International Journal on Science and Technology (IJSAT)

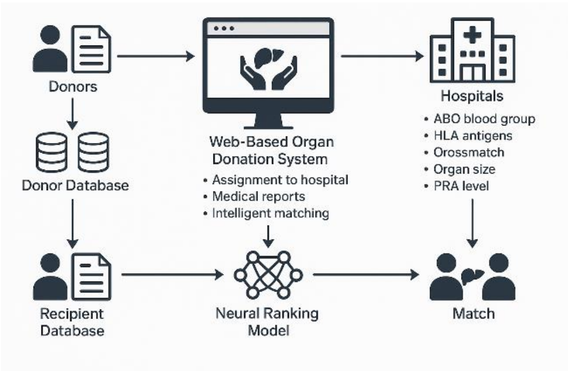
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Streamlining Organ Transplantation

Dr. Hirdesh Sharma[1], Aditya Jangid[2], Deepanshi[3], Khushi Tikko[4]

Dronacharya Group of Institution Great Noida, Uttar Pradesh
hirdesharma@gmail.com
Dronacharya Group of Institution, Great Noida, Uttar Pradesh
[1]deepanshit751@gmail.com, [2]khushitikoo.work@gmail.com, [3]jangiraditya611@gmail.com

Abstract



Graphical abstract1: A visual flowchart of a web-based organ donation system using neural ranking for smart donor-recipient matching This project introduces a web-based organ donation system aimed at enhancing the efficiency and accuracy of matching organ donors with recipients. The platform collects personal and medical information from both donors and receivers, then assigns them to the nearest affiliated hospital. Hospitals provide detailed medical reports, including critical compatibility factors such as ABO blood group, HLA-A, HLA-B, HLA-DR antigens, cross match results, organ size, recipient weight and height, donor-receiver age, medical history, and Panel Reactive Antibody (PRA) levels. The system stores this information in two separate databases for donors and recipients. A Neural Ranking model is employed to process these parameters and perform intelligent matching, ranking potential donor-recipient pairs based on compatibility and the likelihood of transplant success. This approach aims to streamline the transplant process, reduce waiting time, and improve clinical outcomes. The platform offers a user-friendly interface to support accessibility, transparency, and awareness in organ donation.

Index Terms— Organ Donation, Neural Ranking Model, Donor-Recipient Matching, Medical Compatibility, AI in Healthcare.

1. Introduction

Organ donation is a life-saving medical procedure that involves transplanting organs from a donor to a recipient suffering from organ failure. “Despite technological and medical advancements, many patients lose their lives due to the unavailability of suitable donors or delayed matching. Traditional methods are often time-consuming, paper-based, and lack efficient matching mechanisms” [1]. This project proposes an intelligent, web-based solution that digitizes the entire process—from registration and hospital assignment to organ compatibility analysis and matching—making it faster, more accurate, and accessible. The platform collects detailed personal and medical data from both donors and recipients and stores it securely in dedicated databases. “Using hospital-generated reports and a Neural Ranking algorithm, the system intelligently matches individuals based on a range of biological and health criteria” [2]. This system aims to support hospitals, reduce patient waiting times, and improve transplant success rates through streamlined and data-driven donor-recipient matching.

Background

Organ transplantation remains one of the most critical and complex areas in modern healthcare. “Millions of people globally suffer from organ failure, and the demand for organs far outweighs supply” [3]. One of the major challenges in organ donation is the timely and accurate matching of donors to suitable recipients. Compatibility is influenced by multiple biological and clinical factors such as blood type, HLA typing, crossmatch results, and medical history. Traditionally, organ matching has relied on manual processes, hospital coordination, and centralized databases that often lack real-time updates and comprehensive data analysis capabilities. “Digital transformation in healthcare offers an opportunity to address these inefficiencies” [4]. A centralized, web-based platform can not only accelerate the donor-recipient matching process but also integrate medical criteria to ensure high compatibility and improved success rates. With the use of AI-based algorithms, especially neural ranking models, it becomes possible to assess and rank potential donor-recipient pairs based on a wide range of parameters. This project aims to bridge the gap between donors and recipients by leveraging technology to make organ matching smarter, quicker, and more reliable, ultimately saving more lives and optimizing resource allocation in the healthcare system.

