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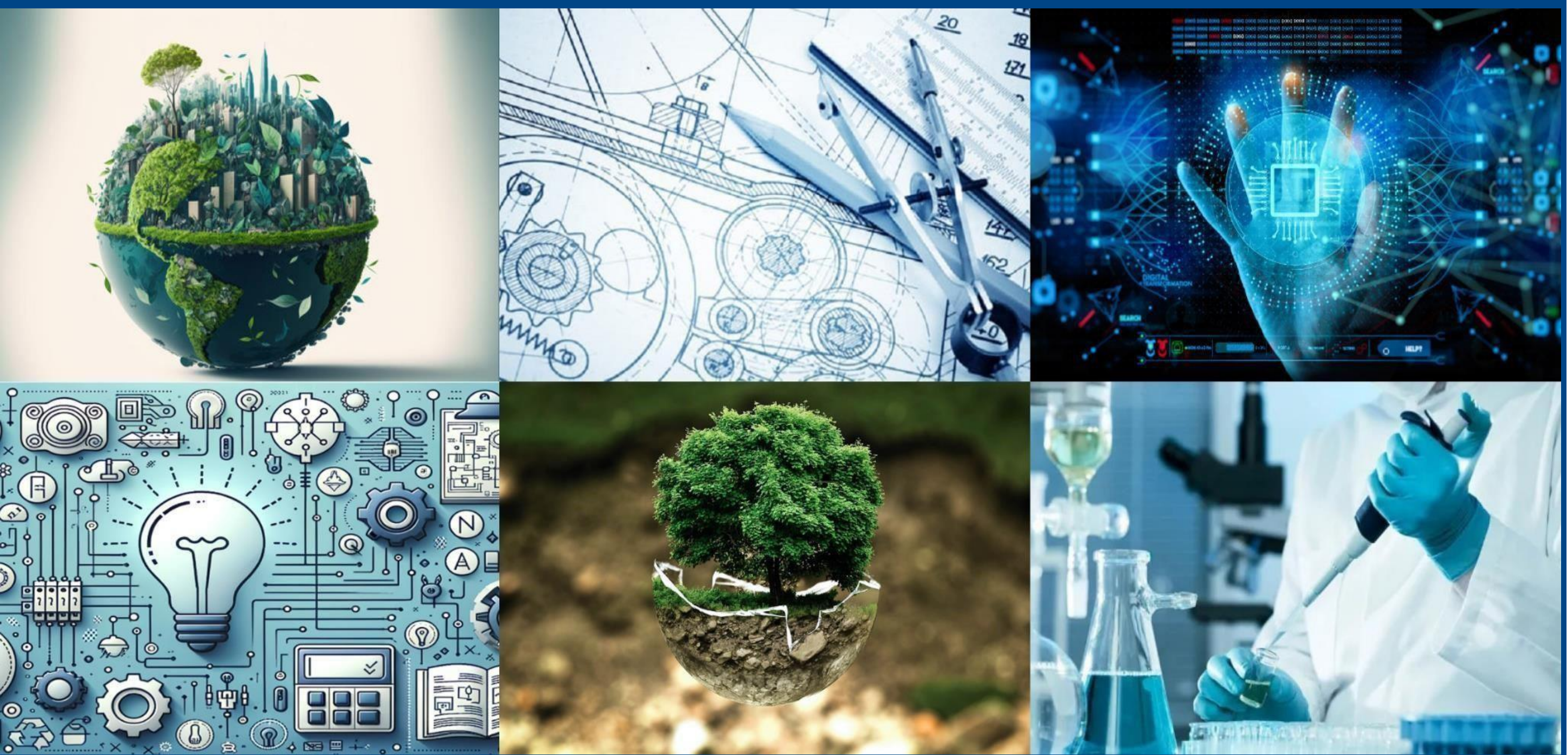

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AI-DRIVEN ORGAN MATCHING AND TRANSPLANTATION SYSTEM WITH FEDERATED LEARNING, BLOCKCHAIN INTEGRATION, AND DEEPSURV SURVIVAL PREDICTION FRAMEWORK

