CrimsonNet: Predictive and Secure Blood Donation Management System Using AI And Blockchain

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Abstract—CrimsonNet is an intelligent and secure blood do- nation management system designed to improve efficiency, transparency, and preparedness in healthcare blood supply chains. Traditional blood management systems often suffer from manual processes, delayed responses, inaccurate demand estimation, and data security vulnerabilities. To address these challenges, the proposed system integrates machine learning–based predictive analytics with blockchain technology on a unified web platform. A one-dimensional Convolutional Neural Network (1D CNN) model is employed to forecast future blood demand using historical hospital blood usage data, enabling hospitals to anticipate daily requirements and optimize inventory management. The system is implemented using the Django framework with MySQL for backend data management, while HTML, CSS, Bootstrap, and JavaScript are used to create a responsive and user-friendly frontend interface. Role-based dashboards are provided for administrators, hospitals, and donors to support registration, scheduling, monitoring, and coordination of blood donation activities. To ensure data integrity, transparency and trust, the system incorporates an Ethereum-based blockchain network where approved donor and hospital records are stored immutably using smart contracts. Additional features such as token-based scheduling, donor and camp recommendations, and real-time interaction enhance operational efficiency and donor engagement. By combining predictive analytics with decentralized data security, Crimson Net offers a scalable, data-driven solution that strengthens healthcare readiness and ensures the timely availability of blood for critical medical needs.

Index Terms—Blood Donation Management, Machine Learning, 1D CNN, Blockchain, Ethereum, Healthcare Analytics, Django

I. INTRODUCTION

Blood is a critical healthcare resource with no synthetic substitute, making efficient management of its supply chain a matter of global life and death. Despite the vital role of blood transfusion services, modern healthcare systems continue to grapple with significant inefficiencies. Recent statistics indicate that millions of lives are put at risk annually due to delayed blood delivery and fragmented communication between donors, hospitals, and blood banks. Traditional management systems are predominantly manual or centralized, leading to issues such as inventory wastage, data redundancy, and a critical lack of real-time coordination during the" golden hour" of medical emergencies.

The primary challenges in current blood donation frame- works are twofold: the inability to accurately forecast demand and the lack of a secure, transparent platform for donor records. Without predictive capabilities, hospitals often face either acute shortages or excessive wastage due to the limited shelf life of blood components. Simultaneously, the centralized nature of existing databases makes them vulnerable to data tampering and privacy breaches, discouraging potential donors and hindering trust between stakeholders.

To address these challenges, researchers have begun exploring the integration of Industry 4.0 technologies. Artificial Intelligence (AI), particularly Deep Learning models like 1D Convolutional Neural Networks (1D CNN), offers the potential to transform historical usage data into actionable demand forecasts. Furthermore, Blockchain technology provides a de- centralized and immutable ledger, ensuring the integrity of donor health records and

the transparency of the supply chain. This survey paper provides a systematic review of existing methodologies in AI-driven predictive modeling and Blockchain-based secure management within the blood do- nation ecosystem. We analyze the evolution from manual systems to intelligent, decentralized frameworks, identifying the technological gaps that still persist. The remainder of this paper is structured as follows: Section II discusses the literature survey and related works; Section III details the technological taxonomy of AI and Blockchain in healthcare; Section IV evaluates current system architectures; and Section V concludes with future research directions.

II. LITERATURE SURVEY

The development of CrimsonNet is informed by a systematic review of contemporary research in blood supply chain management. This section analyzes the four primary works that serve as the foundation for our integrated AI and Blockchain framework.

A. BASE FRAMEWORK: PREDICTIVE ANALYTICS AND DATA SECURITY

The core foundation of our work is the research conducted by Ashini Pushmika et al. [1], which introduces a Web-Based Blood Bank and Donation Management System (BBDMS).

METHODOLOGY: The authors utilize machine learning to predict potential blood donors based on demographic and psychographic factors, alongside encryption for data integrity.

RELATIONSHIP TO CRIMSONNET: This serves as our primary *base paper*. While [1] successfully implements predictive modeling and standard security, it lacks real-time interactive engagement. CrimsonNet enhances this by introducing an AI Chatbot for eligibility and a Token Management System for structured scheduling.

B. TIME-SERIES FORECASTING FOR INVENTORY OPTIMIZATION

Benelmir Et Al. [2] proposed a smart platform specifically for health professionals to minimize blood wastage through demand forecasting.

METHODOLOGY: This work utilizes time-series analysis and ensemble learning to forecast short-term load and demand requirements.

RELATIONSHIP TO CRIMSONNET: We adopt the time-series forecasting philosophy from [2] but refine it by using a 1D-Convolutional Neural Network (1D-CNN), which is better suited for capturing temporal dependencies in daily hospital blood requirements.

C. REAL-TIME ACCESSIBILITY AND EMERGENCY LOGISTICS

The challenge of the" Golden Hour" in medical emergencies is addressed by Singla et al. [3], who focus on the spatial aspect of blood availability.

METHODOLOGY: The authors propose an AI-driven plat- form to locate the nearest blood banks and hospitals in real-time during accidental cases.

RELATIONSHIP TO CRIMSONNET: While [3] provides excel- lent geographic location services, it does not provide a mechanism to alert donors. CrimsonNet bridges this gap by integrating a Real-time Alert System that notifies eligible donors immediately when a nearby hospital fore- casts a shortage.

D. MOBILE-DRIVEN DONOR ENGAGEMENT

Kaur et al. [4] introduced" RaktFlow," a mobile application aimed at easing the donation process, particularly highlighted during the COVID-19 pandemic.