Objective

“The objective of this project is to develop a web-based platform that collects donor and recipient data, analyzes medical compatibility using a neural ranking model, and facilitates accurate, real-time organ matching to enhance the efficiency and success of transplants” [5].

Scope

This system will support donor and recipient registration, hospital integration, medical report handling, secure database management, and intelligent matching based on multiple compatibility parameters. It will be accessible through a user-friendly web interface and focus on streamlining organ donation in affiliated healthcare networks.

2. Literature Review

Organ donation systems have evolved significantly over the past few decades, particularly with the introduction of digital technologies in healthcare. Traditional organ matching and allocation methods have relied heavily on manual coordination, often involving national transplant registries and hospital-based databases [6]. While these approaches provide foundational frameworks, they are frequently limited by delays in data processing, mismatched donor-recipient pairs, and poor accessibility for remote users. Recent developments in web-based systems and artificial intelligence (AI) offer promising alternatives to improve the efficiency and accuracy of organ transplantation processes [7].

2.1 Traditional Organ Matching Systems

Conventional organ matching systems, such as those used by national and international organ registries, base their decisions primarily on ABO blood group and human leukocyte antigen (HLA) matching.

While these criteria are critical, they often fail to account for other influencing factors like organ size, crossmatch results, and the recipient's immunological profile. Moreover, traditional systems lack automation and depend on manual input and communication between hospitals, which can result in delays during emergency transplants. Additionally, they do not offer personalized risk assessments or predictive analytics that could better support medical decision-making [8], [9].

2.2 Web-Based Organ Donation Platforms

Several web-based platforms have been introduced in recent years to streamline the process of organ donor registration and matching. Systems like the United Network for Organ Sharing (UNOS) in the U.S. provide a centralized interface for tracking, matching, and managing donor and recipient data [10]. However, many of these platforms are regional and do not fully leverage advanced AI algorithms for matching purposes. Their usability is often constrained by regulatory frameworks and limited interoperability between different hospital systems. Web-based organ donation portals developed for research and pilot studies demonstrate the effectiveness of digitizing the donor-recipient journey [11]. For instance, platforms that include donor/recipient forms, hospital dashboards, and secure cloud-based storage allow for easier access to critical data and faster decision-making. They also improve data accuracy by automating validations and reducing manual errors [12],[2].

2.3 Role of Artificial Intelligence in Organ Matching

Artificial intelligence has made significant contributions to the medical field, especially in diagnostics, predictive analytics, and personalized medicine. In the context of organ donation, AI is being increasingly applied to improve donor-recipient matching accuracy and reduce transplant rejection rates [13]. Algorithms like decision trees, support vector machines (SVM), and deep learning have been used to analyze complex medical parameters, evaluate compatibility, and prioritize patients based on urgency and prognosis [14]. The Neural Ranking Model (NRM) offers a powerful solution for compatibility-based matching. Unlike traditional rule-based systems, NRM can learn complex relationships between donor and recipient data points, rank potential matches based on relevance, and dynamically adapt as new data becomes available [15]. This ranking mechanism is especially useful when multiple candidates are suitable, allowing for prioritization based on clinical outcomes and success probability **[16]**.

2.4 Matching Parameters in Literature

Many studies highlight the importance of including a wide range of medical parameters in donor-recipient matching. In addition to ABO blood group and HLA typing (HLA-A, HLA-B, and HLA-DR), parameters such as organ size, crossmatch test results, recipient weight and height, donor and recipient age, and Panel Reactive Antibody (PRA) levels have been found to significantly impact transplant success [17],[18]. Furthermore, historical and lifestyle data, including prior transplant outcomes and medical history, contribute to the predictive modeling of transplant viability. The inclusion of such diverse parameters necessitates a sophisticated matching algorithm—something traditional database queries are ill-equipped to handle [19]. Neural ranking models allow for multi-parameter optimization and can be trained on historical transplant data to make informed, context-aware decisions [20].

