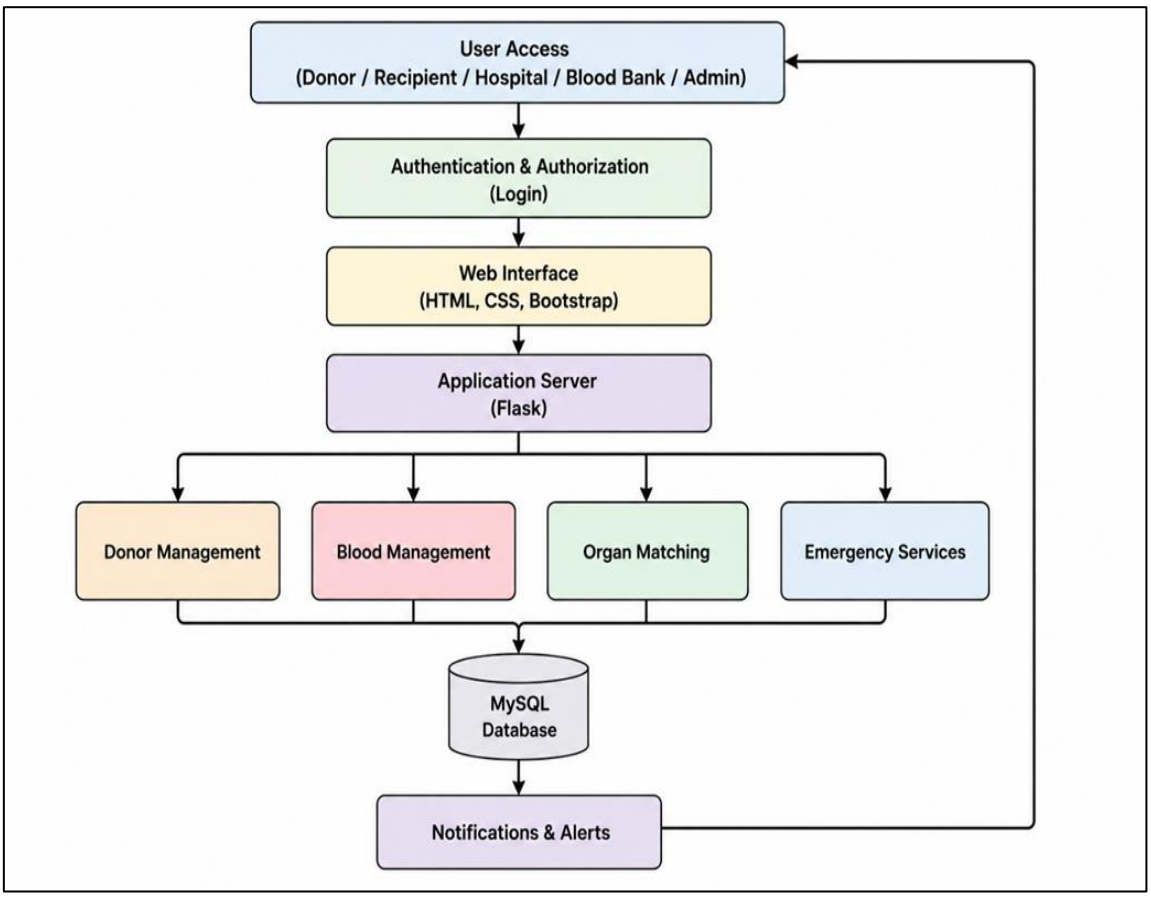

Figure 1. Multi-tier system architecture of the proposed LifeLink healthcare resource management platform

Figure 1 shows the workflow of the proposed LifeLink architecture, starting with user authentication, followed by request processing through the Flask application server, execution

of the core functional modules, data management using the MySQL database, and generation of operational notifications and alerts.