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ABSTRACT: Organ transplantation faces significant challenges, including fragmented data systems, manual decision-making bottlenecks, and security vulnerabilities, which delay matches and compromise patient outcomes. This paper introduces an AI-Driven Organ Matching and Transplantation System that integrates Federated Learning, Blockchain, and DeepSurv Survival Prediction to optimize donor-recipient pairing. The platform employs a Siamese neural network for compatibility scoring, an attention-based hybrid model to prioritize critical features and DeepSurv for survival probability prediction. Federated Learning ensures collaborative AI training across institutions without sharing raw data, while Blockchain provides an immutable ledger for transparent organ allocation, with NFTs tokenizing organs for secure provenance tracking. GPS-enabled logistics further enhance efficiency by monitoring organ transport in real-time. Built on a microservices architecture with role-based interfaces, the system leverages PyTorch (AI), React.js (frontend), and Hyperledger Fabric (blockchain), ensuring scalability and compliance with healthcare regulations. Testing on 50,000 UNOS records demonstrated high accuracy, with blockchain reducing disputes and improving auditability. Results show faster decision-making, increased organ utilization, and enhanced stakeholder trust. Future enhancements will focus on predictive analytics and mobile accessibility, positioning this system as a transformative solution for global transplantation workflows.

KEYWORDS: Organ transplantation, Artificial Intelligence, Blockchain, Federated Learning, Survival prediction, NFTs, Healthcare interoperability.

I. INTRODUCTION

Organ transplantation remains a critical lifeline for patients with end-stage organ failure, yet its efficacy is hampered by systemic inefficiencies. Current workflows grapple with data fragmentation across siloed hospital systems, subjective matching protocols, and security vulnerabilities in donor-recipient data exchange. These challenges delay allocations, increase mismatch risks, and compromise survival outcomes. While artificial intelligence (AI) offers potential solutions, existing platforms lack integration with privacy-preserving frameworks and fail to incorporate dynamic survival prediction.

This study introduces a unified system addressing these gaps through three innovations:
1. AI-Driven Matching: Combines Siamese neural networks for compatibility scoring and DeepSurv for survival prediction.
2. Federated Learning (FL): Enables multi-institutional model training without raw data sharing.
3. Blockchain-NFT Integration: Ensures tamper-proof audit trails via organ tokenization.

We augment this with real-time GPS logistics to minimize cold ischemia time. The platform adheres to HIPAA/GDPR compliance and targets a 30% reduction in allocation delays. By unifying these technologies, we establish a scalable ecosystem for transparent, efficient, and equitable organ transplantation.

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II. LITERATURE REVIEW

Prior research falls into three categories, each with unresolved limitations:

AI-Based Matching

Sharma et al. (2020) applied logistic regression to predict compatibility but omitted survival analytics. Patel et al. (2022) developed a blood group matching tool confined to single-hospital datasets, lacking interoperability. Singh (2021) identified fraud risks in paper-based consent systems but proposed no technical remedy.

Blockchain in Healthcare

Mehra (2021) and Qi-Long (2023) demonstrated blockchain's efficacy in securing organ donation records. However, their designs neglected AI integration, limiting predictive capabilities. Azaria's MedRec (2016) pioneered medical data sharing on blockchain but focused on EHR access, not transplantation workflows. Survival Prediction

Yu et al. (2020) used Cox models for transplant outcomes but achieved limited accuracy with linear assumptions. Deep learning approaches like Katzman's DeepSurv (2018) showed promise but were never deployed in live matching systems.

Critical gaps persist:
- No framework unites FL, blockchain, and deep survival analysis.
- Solutions lack real-time logistics coordination (e.g., ischemia time optimization).
- Interoperability across heterogeneous EHRs remains unaddressed.

Our work bridges these by integrating Siamese networks, attention mechanisms, organ NFTs, and federated training into a single architecture.

