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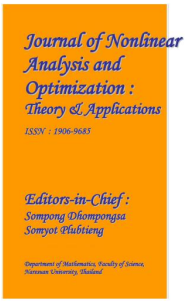

MODERNIZING HOSPITAL ORGAN DONATION OVERSIGHT WITH BLOCKCHAIN

RECORDS

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ABSTRACT

Today's organ donation and transplantation systems pose different requirements and challenges in terms of registration, donor-recipient matching, organ removal, organ delivery, and transplantation with legal, clinical, ethical, and technical constraints. Therefore, an end-to-end organ donation and transplantation system is required to guarantee a fair and efficient process to enhance patient experience and trust. In this paper, we propose a private Ethereumblockchain-based solution to enable organ donation and transplantation management in a manner that is fully decentralized, secure, traceable, auditable, private, and trustworthy. We develop smart contracts and present six algorithms along with their implementation, testing, and validation details. We evaluate the performance of the proposed solution by performing privacy, security, and confidentiality analyses as well as comparing our solution with the existing solutions. We make the smart contract code publicly available on Git hub.

1. INTRODUCTION

Organ failure or damage occurs due to an injury or a disease. It affects the quality of life and, in some cases, leads to death. Donating an organ is one of humanity's most honorable actions to save the lives of patients through organ transplantation. For a successful transplant, the organ must be in acceptable working conditions with donor-recipient matching, and its removal should not pose a life-threatening risk to the donor. The first successful organ donation [1]-[7] occurred with a kidney transplant between twin brothers in 1954. Since then, the annual number of transplants has steadily increased. However, the demand for organ donations still exceeds the number of donors. In fact, while waiting for an organ transplant, twenty people die every day, and a new patient is added to the waiting list in every ten minutes. More importantly, accessing the organ donation waiting list is a basic requirement for organ allocation. Referral for transplantation can be affected by both geographical and socioeconomic factors. Therefore, the allocation process on the waiting list should not discriminate against certain groups of patients.

Organ donation is conducted in two different ways, including deceased donation and living donation. Figure 1 illustrates the typical flow chart for donating an organ and transplanting it to a patient. First, the donor is examined by the hospital transplant team, and if the donor is deceased, a brain death test is performed. Meanwhile, if the donor is still alive, doctors examine the donor and ensure that the donor is fit for live donation. Then, all medical records are reported to the procurement [3] organizer.

The procurement organizer is responsible for evaluating the donor's condition to decide if he is a fit donor and ensuring that the donor is properly registered in the medical system. Next, if the evaluation shows that the donor is eligible for donation, the procurement organizer sends all the data to the organ transplantation organizer[5]. This step can be performed only if the donor gives consent to donate to an anonymous person. After that, the matching process between the available donors and patients on the waiting list is performed by the organ transplantation organizer.

As a result, a ranked list is generated as an output and provided to the transplantation surgeons. Next, the transplant surgeon decides whether the organ is appropriate for the patient based on various considerations, such as the donor's medical records and the current health of the

prospective recipient. Later, when a transplant surgeon accepts the donated organ, the donor's surgeon is notified to remove the donated organ. Finally, the donated organ is transported to the patient's hospital and received by the transplant surgeon[6]. However, suppose the situation is for a live donor and it has been planned to donate to a known person by name. In that case, the data will go directly to the transplant surgeon to start the surgery of removing and transplanting the donated organ. In the past, when a patient died or was near death, the organ procurement organization and hospital worked together to do an initial medical test to decide if the patient could be an organ donor.

This call takes around 15 minutes, and only 6% of these calls result in possible organ donors' being identified. Over the years, this phone call has been replaced by an instant message generated by central computer systems that store all the data required for this process [8]. However, the core issue with this strategy is that the security and validity of such data are entirely dependent on the transplantation centers' ability to keep their systems secure and identify potential harm to donors and recipients. The accuracy of the wait-list data is largely dependent on people's faith and trust in these centers' ability to keep it secure from hackers and fraudulent employees. Moreover, transparency is another challenge affecting the success of the organ donation process. According to World Health Organization (WHO) reports, up to 10% of transplanted organs may have been obtained unethically via organ trafficking, but the exact numbers are unknown.

