The application of blockchain technology in the early warning and monitoring of infectious diseases

TIAN Yu1,a
Shanghai Institute of Technology
SIT
Shanghai,China
1135950474@qq.com

YU Wan-jun2,b
Shanghai Institute of Technology
SIT
Shanghai,China

ZHANG Miao 3,c
Shanghai Institute of Technology
SIT
Shanghai,China

ZHANG Min 4,d
Shanghai Institute of Technology
SIT
Shanghai,China

TANG Jun-yi5,e
Shanghai Institute of Technology
SIT
Shanghai,China

2020 5th International Conference on Intelligent Informatics and Biomedical Sciences (ICIIBMS) | 978-1-7281-8022-9/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICIIBMS50712.2020.9336418

***Abstract*—In order to improve the efficiency of emergency management and decision-making and command of infectious diseases, infectious disease early warning technologies and systems can be used to monitor the trend of abnormal outbreaks and provide timely and accurate warnings. However, the current infectious disease early warning system still has problems such as insufficient intelligence, poor circulation of key information, and difficulty in distributed collaborative decision-making. Based on the blockchain distributed computing architecture, combined with emerging information technologies such as artificial intelligence, big data, and smart contracts, an infectious disease monitoring and early warning technology and its implementation framework are proposed. The technology can efficiently concentrate multi-party monitoring forces, flexibly integrate multiple early warning methods, build a knowledge integration and smart interconnected distributed collaborative monitoring environment under the premise of security and privacy protection, and use smart contracts as open, fair, software-defined monitoring The agent integrates decision-making, monitoring infectious diseases and automatic early warning in real time, so as to take into account the requirements of early warning accuracy and timeliness, and avoid isolated evidence and decision bias.**

Keywords—Blockchain; smart contract; artificial intelligence; infectious disease monitoring; distributed collaboration

I. INTRODUCTION (*HEADING 1*)

The outbreak of the new crown epidemic in 2020 has posed a huge threat to the property safety of people all over the world. The use of infectious disease early warning technology and early warning system to monitor the trend of abnormal occurrence or increase of the epidemic in real time, and take measures for early intervention, is prevention The key strategy to control the epidemic. However, the early warning system and technology of infectious diseases will cause insensitivity to the early detection of unknown diseases due to the problems of automation, informationization, intelligence, and insufficient knowledge, which will cause early warning delays.

Blockchain technology is characterized by a high degree of transparency, decentralization, trustlessness, immutability, and anonymity. Smart contracts are contracts that use computer language to replace legal language to record terms and are automatically executed by programs. As an important extension of the smart contract running on the blockchain, it also has the advantages of open and transparent data, non-tamperable, permanent operation, safer, more economical and efficient, and no need for third-party arbitration. Therefore, this article proposes a key technology and its implementation framework for multi-party decision-making fusion monitoring and early warning based on blockchain. This method integrates a variety of early warning methods and multi-party monitoring resources, has the characteristics of privacy collaboration, security and credibility, long-term incentives, and automatic early warning, and can avoid problems such as isolated evidence bias, decision errors, and poor circulation of key data.

The purpose of this framework is to combine technical means such as artificial intelligence, blockchain and smart contracts with the advantages of human-machine monitoring.First, the use of artificial intelligence technology can enable intelligent algorithms to have expert-level accurate domain knowledge and the ability to detect abnormalities. Greatly reduce the pressure of manual supervision; second, use the technology of the combination of blockchain and smart contracts to maintain multi-party manual and machine direct reporting channels, so that smart contracts can be used as software agents to verify, evaluate, trace, compare, and integrate reported information. [1]If an abnormality is found, it can immediately alert the relevant social departments to improve efficiency and reduce the risk of manual early warning errors and early warning delays. This article is organized as follows: Section 2 outlines the current development status of epidemic early warning technologies and systems, and introduces related key technologies such as cryptography, blockchain and smart contracts; Section 3 proposes the key to epidemic monitoring and early warning based on blockchain

Technology, detailed introduction of its infrastructure and key component implementation; Section 4 discusses and analyzes the possible improvements and enhancements that the technology proposed in this article can bring to the existing system; Section 5 summarizes the full text.

II. LITERATURE REVIEW

A. Background and current situation of infectious disease early warning technology

Infectious disease early warning refers to promptly issuing an alarm when the incidence of infectious diseases increases abnormally so that relevant responsible departments and agencies and people who may be affected by the incident can respond in a timely manner. Epidemic early warning refers to the use of mathematical models and computer information technology to automatically detect possible contagious disease time aggregation signals based on the infectious disease information reported by medical institutions, thereby issuing early warning signals.