METHODOLOGY: The system focuses on a seamless UI/UX for donor registration and checking blood availability across multiple centers.

RELATIONSHIP TO CRIMSONNET: RaktFlow provides the blueprint for user-centric design. We extend this mobile- first approach by adding Blockchain-based decentralized security (Ethereum), ensuring that the donor records managed in the app are immutable and transparent, unlike the centralized databases used in [4].

III. RESEARCH GAP

Despite the advancements made in blood supply chain management through machine learning and blockchain, there still exist numerous deficiencies in the research currently available [?].
While most studies focus primarily on enhancing forecasting accuracy or digitizing records [?], little thought is given to the practicalities of real-time donor engagement, the scalability of decentralized coordination, and the elimination of manual scheduling delays. This results in a limited number of solutions that are only effective in isolated laboratory settings rather than integrated emergency response environments.

Many existing studies, including the base framework pro- posed by Pushmika et al. [?], utilize predictive analytics to forecast demand, yet they fail to provide an interactive interface for immediate donor eligibility verification. Currently, mobile-driven systems like RaktFlow [?] provide reliable access to availability data but operate on centralized databases, which fail to account for the practical security challenges of real-world conditions—such as preserving data integrity against unauthorized tampering and providing transparent traceability of blood units.
Furthermore, while AI-based location tracking systems [?] have enhanced the speed of finding blood banks during the" golden hour" of accidents, there is little coordination between these spatial methods and proactive alert systems. Current frameworks lack a unified approach that integrates 1D- CNN predictive intelligence with a blockchain backbone, nor have they developed automated token management systems to streamline donor flow and prevent center overcrowding.
Due to these continuing problems, there is a great need for a secure, real-time, and predictive blood management framework capable of providing immediate intervention through AI chat- bots and automated alerts to ensure a continuous and reliable blood supply during critical medical emergencies.

IV. FUTURE RESEARCH DIRECTIONS

In light of the gaps observed in the surveyed works, several promising directions for future research in blood supply chain management are identified and discussed:

LIGHTWEIGHT AND MOBILE-READY PREDICTIVE MODELS: Future blood management systems must prioritize efficient models capable of operating on mobile and edge devices used in remote blood donation camps. By utilizing techniques such as model pruning, quantization, and Knowledge Distillation, complex 1D-CNN and Transformer-based demand forecasting models can be adapted to operate at lower resource capabilities without compromising accuracy.

PRIVACY-PRESERVING HEALTHCARE FRAMEWORKS: There is a growing demand for systems that manage sensitive donor health data with a focus on privacy preservation. Future research should explore On-device Inference and Federated Learning to allow hospitals to train predictive models on local data without sharing private donor information with a centralized cloud, thus mitigating risks of large-scale data breaches.

ADVANCED MULTIMODAL FUSION FOR DONOR HEALTH: Further research is needed on durable strategies for combining diverse data modes, such as historical donation trends, real-time hospital inventory levels, and social media sentiment during disasters. Innovative fusion strategies can create more reliable methods for balancing supply and demand while solving issues related to geographical donor distribution.

EXPLAINABLE AND ETHICAL AI IN CLINICAL DECISION MAKING: The implementation of Explainable AI (XAI) in blood demand forecasting will provide transparency into prediction outcomes. This helps medical professionals comprehend the rationale behind a forecasted shortage enabling them to make ethical and informed decisions regarding blood rationing or emergency donor mobilization while reducing algorithmic bias.

PROACTIVE EMERGENCY PLANNING AND EARLY ALERTS: Instead of reactive management, future systems should adopt a proactive methodology. Developing mechanisms to detect

potential" at-risk" inventory levels before a crisis occurs is essential. Proactive warning systems, statistical analysis of behavioral donation trends, and automated donor notification programs are vital to maintaining the" Golden Hour" response time.

BLOCKCHAIN SCALABILITY AND INTEROPERABILITY: As blood management moves toward decentralized architectures like Ethereum, research must focus on the scalability of smart contracts. Future studies should explore Layer-2 scaling solutions or cross-chain protocols to allow different hospital networks and national blood services to interact seamlessly on a unified, immutable ledger.

REAL-TIME SYSTEM INTEGRATION AND DEPLOYMENT: Future studies should focus on the full end-to-end integration of systems—utilizing real-time data ingestion from hospital ERPs and rapid inference for donor matching. Focus must be placed on the practical limitations of deployment, such as energy efficiency for mobile blood units and the continuous upgrading of machine learning models in production.

BIAS MITIGATION IN DONOR RECRUITMENT: Predictive models for blood donation should not exhibit biased out- comes against specific demographic groups. Continuous evaluation through fairness-aware learning is necessary to ensure that recruitment drives and donor alerts are distributed equitably across various cultural and geo- graphical backgrounds.

V. CONCLUSION

This survey presents a review of current advancements in cyberbullying detection using machine learning techniques, Deep learning techniques and NLP (Natural Language Processing) (NLP). While using traditional ML models, their performance tends to be relatively reliable when using well defined feature sets.
However, traditional ML models typically have problems when applying them to complex language patterns. Although deep learning and especially transformer-based systems, notably BERT models

(e.g., Distil BERT) outperform traditional ML models, they provide an advantage over traditional ML in that they capture the underlying context and semantics of language. Recent literature based on deep learning and BERT models emphasize the significance of using multiple classifiers in an ensemble, addressing the issue of class imbalance and analyzing multiple modalities for robustness.
Furthermore, the hybrid framework utilizing deep learning and transformer models may prove to be some of the most effective methods for cyberbullying detection, while future work should concentrate on deploying cyberbullying detection models in real time along with explain ability and cross- platform migration to enhance online safety.

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