The lack of transparency in the current system among participants leads to illegal organ trade and purchases and medical professionals engaging in unethical practices. Moreover, there are hospitals that take advantage of the patient's need for the organ and offer the opportunity to transfer the organ to those who pay a higher amount to the hospital while ignoring the patient with the highest priority on the waiting list. In addition, current transplant systems are also frequently slow, which is unacceptable in such a critical and life-threatening scenario. Such systems are hardly up to date with the minimum security standards. So far, there has recently been a surge in security breaches affecting user privacy and system integrity [9]. In general, modern systems manage data through the use of standard databases; however, most hospitals, health ministries, and other medical facilities lack a standardized data communication system.

2. LITERATURE SURVEY

The proposed system is an organ donation decentralized app using blockchain technology. It would be a web application [10] for patients to register their information-most importantly medical ID, blood type, organ type and state. The system would work on a first-in, first-out basis unless a patient is in critical condition.

The organ donation system in the United States is centralized and difficult to audit by the general public. This centralized approach may lead to data integrity issues in the future. The Organ Procurement and Transplant Network (OPTN) [11] was built and maintained by a non-governmental organization called the United Network for Organ Sharing (UNOS) under its proprietary UNet(SM) umbrella platform. This platform is made up of proprietary closed source software and does not provide the general public easy access to the organ transplant data for auditing. This study investigates the feasibility, challenges, and advantages of a blockchain-based OPTN.

This study proposes an approach to track unethically procured organs in particular in countries or regions where investigations cannot be performed by utilizing forensic DNA [12] methodology. Using China as an example, previous research has concluded that organs in China are in part unethically and extra-legally procured (so called "forced organ harvesting") from living prisoners of conscience without consent. Using forensic DNA-analysis, we propose building a DNA [13] data bank from missing prisoners of conscience in China and comparing these results with DNA from donor organs in patients who received transplants in China. Biological materials collected in China will provide DNA directly or indirectly from potential victims of forced organ harvesting. Archival biopsies from transplant recipients' [14] donor organs will provide DNA profiles of donors. Verified match between DNA profiles of transplanted organs and missing victims will establish proof of such connection, thus provides evidence despite a lack of transparency.

In today's era of digitisation, many technologies have evolved that every manual work can be digitally automatized. In the digital automatizing process, security and privacy are the most important and highly demanding aspects. Blockchain offers many features that can be used in almost every sphere of life. Features like decentralization [15], transparency, privacy makes it an extremely useful technology. Therefore, by making use of all these features, several problems in healthcare sector can be solved like removing complex network of third parties and lack of traceability of transactions. This paper presents a decentralised, secure and transparent organ and tissue transplant web application (also called DApp), which not only nullifies the role of any third party involved in the organ transplantation, but also is a cost effective solution that saves the patient's from high cost of transplantation. The details and Electronic Medical Record(EMR) [16] are hashed using the IPFS(a distributed file server), which reduces the cost of upload to a great extent as shown in the results section of this paper.

Blockchain technology enables a decentralized and distributed environment with no need for a central authority. Transactions are simultaneously secure and trustworthy due to the use of cryptographic principles. In recent years, blockchain technology has become very trendy and penetrated different domains, mostly due to the popularity of cryptocurrencies[17]-[21]. One field where blockchain technology has tremendous potential is healthcare, due to the need for a more patient-centric approach to healthcare systems and to connect disparate systems and increase the accuracy of electronic healthcare records (EHRs). In this systematic review, an analysis of state-of-the-art blockchain research in the field of healthcare is conducted. The aim is to reveal the potential applications of the technology and to highlight the challenges and possible directions of blockchain research in healthcare. First, background information is discussed, followed by a description of the exact methodology used in this paper. Next, an analysis of the results is given, which includes a bibliometric overview, an analysis of gathered data and its properties, and the results of a literature quality assessment. Lastly, there is a discussion of the results from the analysis[21]. The findings indicate that blockchain technology research in healthcare is increasing and it is mostly used for data sharing, managing health records and access control. Other scenarios are very rare. Most research is aimed at presenting novel structural designs in the form of frameworks, architectures or models. Findings also show that technical details about the used blockchain elements are not given in most of the analyzed