The existing methods of infectious disease analysis still have some shortcomings: First, the coarse granularity of the analysis method is simply divided by administrative divisions. The larger the administrative area, the more meaningless the warning effect of identifying infectious diseases. The truly valuable and meaningful infectious disease map can identify the distribution of patients. Secondly, manual carpet reporting not only costs a lot of manpower, but also has strong subjectivity and inaccuracy. In the information age, people's behavior data such as clothing, food, housing, and transportation can be obtained through network analysis, which is the first to understand infectious diseases. First-hand data. Finally, the existing methods still have a serious lag. With the epidemiological transmission thinking, close contacts are found in the whereabouts of the confirmed patients. The lag period has expanded the contact surface of the pathogen population due to the longer incubation period.

B. The connection between blockchain and cryptography

Cryptography is the research and practice of secure communication technology in the presence of a third party. The cryptographic technologies related to the blockchain include one-way function, AES symmetric encryption, Hash function, RSA, ECC public key encryption, digital signature and its promotion, commitment scheme, and zero-knowledge proof. [2]

Hash function is a function that maps messages of any length into a shorter fixed-length output message.Zero-knowledge proof means that the prover can convince the verifier that a certain assertion is correct without providing any useful information to the verifier. [3]Zero-knowledge proof is essentially an agreement involving two or more parties, that is, a series of steps that two or more parties need to take to complete a task.

C. Blockchain

Blockchain is a new application mode of computer technology such as distributed data storage, point-to-point transmission, consensus mechanism, and encryption algorithm. The so-called consensus mechanism is a mathematical algorithm in the blockchain system to establish trust between different nodes and obtain rights and interests.

The blockchain system is composed of data layer, network layer, consensus layer, incentive layer, contract layer and application layer. Among them, the data layer encapsulates the underlying data blocks and related data encryption and time stamping and other basic data and basic algorithms; the network layer includes distributed networking mechanisms, data transmission mechanisms, and data verification mechanisms; the consensus layer mainly encapsulates network nodes The incentive layer integrates economic factors into the blockchain technology system, including the issuance mechanism and distribution mechanism of economic incentives, etc.; the contract layer mainly encapsulates various scripts, algorithms and smart contracts, which is a blockchain The basis of programmable features; the application layer encapsulates various application scenarios and cases of blockchain. [4]In this model, the chain block structure based on timestamp, the consensus mechanism of distributed nodes, the economic incentive based on consensus computing power and the flexible and programmable smart contract are the most representative innovations of blockchain technology.

D. Smart contract

The term smart contract can be traced back to at least 1995 and was coined by Nick Szabo, a prolific cross-field legal scholar. He mentioned the concept of smart contracts in several articles published on his website. His definition is as follows: "A smart contract is a set of commitments defined in digital form, including agreements on which contract participants can execute these commitments." "A set of commitments" refers to the agreement between contract participants (often mutual) Rights and obligations. These commitments define the nature and purpose of the contract. Take a sales contract as a typical example. [5]The seller promises to send the goods, and the buyer promises to pay a reasonable price. "Digital form" means that the contract has to be written in computer-readable code. This is necessary because as long as the participants reach an agreement, the rights and obligations established by the smart contract are executed by a computer or computer network.