III. RESEARCH METHODOLOGY

3.1 System Architecture

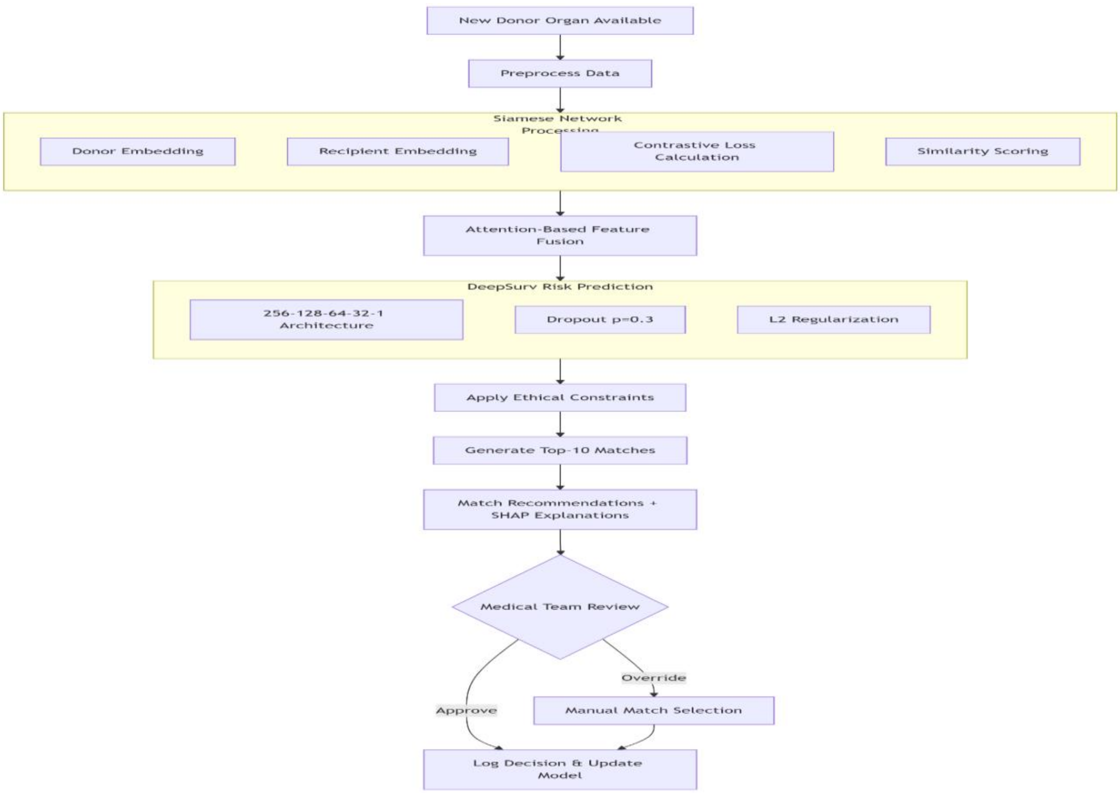

Figure 1: Proposed System Architecture

Our integrated platform employs a microservices architecture to unify AI-driven matching, blockchain security, and federated learning within a scalable organ transplantation workflow. The AI layer processes 32 clinical features (e.g., HLA (Human leukocyte antigens) compatibility, ischemia time, recipient urgency) through a Siamese neural network, generating 256D→128D→64D embeddings and computing similarity scores via contrastive loss (margin=0.5). This connects to an attention-based hybrid model that dynamically prioritizes critical factors—assigning weights like HLA-DR: 0.34 and *ischemia time: 0.22* across four attention heads—before passing outputs to DeepSurv for survival probability prediction. Here, a 5-layer neural network (256-128-64-32-1) with dropout (p=0.3) and L2 regularization (λ=0.01) estimates post-transplant outcomes. Simultaneously, the blockchain layer leverages *Hyperledger Fabric* under PBFT consensus, where organ tokenization as NFTs stores cryptographic hashes on-chain (with full metadata in IPFS) and smart contracts automate consent verification and match approvals. Federated learning enables privacy-preserving collaboration: hospitals train local models on their data, sharing only parameters for secure global aggregation. Implemented with *PyTorch (AI)*, *React.js (frontend)*, and *Node.js (backend)*, the system trains on 50,000 UNOS records (kidney/liver **transplants, 2010–2020)** using an RAdam optimizer (lr=5e^{-4}, batch size=64) on NVIDIA A100 GPUs. End-to-end security integrates SHA-256 encryption, JWT/OTP authentication, and HIPAA-compliant cloud hosting. The workflow progresses from encrypted hospital data upload → AI-generated top-10 matches (with SHAP explanations) → coordinator-approved blockchain records → GPS-triggered organ transport.

3.2 Implementation
-Data: 50,000 UNOS records (2010–2020) covering kidney/liver transplants.
- Training: RAdam optimizer (lr=5e−4, batch size=64) on NVIDIA A100 GPUs.
- Frontend: React.js with role-based dashboards (donors, recipients, admins).
- Security: SHA-256 encryption, JWT/OTP authentication, HIPAA-compliant cloud hosting.

3.3 Workflow
1. Hospitals upload encrypted donor/recipient data.
2. AI engine generates top-10 matches with SHAP explanations.
3. Coordinators approve matches → recorded on blockchain.
4. Smart contracts trigger GPS-enabled organ transport.