publications and that most research does not present any prototype implementation or implementation details. Often even with a prototype implementation, no details about blockchain elements are given.

The transplant of cadaveric organs must be performed in a short period of time in order to achieve satisfactory results. In Hospital S. João (HSJ) [22], a large Portuguese hospital, during 2008 and 2009, 65 and 61 respectively potential donors were identified, but 12 and 19 of them were not validated as such in time. The number of validated donors could increase if the information workflow between donor hospitals and coordinator offices became more efficient. The goal of this work is to design and implement a multi-agent software platform to assist the information workflow between donor hospitals and coordinator offices. Through several meetings with HSJ [23],[24] coordinator office it was characterized a set of basic data that would allow coordinator offices to early identify possible organs donors. This preliminary characterization provided the necessary grounds for the development of an agent based software application allowing the storage and management of potential donors' information and optimizing the information workflow. The information workflow and the current communication processes characterization allowed the development of a multi-agent web platform, providing a way to assist the information workflow, between coordinator hospitals and their attached hospitals network. The platform also improves direct communication between coordinator offices about most relevant facts. By using this tool or a similar one the information workflow between donor hospitals and coordinator offices can become more efficient, optimizing the pre-transplantation tasks and consequently the number of successful transplants in our country.

Purpose The purpose of this paper is to describe a proposed framework for traceability purpose. Hence, the framework provides a formal and structured way of viewing a traceability solution. This structure lays the required bases for a traceability system before starting development and deployment. Design/methodology/approach The paper examines several traceability publications, including systems and literature review. The study covers the traceability implementation phase. Therefore, this research approaches the traceability issue from three perspectives (description, engineering and executive one). The separation between aspects is essential when describing and comparing traceability systems. This distinction is also helpful when recommending solution improvements. Findings The framework identifies six traceability bases: aims, functions,

specifications,[25] data classification, processes and procedures. These can establish a basis for a general purpose tool that can enable users to develop an efficient traceability solution. Thus, the first ontology expresses the framework domain and ensures optimal use of it. The second one represents the bases that can serve as a knowledge base to manage the product data. Research limitations/implications The suggested framework tackles the implementation of traceability. Therefore, the design emphasizes the importance of technological concerns. Some studied cases could require[17] more research angles (i.e. economic and legislative). Thus, framework enrichment is essential for further improvements. Practical implications The framework helps users to develop a general, interoperable and scalable traceability solution. These are important to promote the generalization of traceability systems. Originality/value The framework fulfills a requirement for establishing general traceability foundations. Therefore, the guide independently operates of the product or the industry specificity. Moreover, the bases aim to bridge the gap between solution engineering and traceability requirements.

Matching donations from deceased patients to patients on the waiting list account for over 85% of all kidney transplants performed in Australia. We propose a simple mechanisms to perform this matching and compare this new mechanism with the more complex algorithm currently under consideration by the Organ and Tissue Authority in Australia[18]. We perform a number of experiments using real world data provided by the Organ and Tissue Authority of Australia. We find that our simple mechanism is more efficient and fairer in practice compared to the other mechanism currently under consideration.