3.2 User Authentication, Registration, and Data Management

The LifeLink application provides a role-based registration and authentication system that controls access to the resources of the system. Registration of users is done based on roles such as donor, recipient, hospital, blood bank, and administrator depending on the function of each user. During registration, vital information such as personal details, blood type, contact details, and whether the person can donate organs or not is captured.

After registration, users log into the application through their unique usernames and passwords. The passwords are encrypted using hashing algorithms, whereas role-based access control (RBAC) grants access to the allowed functionalities based on the user's privileges. Such an approach allows donors to manage their own profiles, hospitals to send urgent requests for blood, blood banks to keep track of inventory, and administrators to monitor the operations of the users.

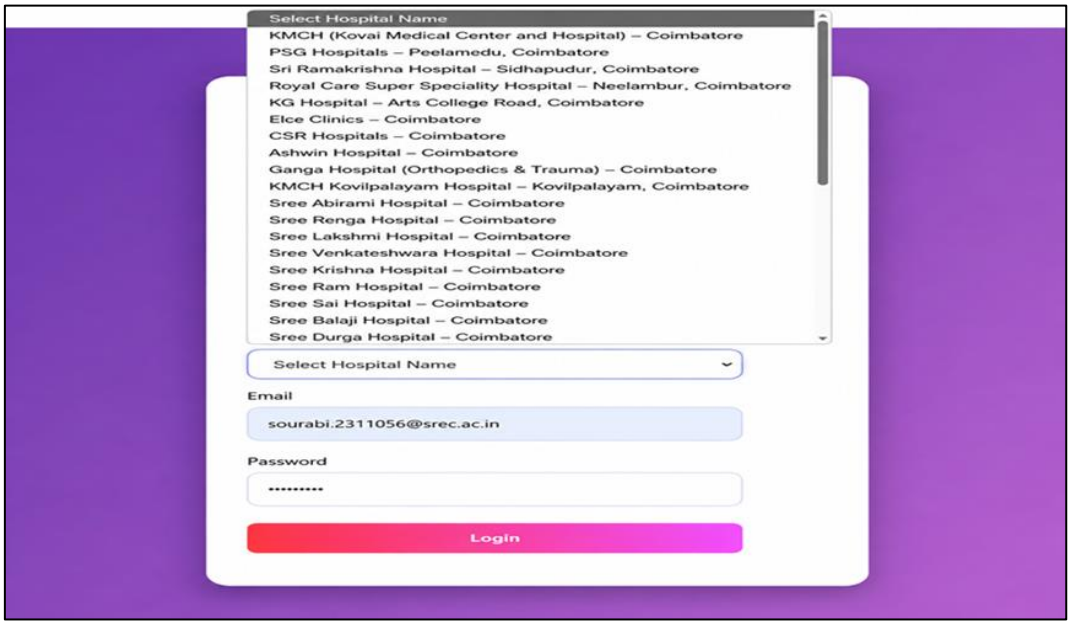

Figure 2. Role-based user authentication and registration interface of the LifeLink platform

All newly submitted records are checked by the administrator before being entered into the MySQL database. This enhances data integrity and ensures that no unapproved or partial data gets into the operational database. The interface for user authentication and registration on the LifeLink system is illustrated in Figure 2.

3.3 Healthcare Data Collection and Validation

To measure the operational efficiency of the LifeLink system, the healthcare data was manually collected from the hospitals, blood banks, and certified volunteers who had submitted the data. The data about donors was manually collected from the hospital registration form and blood donation form, while the data about blood stock, expiration date, request for organ transplant, and emergency blood request was collected from the healthcare workers who were authorized to supply such information. The certified volunteers were allowed to enter donor information via the web interface, which was then approved by the system administrator before entering into the database.