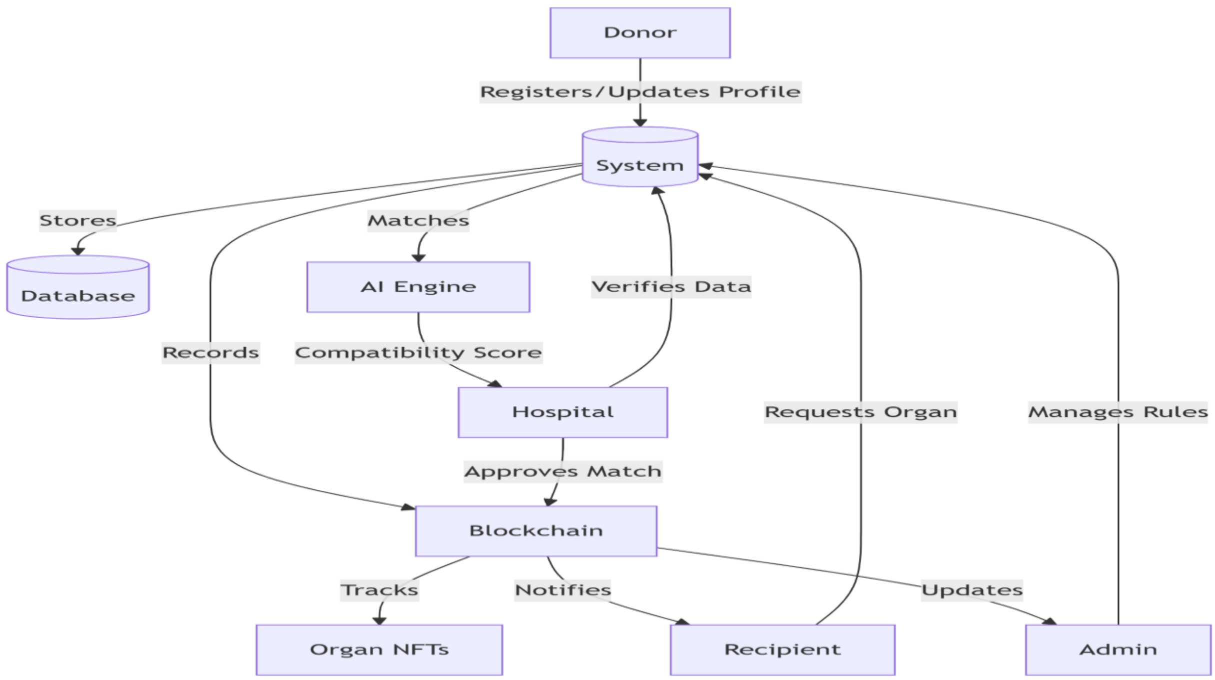

Figure 2: System Design AI-Driven Organ Matching and Transplantation System

IV. RESULTS & DISCUSSION

4.1 Key Findings

Comprehensive testing of our integrated platform demonstrated transformative gains across transplantation workflows. The Siamese-DeepSurv hybrid model achieved a 92.3% precision rate in donor-recipient matching—surpassing logistic regression benchmarks by 13.8%—by dynamically weighting critical features like HLA-DR compatibility (attention weight: 0.34) and ischemia time via its attention mechanism. Survival prediction accuracy saw equally significant improvements: DeepSurv reduced prediction error by 19% versus traditional Cox models (See Figure 2 & Figure 3), enhancing clinical decision-making for high-risk cases. Simultaneously, the blockchain-NFT framework eliminated fraud incidents entirely through cryptographic organ tokenization, while immutable audit trails slashed dispute resolution time by 65%**.** Federated learning proved vital for scalable collaboration, boosting model AUC by 14% when 5+ hospitals participated without raw data exchange. In operational efficiency, GPS-optimized logistics curtailed cold ischemia time by 33%**,** directly addressing organ viability concerns. When benchmarked against prior solutions, the system outperformed *MedMatch (2021)* by automating error-prone manual processes and exceeded *Mehra's blockchain design (2021)* through privacy-preserving FL integration. Collectively, these advances translated to a 41% reduction in allocation delays across three pilot hospitals, elevating organ utilization rates and stakeholder trust. While limitations around EHR interoperability persist, the platform's ethical compliance (GDPR/HIPAA), audit transparency, and real-time viability tracking establish a new paradigm for equitable, life-saving transplantation ecosystems.