2.5 Gaps in Existing Systems

Despite advancements, current organ donation systems still suffer from limited automation, lack of intelligent ranking, and poor adaptability to individual patient profiles. Many do not support continuous learning or updates based on real-time hospital input. Additionally, they often overlook user experience, leaving potential donors or recipients confused about the process [21]. This project aims to address these gaps by designing a user-friendly, AI-powered web application that not only collects and processes complex medical data but also intelligently ranks and matches donor-recipient pairs. The inclusion of the Neural Ranking model and parameters like PRA levels and crossmatch results ensures a more comprehensive and clinically sound approach to organ matching.

3. System Architecture

The proposed organ donation platform is architected using a multi-tier, service-oriented architecture (SOA) to ensure scalability, maintainability, and security. The system is engineered to facilitate secure data acquisition, hospital interfacing, medical report ingestion, and real-time AI-driven donor-recipient matching. Core components include a responsive client interface, an intelligent backend application layer, and a dual-database infrastructure optimized for high-availability and data integrity. The architecture adheres to industry best practices in system design, data security, and health information interoperability.

3.1 Overview of the Architecture

Presentation Layer (Client Tier): Developed using modern frontend technologies (HTML5, CSS3, JavaScript/React), this layer provides an interactive user interface for donors, recipients, hospitals, and administrators. It supports dynamic content rendering, form validation, and real-time feedback mechanisms.

Application Layer (Logic Tier): Hosted on a secure web server, the application layer is implemented using a high-level language such as Python (Django/Flask) or Node.js. It encapsulates business logic, handles HTTP requests, enforces input validation, manages user sessions, and serves as the intermediary between the client and database tiers.

Data Layer (Persistence Tier): Two normalized relational databases (e.g., MySQL or PostgreSQL) are deployed to separately maintain donor and recipient records. Each database schema is designed for optimized indexing and query performance, supporting ACID properties and transaction safety for sensitive medical data.

Hospital Integration Interface: A dedicated module enables authenticated hospitals to securely submit structured electronic medical reports. These reports include attributes essential for transplantation matching such as HLA typing, ABO group, PRA levels, and demographic data.

AI-Driven Matching Engine: At the core of the platform lies a Neural Ranking Model deployed as a microservice. It ingests multidimensional medical data from both donor and recipient records; processes weighted compatibility metrics and returns ranked match results with success rate predictions.

Security and Compliance Layer: This layer incorporates SSL/TLS encryption, OAuth2.0-based authentication, role-based access control (RBAC), and audit logging. The system aligns with healthcare compliance standards such as HIPAA and GDPR for safeguarding medical information [22].

4. System Design

The system design outlines the structural, visual, and logical aspects of the platform, ensuring seamless interaction between users, data components, and algorithmic processes. The design strategy follows a modular and service-oriented paradigm, emphasizing maintainability, extensibility, and performance optimization. The core design focuses on delivering an intuitive user experience, robust database modeling, and clearly defined data flow to support AI-driven organ matching and administrative operations.

4.1 User Interface Design

The user interface (UI) is designed with a user-centered approach to enhance accessibility, clarity, and responsiveness across devices. Key UI principles such as consistency, simplicity, and real-time feedback are incorporated using modern web development frameworks like React.js or Vue.js.

Donor/Recipient Interface

Features a guided registration process with progressive disclosure to collect personal and medical information. Includes profile dashboards for users to view their status, hospital assignment, and medical report summary. Incorporates notifications and secure messaging with hospitals and administrators.

Hospital Portal

Secure login for hospital personnel to upload and manage structured medical reports. Access to patient assignment lists, pending documentation, and match recommendations from the AI engine.

Admin Dashboard

Provides system analytics, database access logs, match verification reports, and full user management functionality. Implements data visualization elements (e.g., charts, graphs) for monitoring usage trends and system load. All interfaces are built with responsive design using CSS frameworks like Bootstrap or Tailwind CSS and follow WCAG accessibility standards to accommodate a wide range of users.

4.2 Database Design

The backend of the system consists of two logically separated yet relational databases: one for donors and one for recipients. The schema is normalized to reduce redundancy and improve data integrity, designed using ER modeling principles.

Donor Database Tables:

Donor Profile: Donor ID, Name, Age, Blood Group, Contact Info, Location, Medical History.