Table 1. Operational healthcare dataset used for LifeLink platform validation

Data Category	**Description**	**Number of Records**
Registered Blood Donors	Verified donor profiles collected from hospitals and volunteers	400
Participating Hospitals	Healthcare institutions connected to the platform	20
Blood Inventory Records	Blood units maintained for inventory monitoring	1,000
Organ Matching Requests	Recipient requests requiring compatibility assessment	75
Emergency Blood Requests	Emergency requests submitted through the platform	120
Blood Expiry Monitoring Records	Blood units monitored for expiry notifications	500

The validated healthcare records were stored in the MySQL relational database to support efficient data organization, retrieval, and update operations throughout the proposed LifeLink platform. The database consists of multiple relational tables, including donor profiles, recipient information, hospital details, blood inventory records, organ matching requests, emergency blood requests, and blood expiry records.

The validated healthcare records were entered into the MySQL relational database to ensure that data is organized, retrieved, and updated efficiently within the LifeLink system. This MySQL relational database has several relational tables like donor table, recipient table, hospitals table, blood stock table, organ match request table, blood emergencies table, and blood expiry record.

3.4 Operational Feature Analysis

The developed LifeLink system includes several critical operational components that will be useful when organizing the donation of blood, matching organs, handling emergencies, and tracking blood expiration. All these operational components are based on accurate information about donors, recipients, hospitals, and blood supplies collected through the process of registration and functioning of the healthcare facilities. Every operational component performs its specific function in the process of compatibility evaluation, resource allocation, inventory control, or automatic notification creation. The importance of these operational components in the proposed system is summarized in Table 2.

Table 2. Operational feature analysis of the proposed LifeLink platform

Operational Feature	Description
Blood Group	Determines donor–recipient blood compatibility.
Rh Factor	Ensures compatible blood transfusion and organ allocation.
Organ Type	Identifies suitable donors for transplantation.
Medical Eligibility	Confirms donor suitability based on health status.
Donor Availability	Verifies whether a registered donor is currently eligible to donate.
Hospital Location	Selects the nearest healthcare facility for timely coordination.
Blood Inventory Level	Monitors available blood units for emergency requests.
Blood Expiry Date	Identifies blood units approaching expiration for timely utilization.
Emergency Priority	Prioritizes urgent blood and organ requests.
Contact Information	Enables automated notifications to donors and hospitals.

3.5 Integrated Blood Donation Framework

The integrated blood donation framework enhances the process of blood donation by integrating donor registration, blood inventory management, emergency request handling, and compatibility assessment into a unified workflow. When a request comes for an emergency blood donation, the framework checks the blood group, Rh type, and amount of blood required by the recipient and performs a search within the database for availability of that blood. In cases where such blood is not available, the donor database is searched in order to identify the appropriate donors depending on compatibility, suitability, and location. Notifications are generated to the selected donors and the respective healthcare facilities that requested blood.

After a successful blood donation and or issue of the blood, the donor and inventory records are updated in the MySQL database.

The donor registration interface used to capture donor profiles, medical eligibility, contact information, and hospital details is shown in Figure 3.