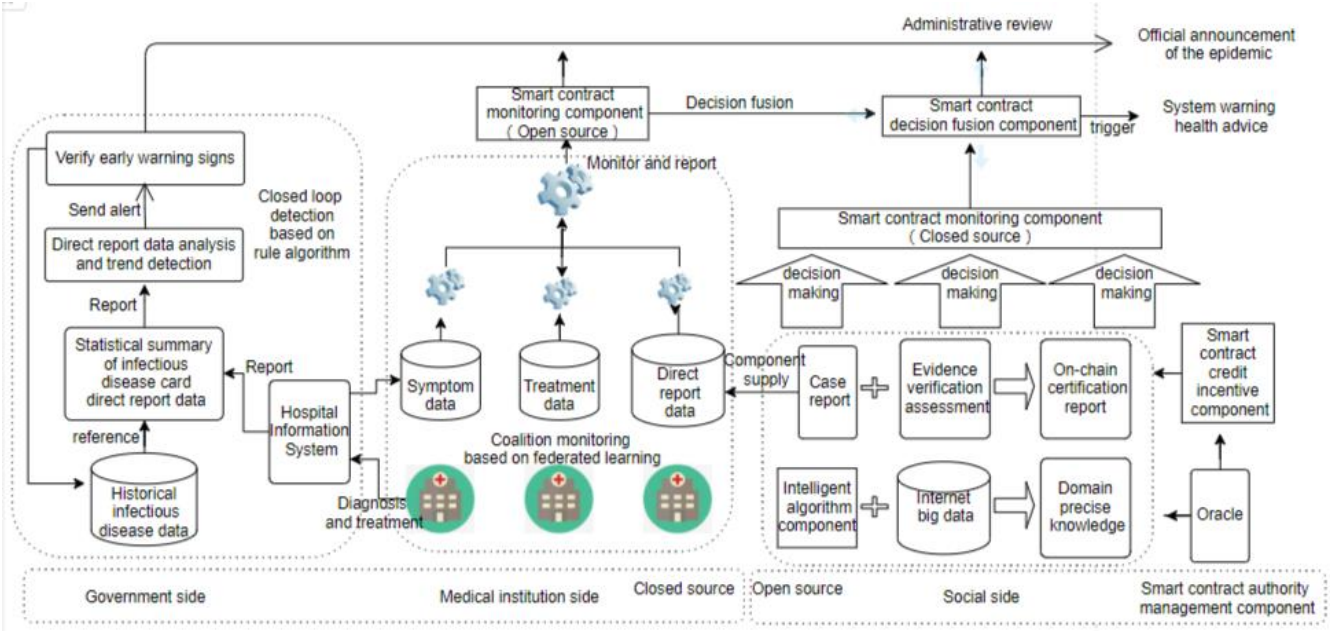
III. KEY TECHNOLOGIES FOR INFECTIOUS DISEASE MONITORING AND EARLY WARNING BASED ON BLOCKCHAIN

The monitoring and prevention of infectious diseases is the top priority of the prevention and control of infectious diseases, and timely monitoring and alertness to abnormal signals can prevent the spread of the epidemic. The key technology of infectious disease monitoring and early warning based on blockchain can concentrate the monitoring forces of the government, medical institutions and the general public, real-time and stable early warning of infectious diseases and public information disclosure, and timely reporting of abnormal information. The following will introduce two aspects of the basic architecture and key technology realization.

A. Infrastructure

Identify applicable sponsor/s here. *(sponsors)*

Figure 1 shows the basic architecture of the early warning technology in this article. The technology uses a blockchain and is divided into three sub-modules. Among them, the government side adopts the closed-loop detection based on the rule algorithm, the medical institution side adopts the federated learning-based alliance to detect medical treatment, and the social side adopts the collaborative monitoring based on the open blockchain market. Each sub-module user customizes the client through this module port, namely integration The decentralized application of smart contracts is used to interact with other module users or the blockchain to complete their respective monitoring tasks. During the interaction, all private files will be encrypted and stored in IPFS. Only the hash of public files is stored on the blockchain. Values and all interaction records are for verification and traceability. The system includes five main smart contract components: smart contract authority management component, smart contract monitoring component (open source data), smart contract monitoring component (closed source data), smart contract decision fusion component and smart contract credit incentive component. Each component consists of one The group runs on the blockchain to inherit and call sub-contracts, and set different usage permissions and data visibility according to functional requirements. The oracle will serve as a trusted external data source for smart contracts in the system, linking to verified authoritative sites under the chain, IPFS addresses, or other designated blockchain data sources for the contract to query the state of the external world, check trigger conditions, and execute the contract. The system contains 2 early warning channels: one is an epidemic warning channel issued by administrative agencies combining government, medical institutions and social decision-making information after administrative review; the other is smart contract decision-making fusion components that integrate medical care based on preset algorithms Institutional and social decision-making information is judged, and the epidemic early warning channel is automatically released after the early warning conditions are met.



The system includes five main smart contract components: smart contract authority management component, smart contract monitoring component (open source data), smart contract monitoring component (closed source data), smart contract decision fusion component and smart contract credit incentive component. Each component consists of one The group runs on the blockchain to inherit and call sub-contracts, and set different usage permissions and data visibility according to functional requirements. The oracle will serve as a trusted external data source for smart contracts in the system, linking to verified authoritative sites under the chain, IPFS addresses, or other designated blockchain data sources for the ontract to query the state of the external world, check trigger conditions, and execute the contract.