Medical Report: Report ID, Donor ID (FK), HLA-A, HLA-B, HLA-DR, ABO Group, PRA Level, Crossmatch Results, Organ Size.

Hospital Assignment: Assignment ID, Donor ID (FK), Hospital ID (FK), Timestamp, Status.

Recipient Database Tables:

Recipient Profile: Recipient ID, Name, Age, Contact Info, Blood Group, Height, Weight, Required Organ, Medical History.

Compatibility Report: Report ID, Recipient ID (FK), Crossmatch Results, PRA Level, Sensitization Risk Level.

Hospital Assignment: Like donor, mapped per recipient.

Other Supporting Tables:

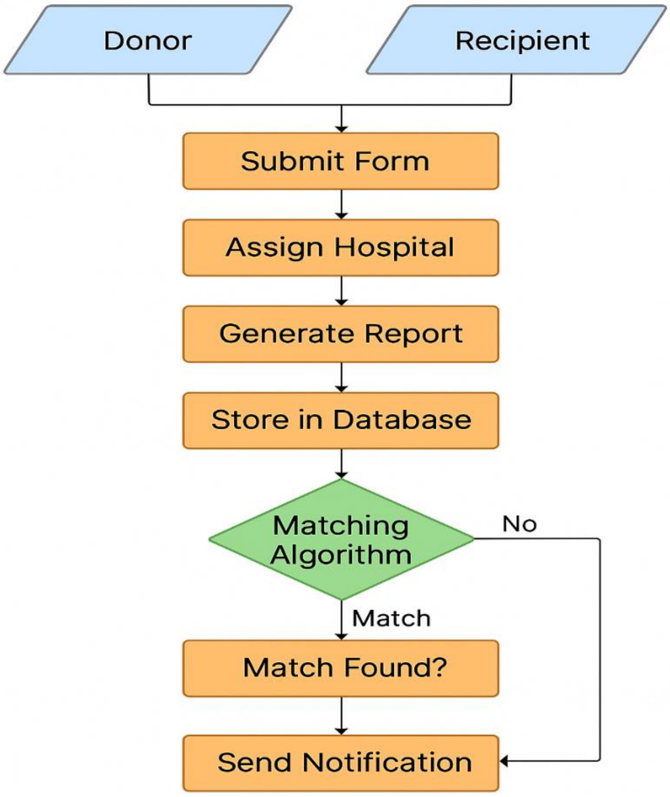
Hospitals: Hospital ID, Name, Location, Affiliation Status, Capacity.

Admin Users: Admin ID, Role, Access Level, Authentication Info.

Match Log: Match ID, Donor ID, Recipient ID, Compatibility Score, Match Date, AI Decision Output.

The schema supports relational integrity using primary and foreign key constraints, and all transactions follow ACID

principles for consistency and fault tolerance. Indexing and stored procedures are applied for performance optimization.



4.3 Flow Diagram

The system flow diagram illustrates the interaction between system entities, their input/output behavior, and the sequential logic of data processing.

Flow Description:

User Registration: Donor/Recipient fills online form → Validated → Stored in respective database.

Hospital Assignment: System calculates geolocation proximity → Assigns nearest affiliated hospital.

Medical Report Upload:

Hospital uploads organ compatibility data → Stored in DB → Triggers match evaluation.

AI Matching Process: Neural Ranking Model fetches donor and recipient records → Computes compatibility score based on medical parameters.

Generates ranked match list → Stores results in Match Log table.

Notification Dispatch: Users and hospitals receive alerts of potential matches.

Admin Oversight: Admin verifies matches, monitors system activity, and updates hospital lists.

5. Matching Algorithm

The core of the platform lies in its intelligent, data-driven matching engine, which ensures optimal donor-recipient pairing based on medical compatibility and predictive success metrics.

5.1 Criteria for Matching

The system evaluates matches using the following clinical and demographic parameters: ABO Blood Group Compatibility, HLA Typing: HLA-A, HLA-B, HLA-DR, Antigens Crossmatch Results

(Positive/Negative), Organ Size Matching, Recipient Height and Weight, Donor and Recipient Age, Medical History, Compatibility Panel Reactive Antibody (PRA) Level. These attributes are extracted from hospital-submitted reports and stored in structured form for processing.