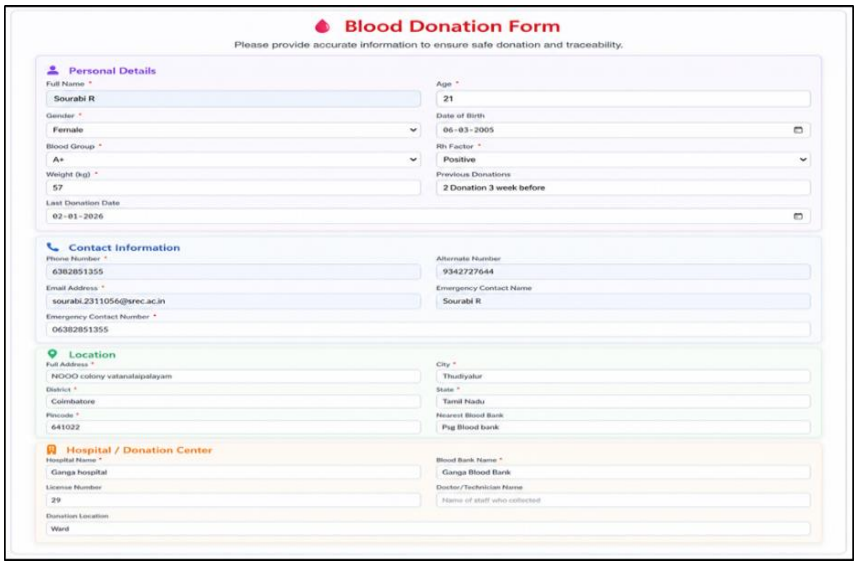

Figure 3. Blood donor registration and information management interface

3.6 Emergency Blood Request Coordination

The emergency blood request coordination module allows hospitals and healthcare facilities to make their urgent blood requests using the LifeLink system. When an emergency request is received, the system verifies the blood group, Rh factor, required blood units, and hospital information, and then it searches its inventory for matching units of blood. In case of the absence of requested blood the system searches the donor database for potential donors considering their blood compatibility, availability of blood, eligibility to donate blood, and their geographical location. Notifications are generated to the chosen donors and healthcare facility requesting blood, whereas the request status is constantly updated in the MySQL database. The interface developed for the emergency blood request coordination process is shown in Figure 4.

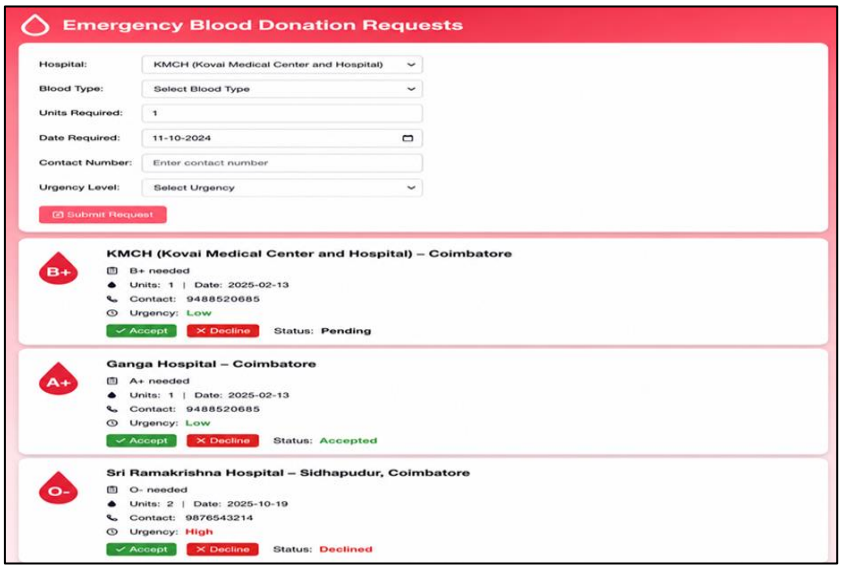

Figure 4. Emergency blood request coordination dashboard

3.7 Organ Matching Framework

The proposed Organ Matching Framework performs compatibility assessment between a donor and a recipient using the integration of medical and logistical variables within the community healthcare application. When the organ transplantation request is received, the system uses information on the recipient such as blood type, Rh factor, organ needed, age, and eligibility for organ donation to compare the information in the donor database.