Individuals suffering from kidney failure today face significant challenges in order to obtain a transplant. They are placed on a waiting list and ranked by priority in hope that a kidney from a deceased donor is a transplant match. They do have another option: a living donor; someone they know, family or friend, willing to give them a kidney. These people may not be a transplant match, however there is a solution, a “Kidney Exchange” [18] or a “Kidney Paired Donation”. In these programs, if two mismatched pairs (living donor and kidney recipient) can be grouped together so that they become transplant matches, both kidney failure patients can receive a kidney. While a great solution, these programs have a significant pitfall. They are limited to the specific registry regions participating in their program. The Kidner project [19] was developed

to help these exchange programs better detect life-saving opportunities and enable more people to access kidney transplants.

The proposed system is an organ donation decentralized app using blockchain technology. It would be a web application for patients to register their information-most importantly medical ID, blood type, organ type [13] and state. The system would work on a first-in, first-out basis unless a patient is in critical condition.

3. PROBLEM STATEMENT

Managing organ donation and transplantation has become challenging due to the lack of data accountability, immutability, audit, transparency, traceability, and trust features in the existing systems.

The following are the paper's main contributions:

We propose a private there um blockchain-based solution that ensures organ donation and transplantation management in a manner that is decentralized, secure, reliable, traceable, auditable, and trustworthy. We develop smart contracts that register actors [3]and ensure data provenance through producing events for all the necessary actions that occur during the organ donation and transplantation stages. The smart contracts code is made publicly available on Github. We develop an auto-matching process between the donor and recipient through a smart contract based on certain criteria. We present six algorithms along with their full implementation, testing, and validation details.

We conduct security analysis to determine that the proposed solution is secure against common security attacks and vulnerabilities. We compare our solution with the existing solutions to show its novelty. Our proposed solution is general and may be easily adjusted to meet the needs of a variety of related applications.

4. PROPOSED SYSTEM

The proposed blockchain-based solution for donated organ transplantation is explained in Section III. Then, it is followed by the implementation details of the proposed blockchain-based solution in Section IV and the details of testing and evaluation in Section V. The discussion and analysis of the proposed solution are given in Section VI. Finally, section VII concludes the paper by summarizing our contributions and outlining future research opportunities.

In this section, we present details of our blockchain-based organ donation and transplantation solution. Figure 2 presents an overview of the system architecture of our proposed solution. It shows that our solution uses two smart contracts (SCs) [9] namely, organ donation and organ transplantation. The participants can access the functions and events of these smart contracts through a front-end decentralized application (DApp), which is connected by an application program interface (API). Every smart contract has unique functions that can be executed only by pre-authorized participants, who will have the ability to access data stored on the chain to review transactions, logs, and events.

The participants include doctors, hospital transplant team members, procurement organizers, organ matching organizers, a transporter and a transplant surgeon. The Organ Donation Smart Contract is responsible for creating a waiting list, accepting donors after medical test approval, and auto-matching between the donor and recipient [10]. The Organ Transplantation Smart Contract is mostly in charge of the transplant process. It has three parts: removing an organ from a donor, getting the organ to the recipient, and putting the organ into the recipient. All the previous phases are logged and stored on the ledger for revision and verification purposes. Additionally, authorization, secrecy, and privacy are ensured by utilizing a private permissioned there um blockchain.

5. IMPLEMENTATION

NON-BLOCKCHAIN-BASED SOLUTIONS FOR ORGAN DONATION MANAGEMENT

In non-blockchain-based processes, various approaches and tools are utilized to come up with solutions that enhance organ donation, transplantation management, and the matching process. The authors in developed a multi-agent software platform to represent the information workflow model among donor hospitals, regulators, and recipient hospitals. This platform optimizes the

pre-transplantation tasks, which can improve the process efficiency. In addition, it allows storing potential donor information and improves direct communication among all participants in the organ transplantation process. An information workflow was simulated using the developed platform, and it was estimated that the saved time might be between three to five hours.