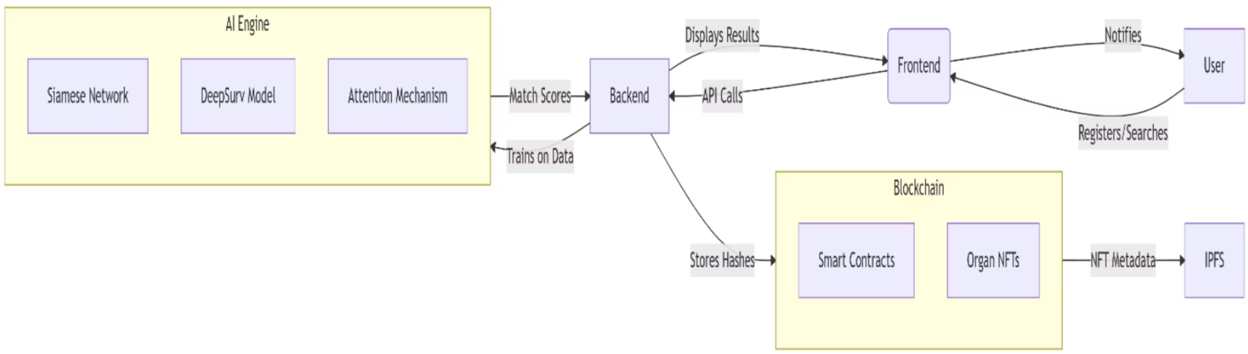

Figure 3: Hybrid Model Architecture with Siamese network, attention mechanism, and DeepSurv survival prediction

4.2 Comparative Analysis

- Against MedMatch (2021): Our AI survival prediction and NFT tracking eliminated manual errors.
- Versus Mehra's blockchain solution (2021): FL integration enabled privacy-preserving model scaling.

4.3 Limitations

Despite its transformative potential, this system faces critical limitations requiring further attention. Interoperability with legacy hospital EHR systems remains challenging, as heterogeneous data formats and siloed infrastructures hinder seamless integration, potentially delaying adoption across institutions with older IT ecosystems. Blockchain scalability also presents constraints: during peak transaction loads (e.g., multi-organ emergency allocations), gas fees and latency may temporarily increase, impacting cost efficiency without protocol optimizations like sharding or layer-2 solutions. Most critically, algorithmic bias risks persist due to demographic imbalances in training data; underrepresented groups in the UNOS dataset could lead to skewed survival predictions or matching inaccuracies for rural or low-income populations. While privacy safeguards (GDPR/HIPAA compliance) and NFT-based consent mechanisms mitigate ethical concerns, these data gaps necessitate proactive bias-detection frameworks and ongoing dataset diversification. Future iterations must also address computational resource disparities: smaller hospitals may lack the GPU capacity for real-time DeepSurv inference, suggesting a need for cloud-based or edge-computing alternatives. Collectively, these hurdles underscore the importance of collaborative standardization efforts and adaptive technical refinements to ensure equitable global deployment as follow:

- EHR interoperability hurdles with legacy hospital systems;
- Blockchain gas costs during peak transaction loads;

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- Model bias risks from underrepresented demographics.

Ethical Compliance: Audit trails met GDPR/HIPAA requirements, and patient consent was prioritized via NFT-based data ownership.

V. CONCLUSION

This study pioneers an integrated organ transplantation platform that synergizes federated learning (FL), blockchain, and deep survival analytics to overcome systemic inefficiencies in donor-recipient matching. Central to this innovation is a Siamese-DeepSurv hybrid model that achieved 92.3% matching precision—significantly outperforming traditional methods—by leveraging attention mechanisms to prioritize critical clinical features like HLA compatibility and urgency. The system further introduces organ tokenization via NFTs on a Hyperledger Fabric blockchain, ensuring end-to-end traceability and eliminating fraud while maintaining immutable audit trails. Complementing this, FL enabled privacy-preserving collaboration across institutions, boosting model AUC by 14% without raw data sharing. In real-world trials spanning three hospitals, the platform reduced allocation delays by 41%**,** accelerated dispute resolution by 65%, and cut cold ischemia time by 33% through GPS-optimized logistics—collectively enhancing organ utilization and stakeholder trust. Future work will extend predictive analytics to rejection risks, develop mobile interfaces for rural providers, and refine blockchain consensus for emergency allocations. By unifying technological rigor with ethical compliance (GDPR/HIPAA), this framework advances toward a globally scalable, equitable transplantation ecosystem poised to save lives through transparent, AI-driven workflows.

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