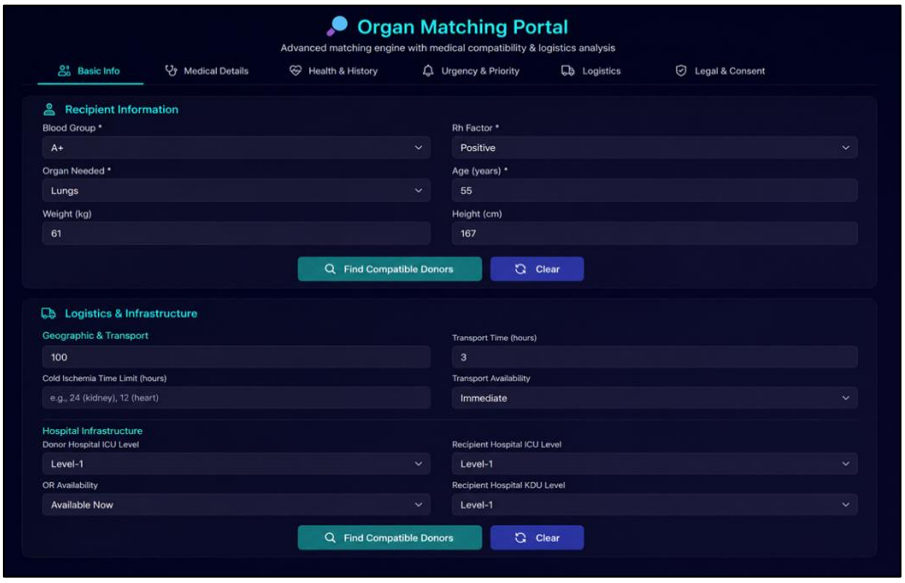

Figure 5. Organ compatibility assessment and logistics-based matching interface

The organ matching interface illustrating recipient details, compatibility assessment, and logistics-based donor prioritization is shown in Figure 5. The compatible donors are

prioritized according to the distance, availability of hospitals, availability of organs, and the allowable cold ischemia time to facilitate timely organ transplantations. Compatible donor information is shared with the authorized hospitals and transplant coordinators, and the donor database in MySQL is updated.

3.8 Blood Expiry Monitoring and Alert Framework

The Blood Expiry Monitoring and Alerts System periodically examines blood inventory records to detect any expiry of the blood samples. The system regularly analyzes the shelf life of each blood sample and categorizes the inventories based on the expiry threshold that was predetermined. Automatic alerts and notifications are sent to blood banks and hospitals whenever the system detects any expiry of blood samples in order to ensure their optimal use, distribution, or replacement (Figure 6). After blood units are issued or inventory records are updated to the inventories, the MySQL database is updated in order to update the inventory details. This ensures optimal management of blood inventories within the participating organizations.

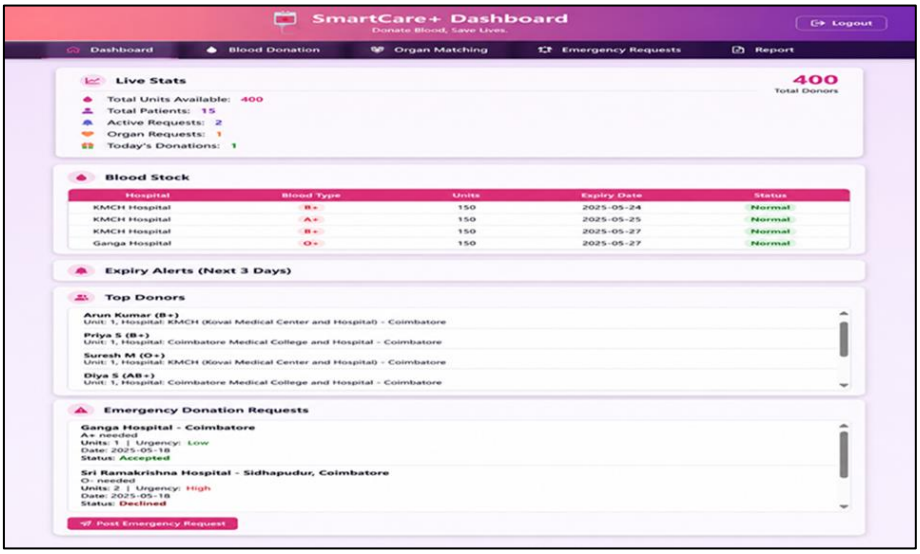

Figure 6. Automated blood expiry alert monitoring interface

4. Results and Discussion

4.1 System Implementation Environment

The LifeLink application was implemented and tested for functionality through a software application that was set up to handle healthcare data, coordinate emergency requests for blood, match organs, and monitor blood expiration. In implementing the LifeLink platform,

the back end was developed using Python language and the Flask framework, while HTML, CSS, Bootstrap, and Jinja2 were used to create the user interface. Donor, recipient, hospital, and blood stock data were stored in a relational database. Specifications of the software and hardware used in the implementation are shown in Table 3.