BLOCKCHAIN-BASED SOLUTIONS FOR ORGAN DONATION MANAGEMENT

In a blockchain-based kidney donation system named ‘‘Kidner’’ has been proposed. It offers a kidney-pair donation module instead of the traditional kidney waiting list, which is already in use. For example, when someone wishes to donate his/her kidney to a family member but their kidney is incompatible with the person they want to donate to, the system matches the donor’s kidney to another patient who also has an inconsistent donor’s kidney.

PRIVATE PERMISSIONED ETHEREUM NETWORK

Private blockchains provide enhanced security and privacy where the transactions and data are not accessible to the public and only viewed by authorized entities. Enterprises can use the Ethereum blockchain to develop their own private-permissioned blockchain to improve privacy, security, and confidentiality. In general, details of donated organ transplantation are strictly confidential. These details include the patients’ health records and family histories; therefore, a private permissioned Ethereurm blockchain is ideal for such an implementation.

BLOCKCHAIN INTEGRATION

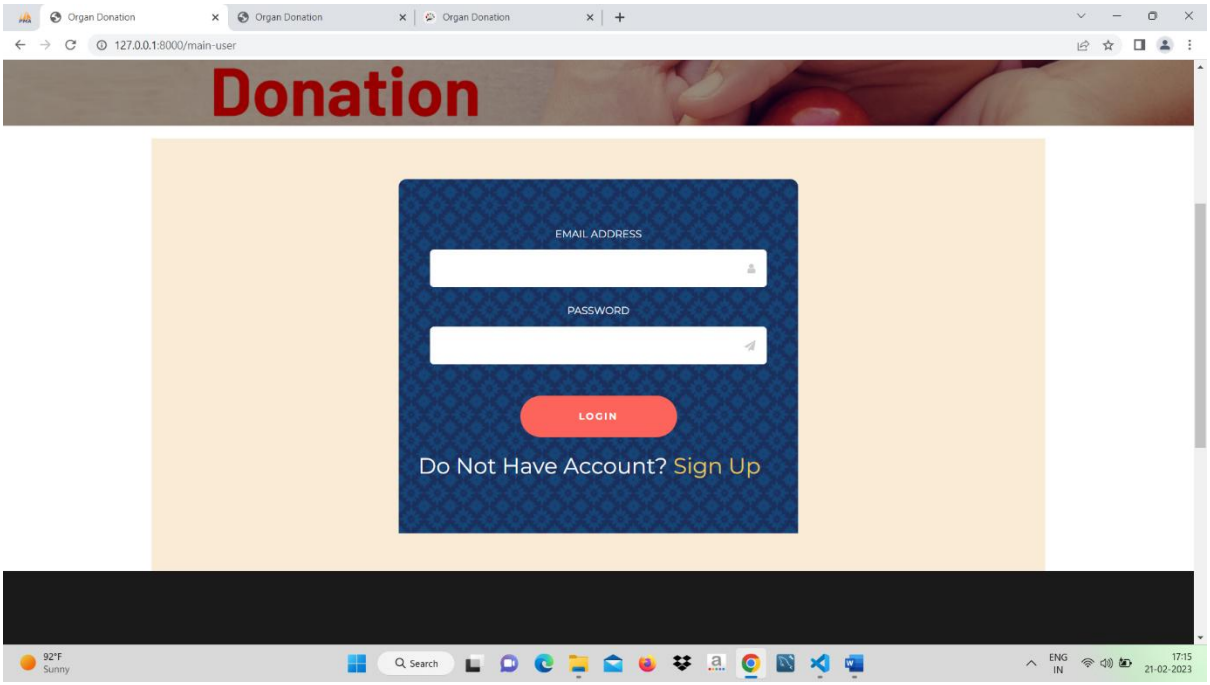
The blockchain network is the backbone of our proposed solution. It serves as the basis for recording transactions andevents permanently to ensure accountability and data provenance. The developed smart contracts must be deployed on the blockchain to ensure they are accessible at all times. However, it would not be ideal to deploy them on the main network during the testing phase.