IV. KEY TECHNOLOGY REALIZATION

A. Blockchain-based federated learning

Federated learning is a new type of machine learning framework used to solve the problem of data islands and protect data privacy. In this framework, users exchange and integrate local model parameters to jointly establish a virtual federation model to aggregate without exchanging private data Training data to improve model accuracy. Taking the early warning technology based on symptom monitoring as an example, the process of classifying unknown diagnosis data after learning disease characteristics from historical diagnosis data sets using machine learning algorithms can be transformed into a supervised machine learning classification problem.

Remember that the local symptom database of the first medical institution containing data samples of symptoms is $D_k = \{(x_1, y_1), \cdots, (x_{n_k}, y_{n_k})\}$. The empirical risk of the local classification model to the local symptom database, that is, the objective function of the local classification model can be formalized as equation (1) [6]:

$$F_k(w) = \frac{1}{n_k} \sum_{j_i=1}^{n_k} f_{j_k}(w; x_{j_k}, y_{j_k}) \qquad (1)$$

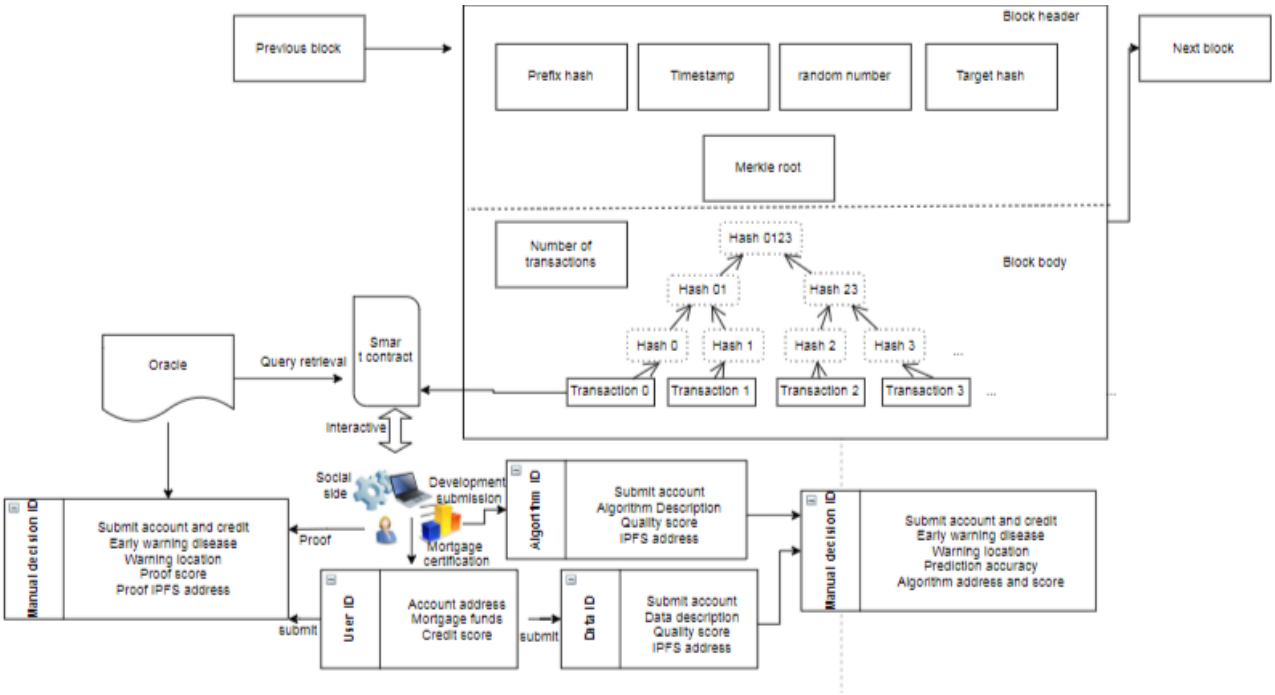
Among them, w is the model parameter. Then the global model composed of m medical institutions needs to minimize the overall classification error, that is, the objective function of the global model is formalized as follows:

$$\min_w F(w), F(w) := \sum_{k=1}^{m} p_k F_k(w), p_k \cdot 0, \sum_{k=1}^{m} p_k = 1 \quad (2)$$

among them, p_k is the weight of k local classification model in the overall model.