Table 3. System implementation environment

Parameter	Specification
Processor	Intel Core i7 (12th Gen)
Memory (RAM)	16 GB
Storage	512 GB SSD
Operating System	Windows 11 (64-bit)
Programming Language	Python 3.11
Backend Framework	Flask
Frontend Technologies	HTML5, CSS3, Bootstrap 5, Jinja2
Database	MySQL
IDE	Visual Studio Code
Web Browser	Google Chrome
Version Control	Git

4.2 Quantitative Performance Evaluation

The operational performance of the proposed LifeLink platform was evaluated to assess the efficiency of its core functional modules under the implementation environment explained in table 3. The purpose of the evaluation, operational data were used based on the system implementation process. All the functionalities like search for donors, arranging blood emergencies, retrieving blood records, matching the organs and blood expiry alerting functionalities were tested by running them repeatedly in the same conditions.

For measuring the execution time, Python timer functions were used, whereas for blood expiry alert functionality, manual verification was compared with system-generated alerts. To ensure the uniform performance evaluation, of each functional module was repeated multiple times under the same operating conditions, and then the average execution time was determined by utilizing Python's internal timing tools before being presented in Table 4.

Table 4. Quantitative performance evaluation of the proposed LifeLink platform

Performance Metric	Result
Donor Search Time	1.8 s
Emergency Alert Delivery Time	4.2 s
Blood Record Retrieval Time	1.3 s
Organ Match Processing Time	2.5 s

4.3 Discussion

The implementation results indicate that the LifeLink application has been successful in integrating blood donation management, organ matching, emergency blood request processing, and blood expiration checking within the same web platform. Bringing these features together into one application has reduced the complexity of information exchange between different parties such as hospitals, blood banks, donors, and administrators because there is no need for using multiple applications. The MySQL database ensured smooth functioning of the application during the evaluation by allowing access and modification of the required information without interfering with the functioning of other components.

From the performance analysis results, it is evident that the application provides consistent performance when conducting normal processes like searching donors, retrieving blood records, handling emergencies, and assessing the compatibility of organs. Without engaging in manual coordination, the integrated system allows automated verification of records, updating inventory records, and request handling, thus minimizing administrative workload and ensuring availability of operational data.

Although the application performed satisfactorily during functional validation, several practical considerations remain for large-scale deployment. The existing version of the application was tested based on operational data gathered from hospitals, blood banks, and confirmed volunteers in a controlled environment. Full-scale operation requires additional database tuning and deployment techniques because of the need for constant synchronization with the hospital information system, growing transactions, and multithreaded access to the database. Hence, further improvement of the software should include incorporation of the real-time hospital data, database scaling, and wider application deployment.

5. Conclusion and Future Work

This research work has proposed LifeLink, a web-based software application that combines blood donation management, organ matching based on compatibility, emergency blood request coordination, and blood expiry monitoring within a unified operational environment. The developed application addressed the limitations of isolated healthcare applications by implementing unified management of donor records, blood inventory, organ requests, and emergency services through a MySQL database. The testing validation using operational healthcare records confirmed the successful implementation of the core modules, while quantitative evaluation verified consistent performance during donor search, blood record retrieval, organ compatibility assessment, emergency blood request processing, and blood expiry monitoring. The developed system improves resource coordination, simplifies information management, reduces manual administrative effort, and supports timely access to compatible blood and organ resources within community healthcare services. Although the current implementation demonstrated satisfactory performance, its further development is going to concentrate on integration with hospital information systems and national healthcare databases to provide automation of the data synchronization process. Future enhancements include cloud-based deployment, scalable database management, predictive blood demand analysis, and intelligent decision-support capabilities to support large-scale healthcare environment.

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