PARTICIPANTS INTERACTIONS

The interaction among different participants within the matching smart contract, which can be divided into three phases. Phase 1 begins with creating a waiting list, in which an authorized doctor will add a new patient to the waiting list. The doctor will record the patient’s ID, age, BMI, and blood type. Phase 2 is fulfilled by receiving donors who have given their consent to

donate their organs. Only an authorized transplant team member will run the test approval function, and an event will be sent immediately. After that, the procurement organizer is ready to evaluate and register the donor. To make the announcement that a new donor has been registered, an event will be triggered. In Phase 3, the auto-matching between the donor and recipient is handled by the organ transplantation organizer. The auto-matching process is done based on the age range, blood type, and BMI range obtained from the donor. Finally, a matched patient ranked list is announced.

5. EXPECTED RESULTS


Organ Donation
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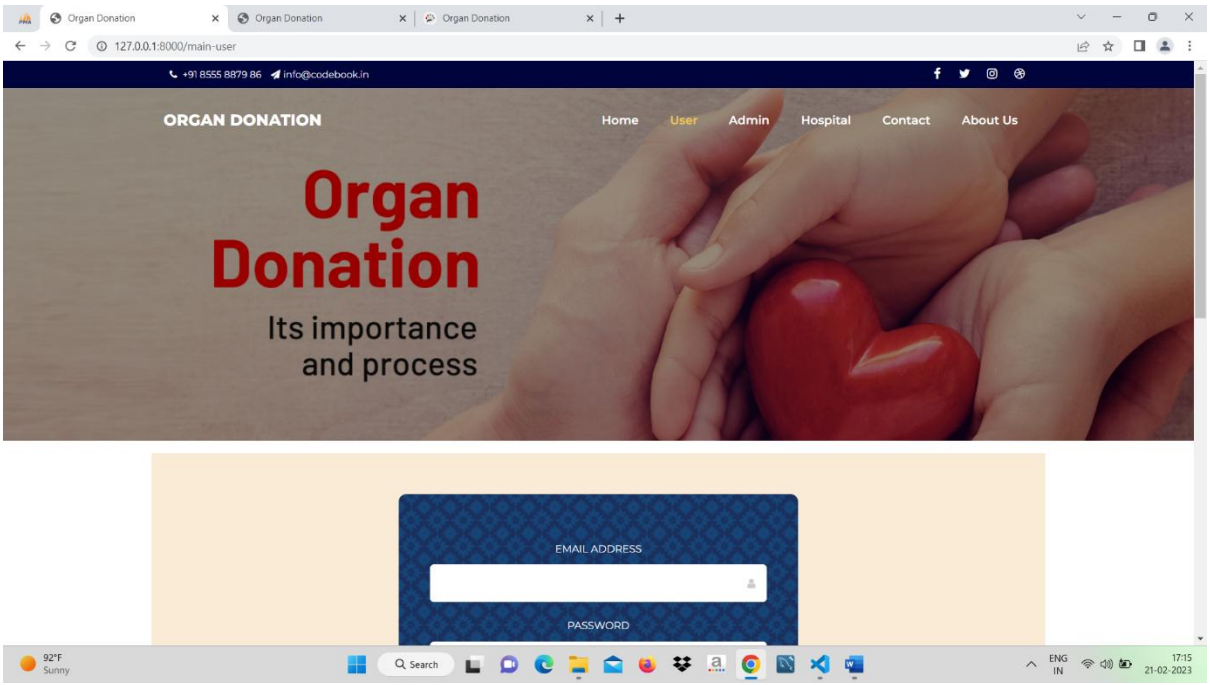
Donation
EMAIL ADDRESS
PASSWORD
LOGIN
Do Not Have Account? Sign Up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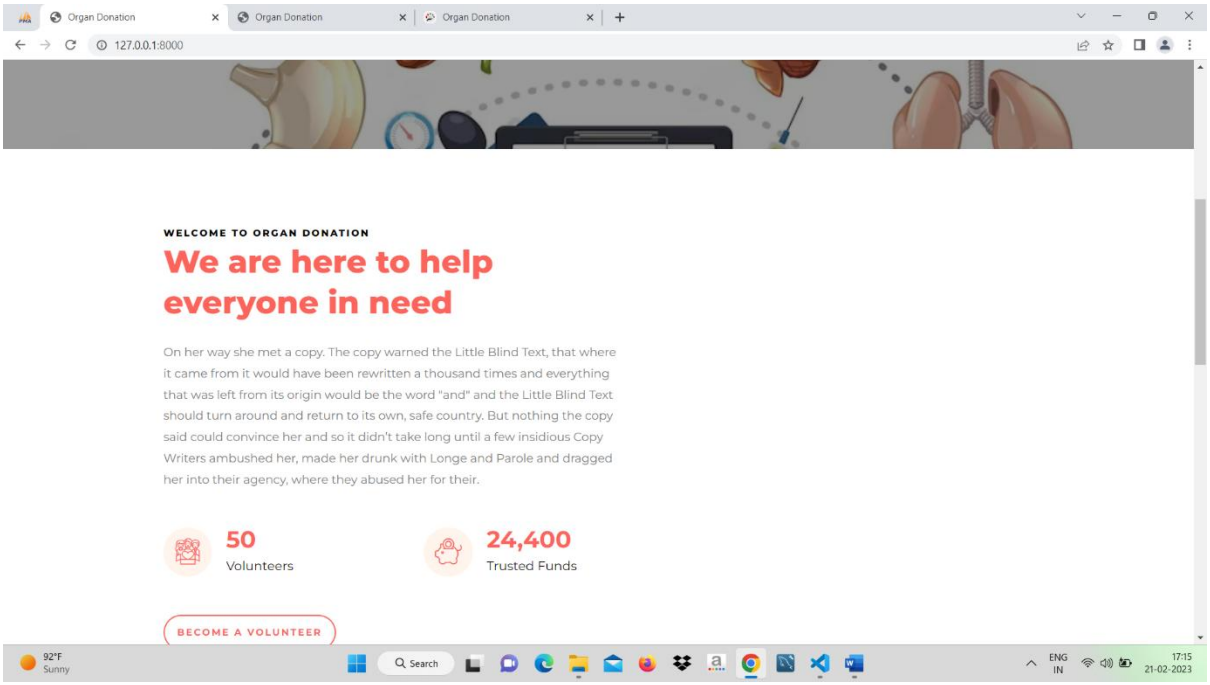
Organ Donation
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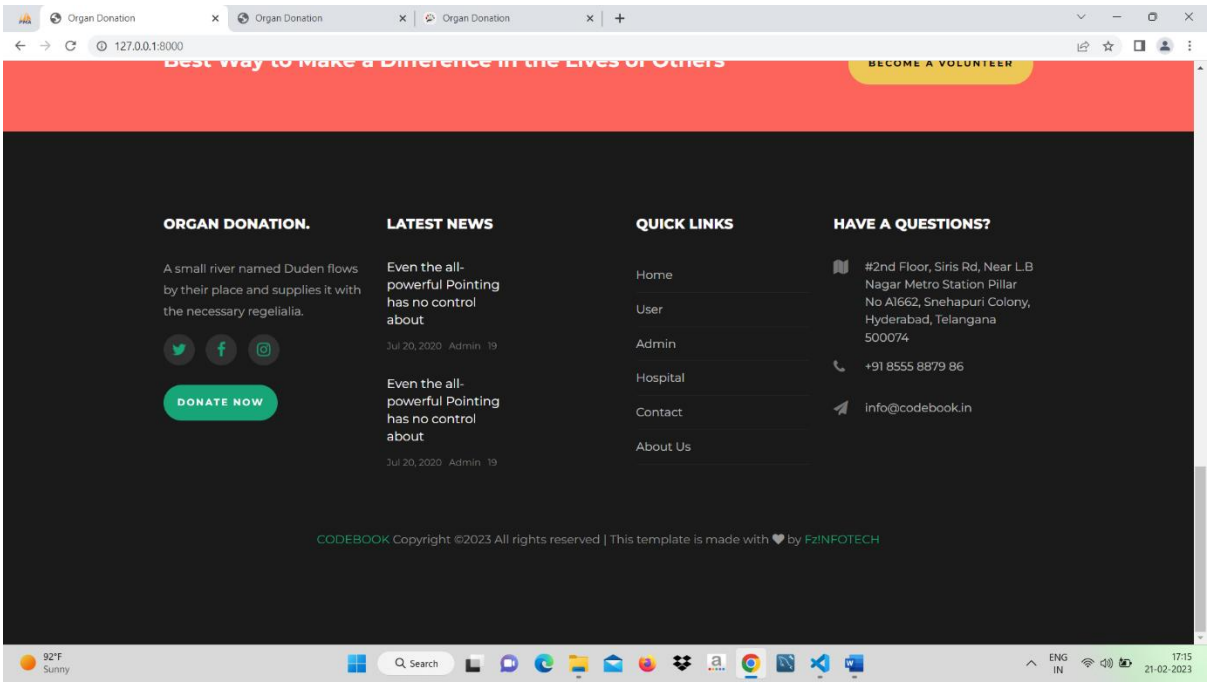
WELCOME TO ORGAN DONATION
We are here to help everyone in need
On her way she met a copy. The copy warned the Little Blind Text, that where it came from it would have been rewritten a thousand times and everything that was left from its origin would be the word "and" and the Little Blind Text should turn around and return to its own, safe country. But nothing the copy said could convince her and so it didn't take long until a few insidious Copy Writers ambushed her, made her drunk with Longe and Parole and dragged her into their agency, where they abused her for their.
50
Volunteers
24,400
Trusted Funds
BECOME A VOLUNTEER