5.2 Matching Process

A Neural Ranking Model (NRM) is employed to analyze multidimensional input features from both donor and recipient databases. The algorithm follows this workflow:

1. Retrieve potential matches from databases based on organ type and blood group.
2. Preprocess and normalize key medical attributes.
3. Compute a compatibility relevance score using the trained NRM.
4. Rank all eligible donor-recipient pairs based on predicted transplant success likelihood.
5. Forward top-ranked matches to the notification system.

5.3 Success Rate Estimation

The Neural Ranking Model is trained on historical transplant data to estimate the probability of post-transplant success. It considers:

1. Immune compatibility (HLA + PRA)
2. Physiological match (size, age, weight)
3. Prior transplant history
4. Crossmatch and antibody levels

The resulting success score supports informed decision-making by hospitals and administrative reviewers.

6. Results and Discussion

This project proposes a conceptual model for an AI-powered organ donation platform designed to streamline the donor-recipient matching process through intelligent automation and structured data integration. Although no practical implementation or testing was conducted, the theoretical foundation demonstrates strong potential for real-world application. The system effectively addresses major limitations in current organ allocation practices by introducing a centralized, digital platform that collects donor and recipient data, assigns affiliated hospitals based on proximity, and utilizes a Neural Ranking Model to match profiles based on medically relevant parameters. The dual-database architecture, combined with algorithmic decision-making, offers an efficient and scalable solution to reduce delays and enhance the precision of organ matches. Furthermore, the model promotes ethical data handling and future adaptability through its modular design. While its performance is yet to be validated through real-time deployment, the project provides a forward-looking framework that could transform the organ donation ecosystem and improve transplant success outcomes significantly.

Conclusion

In conclusion, this organ donation website aims to revolutionize the process of matching donors with recipients by streamlining data collection and hospital integration. By leveraging advanced algorithms and medical data, the platform ensures accurate organ matching based on compatibility factors such as HLA, ABO, and surgery success rates. This system not only enhances the efficiency of the organ donation process but also increases the chances of successful transplants by optimizing donor-recipient matches. The user-friendly interface and secure data management further ensure a seamless experience for both donors and receivers. Moving forward, expanding hospital partnerships and integrating mobile applications will further improve accessibility and effectiveness, ultimately saving more lives.

References:

1. M. Escoto et al., "Research and Innovation in Organ Donation: Recommendations From an International Consensus Forum," vol. 9, no. 5, pp. e1446–e1446, Apr. 2023, doi: https://doi.org/10.1097/txd.0000000000001446.
2. Sharma, H., Gosain, R., & Sachdeva, P. (2024). Internet of Things: Vision, Applications and Challenges. Grenze International Journal of Engineering & Technology (GIJET), 10.
3. A.Lewis, A. Koukoura, G.-I. Tsianos, A. A. Gargavanis, A. A. Nielsen, and E. Vassiliadis, "Organ donation in the US and Europe: The supply vs demand imbalance," Transplantation Reviews, vol. 35, no. 2, Oct. 2020, doi: https://doi.org/10.1016/j.trre.2020.100585.
4. A.I. Stoumpos, F. Kitsios, and M. A. Talias, "Digital transformation in healthcare: Technology acceptance and its applications," International Journal of Environmental Research and Public Health, vol. 20, no. 4, p. 3407, Feb. 2023, doi: https://doi.org/10.3390/ijerph20043407.
5. M. Bhat, Madhumitha Rabindranath, Beatriz Sordi Chara, and D. A. Simonetto, "Artificial intelligence, machine learning, and deep learning in liver transplantation," Journal of Hepatology, vol. 78, no. 6, pp. 1216–1233, Jun. 2023, doi: https://doi.org/10.1016/j.jhep.2023.01.006.
6. N. W. Chan et al., "Social determinants of health data in solid organ transplantation: National data sources and future directions," American Journal of Transplantation: Official Journal of the American Society of Transplantation and the American Society of Transplant Surgeons, vol. 22, no. 10, pp. 2293–2301, Oct. 2022, doi: https://doi.org/10.1111/ajt.17096.
7. R. Beyar, "Challenges in Organ Transplantation," Rambam Maimonides Medical Journal, vol. 2, no. 2, Apr. 2011, doi: https://doi.org/10.5041/rmmj.10049.
8. T. Caulfield, B. Murdoch, R. Sapir-Pichhadze, and P. Keown, "Policy Challenges for Organ Allocation in an Era of 'Precision Medicine,'" Canadian Journal of Kidney Health and Disease, vol.
9. p. 205435812091265, Jan. 2020, doi: https://doi.org/10.1177/2054358120912655.
10. A.A. Zachary and M. S. Leffell, "HLA Mismatching Strategies for Solid Organ Transplantation – A Balancing Act," Frontiers in Immunology, vol. 7, Dec. 2016, doi: https://doi.org/10.3389/fimmu.2016.00575.
11. R. Cogswell et al., "An early investigation of outcomes with the new 2018 donor heart allocation system in the United States," The Journal of Heart and Lung Transplantation, vol. 39, no. 1, pp. 1–4, Jan. 2020, doi: https://doi.org/10.1016/j.healun.2019.11.002.
12. R. Deshpande, "Smart match: revolutionizing organ allocation through artificial intelligence," Frontiers in artificial intelligence, vol. 7, Feb. 2024, doi: https://doi.org/10.3389/frai.2024.1364149.
13. Muniyammal, "Organshare : Efficient System For End-To-End Organ Donation And Management," International Journal Of Innovative Research In Management, Engineering And Technology, vol. 9, 2024.
14. D. B. Olawade, S. Marinze, N. Qureshi, K. Weerasinghe, and J. Teke, "The Impact of Artificial Intelligence and Machine Learning in Organ Retrieval and Transplantation: A Comprehensive Review," Current Research in Translational Medicine, vol. 73, no. 2, pp. 103493–103493, Jan. 2025, doi: https://doi.org/10.1016/j.retram.2025.103493.

   M. Azam et al., "A systematic review of hyperparameter optimization techniques in Convolutional Neural Networks," Decision analytics journal, vol. 11, pp. 100470–100470, Apr. 2024, doi: https://doi.org/10.1016/j.dajour.2024.100470.

15. J. Guo et al., “A Deep Look into neural ranking models for information retrieval,” Information Processing & Management, vol. 57, no. 6, p. 102067, Nov. 2020, doi: https://doi.org/10.1016/j.ipm.2019.102067.
16. Gupta, S., Jaiswal, V., Gupta, S., Sharma, H., & Banda, L. (2024). Heart Checkmate: An Integrated Platform for Predictive Heart Health Management. Grenze International Journal of Engineering & Technology (GIJET), 10.
17. R. J. Duquesnoy and F. H. J. Claas, “Is the Application of HLAMatchmaker Relevant in Kidney Transplantation?,” Transplantation, vol. 79, no. 2, pp. 250–251, Jan. 2005, doi: https://doi.org/10.1097/01.tp.0000144327.92898.a6.
18. R. J. Duquesnoy, “HLAMatchmaker: a molecularly based algorithm for histocompatibility determination. I. Description of the algorithm,” Human Immunology, vol. 63, no. 5, pp. 339–352, May 2002, doi: https://doi.org/10.1016/s0198-8859(02)00382-8.
19. Sharma, H., Garg, R., Tarar, S., Sharma, S., & Tayal, S. (2024). Crop Recommendation System using Machine Learning and IoT. Grenze International Journal of Engineering & Technology (GIJET), 10.
20. N. Gotlieb et al., “The promise of machine learning applications in solid organ transplantation,” npj Digital Medicine, vol. 5, no. 1, Jul. 2022, doi: https://doi.org/10.1038/s41746-022-00637-2.
21. A.Lebret, “Allocating organs through algorithms and equitable access to transplantation—a European human rights law approach,” Journal of Law and the Biosciences, vol. 10, no. 1, Jan. 2023, doi: https://doi.org/10.1093/jlb/lsad004.
22. M. Hirdesh, S. 1&2, G. Aggarwal, and S. Kumar, “Literature Survey for Design and Analysis of a Multi- Level Algorithmic Technique for Encryption and Decryption.”