B. *Open blockchain market and decision fusion algorithm*

Figure 2 shows the collaborative monitoring process of the open blockchain market in this article. The key parameters such as user ID, data ID, algorithm ID, manual decision ID, and algorithm decision ID described in this article are shown in Figure 2. The data stored by IPFS in the system includes shared early warning data, shared intelligent early warning technology and manual decision-making evidence materials. The credit/quality scores of all users, data, algorithms, and decisions are initialized by the smart contract authority management component, and subsequently recorded and updated by the smart contract credit incentive component. The update methods include user verification and system evaluation.



V. DISCUSSION AND ANALYSIS

The key technologies of multi-party decision-making fusion monitoring and early warning of infectious diseases based on blockchain proposed in this paper are discussed from three aspects: early warning data, early warning technology and early warning subject.

(1) Early warning data, using open/closed source information fusion, credible connectivity and privacy calculations, identity authentication and credit tracing of all users, data, algorithms and decisions, thereby encouraging low-noise data and high-quality data in the long-term monitoring cycle Algorithm sharing and fusion of trusted multi-source decision-making.

(2) Early warning technology. This article proposes to build a decentralized intelligent algorithm component market: encapsulate intelligent early warning algorithms such as machine learning, deep learning, automatic machine learning, or smart contracts such as permission management, credit incentives, and decision fusion into pluggable standardized program components , The encryption is stored in IPFS, and then submitted to the blockchain market for trading, sharing and evaluation, which can avoid lone evidence decision bias.making.

(3) Early warning subject, long-term incentives, and large-scale multi-party collaboration. Disease monitoring is a long-term continuous collection, verification, and analysis of the dynamic distribution of disease and its influencing factors. The smart contract credit incentive component collects and compares information and early warnings of all participants in real time As a result, all participants and participating elements are reversely evaluated and contribution quantified, thereby providing long-term incentives for distributed collaboration, adjusting data algorithms and decision weights, and improving distributed decision-making accuracy. [7]

CONCLUDING REMARKS

This paper proposes a key technology of infectious disease monitoring and early warning based on blockchain, smart contracts, artificial intelligence and other technical means. The technology is composed of three monitoring modules: closed-loop monitoring based on rules and algorithms on the government side, alliance monitoring based on federated learning on the medical institution side, and open market collaborative monitoring on the social side based on blockchain. It can promote multiple sources under the premise of security and privacy. The sharing of early warning data, the expansion and integration of multiple early warning technologies, and the long-term coordinated monitoring of multi-party monitoring forces. The smart contract with preset rules in the system will serve as an open, fair, software-defined monitoring agent, which will provide real-time warning when monitoring abnormalities. It is conducive to the public prevention and control of infectious disease epidemics, and avoids bias in decision-making of isolated evidence and poor circulation of key data. With the further development of blockchain cross-chain technology, second-layer expansion solutions, trusted computing hardware and homomorphic encryption technology, the key technical architecture proposed in this article is expected to be applied to independent research and development of secure and controllable blockchain as a service , And form an intelligent blockchain system focusing on infectious disease monitoring and early warning.

REFERENCE

[1] XIONG W Y, FENG Z J. Overview on communicable disease surveillance in China[J]. Chinese Journal of Epidemiology, 2011, 32(10):957-960.

[2] OUYANG L W, YUAN Y, WANG F Y. A blockchain-based framework for collaborative production in distributed and social manufacturing[C]//2019 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI). Piscataway: IEEE Press, 2019:76-81.

[3] YANG W Z, LAN Y J, LI Z J. Review and prospect of research on early warning of infectious diseases[J]. Chinese Journal of Preventive Medicine, 2014, 48(4): 244-247.

[4] SALATHE M. Digital pharmacovigilance and disease surveillance: combining traditional and big-data systems for better public health[J]. Journal of Infectious Diseases, 2016, 214(suppl_4): S399-S403.

[5] GINSBERG J, MOHEBBI M H, PATEL R S, et al. Detecting influenza epidemics using search engine query data[J]. Nature, 2009,457(7232): 1012-1014.

[6] ODLUM M, YOON S. What can we learn about the Ebola outbreak from tweets?[J]. American Journal of Infection Control, 2015, 43(6):563-571.

[7] HASSELGREN A, KRALEVSKA K, GLIGOROSKI D, et al. Blockchain in healthcare and health sciences, a scoping review[J]. International Journal of Medical Informatics, 2019, 134: 104040