Organ Donation
127.0.0.1:8000
BECOME A VOLUNTEER
ORGAN DONATION.
A small river named Duden flows by their place and supplies it with the necessary regelialia.
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6. CONCLUSION

In this paper, we have proposed a private Ethereumblockchain-based solution that manages organ donation and transplantation in a decentralized, accountable, auditable, traceable, secure, and trustworthy manner. We developed smart contracts that ensure the data provenance by recording events automatically. We present six algorithms with their implementation, testing, and validation details. We analyze the security of the proposed solution to guarantee that smart contracts are protected against common attacks and vulnerabilities.

We compare our solution to other blockchain-based solutions that are currently available. We discuss how our solution can be customized with minimal effort to meet the needs of other systems experiencing similar problems. In the future, our solution can be improved by developing an end-to end DApp. Furthermore, the smart contracts can be deployed and tested on a real private Ethereum network. Finally, the Quorum platform can provide better confidentiality because transactions among entities can only be viewed by specific participants and nobody else, which is not the case in our solution, where transactions between two participants are viewed by other actors authorized in the private blockchain.

Future Scope

In the future, modernizing hospital organ donation oversight with blockchain technology could revolutionize the field by introducing unprecedented levels of transparency, security, and efficiency. Blockchain's ability to create an immutable, decentralized ledger would ensure that organ donation activities are recorded transparently and securely. This would enhance trust in the system and streamline the process, reducing administrative burdens and costs. Additionally, blockchain could enable more accurate and efficient matching of donors and recipients, potentially saving more lives. Furthermore, by ensuring the integrity and privacy of donor and recipient information, blockchain could address concerns related to data security and compliance with regulatory requirements. Overall, the future scope of modernizing hospital organ donation oversight with blockchain holds immense promise for improving the organ donation process and increasing the number of successful transplantations.

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