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Organizational Management using Software-defined Robots based on Smart Contracts

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***Abstract*—With the rapid development of social media, fast transition of organizational management modes, as well as the increasing security risks caused by human intervention and operations, the existing organizational management systems suffer a severe problem of lowered efficiency and security. This motivates our research. In this paper, we strive to design a new solution to this problem, via instantiating the traditional PDCA cycle theory and using software robots powered by blockchain and smart contracts. In our framework, blockchain and smart contracts can guarantee privacy-protected, traceable, and tamper-resistant data access, and can also help reduce the human intervention. Based on the PDCA cycle theory, we propose the PDCA closed-loop ecological chain on the basis of blockchain. We also validate our work in a real-world scenario, and the results can prove the effectiveness of our model.**

Keywords—PDCA; blockchain; software-defined robot; smart contract

I. INTRODUCTION

In literature, organizational management systems refer to the management systems that provide a scientific basis for decision-making and organizing through unified or classified management, including planning, organizing, directing, staffing, daily operations and controlling work services for an organization [1]. Organizational management systems need to provide administrations with four aspects of information services: collecting information, processing information, identifying information, and using information. The application of organizational management systems in the grass-roots level can improve the efficiency of work and reduce redundancy. For the middle level, it can change the structure of power and organizational structure. For the senior level, it helps provide decision support systems, enhance the economic benefits of enterprises or organizations and find opportunities for development.

With the development of socio-economics and the emergence of new organizational forms, the organizational management systems in practical applications are exposed to an increasingly large number of problems. The design and application of the organization management systems are thus facing new challenges.

The most critical one is without doubt the poor efficiency [2]. In most of the organizational management systems, manual operation is an indispensable part in the whole management process, involving inputting, processing and storage [3]. In particular, if the main business functions of the system are involved in abundant manual operations, the repeated manual operations will drag down the system efficiency and quality with the frequent invocations of the business. Manual operation has become the key point to restrict the efficiency of modern organizational management systems. This is an urgent problem to be solved.

The second key limitation of current organizational management systems is unpredictable security risks in the manual operation [4]. Besides, modern cryptography technology can only ensure the security of the digital information in the communication process, but cannot solve the manual operation or malicious misuse behavior efficiently. It has been a widely discussed problem that how to enhance the security of the data in the design and operation stage of the organizational management systems.

Additionally, the traditional organizational management system is not suitable for the new type of organization structure. The organizational managements in the past often had a multi-level structure, and the data in them was static. Nowadays, the Internet technologies and the social medium have gained success, such as Twitter and WeChat [5]. It is not only enriching the personal life, but also changing the structure of the organizational management to the flat structure [6, 7]. It leads to the fact that the traditional organizational management systems are no longer suitable.

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Most of the current studies try to optimize the efficiency of the organization management systems from two aspects. The one is to reduce the manual operations and integrate the data resources using the information technologies, such as data mining and data warehousing [8, 9]. Although some studies are trying to use artificial intelligence, data mining and other information techniques to reduce manual operations, these cannot guarantee the security and reliability of data during inputting and processing. The other is to explore more standardized and efficient organizational management mode by optimizing the organization management model.

In this paper, we present an organizational management solution to instantiate the PDCA theory with software-defined robots powered by blockchain and smart contracts. We utilize blockchain to enhance system security because of its non-repudiation, unforgeability and traceability [10]. In addition, the smart contracts enabled by the blockchain can help improve the system automation by reducing the manual operation of the organizational management systems [11]. It is applicable to the flat organization structure because all authorized nodes can participate in the implementation of the contracts. For dealing with the changeable data resource, we choose the dynamic software-defined robot to service as an agent [12], which is a kind of networking tool integrated with artificial intelligence, natural language processing, machine learning and intelligent management and a series of methods and technologies, designed for specific domain knowledge management applications, and implemented in software programming language. In order to adapt to the dynamic management structure and improve the quality of the system, we design our system based on the classical PDCA cycle theory [13]. It is applicable to various scenarios of quality management and is the basic theory of quality management.

The ultimate goal for our solution is to achieve a safe and efficient organizational management system deployed on blockchain. The remaining part of the paper is organized as follows. In Section II we introduce the basic technologies, including blockchain, smart contract and PDCA cycle. In Section III we describe the PDCA closed-loop management ecosystem framework based on bockchain and smart contracts. In the following three sections, we described the core models of this ecosystem in detail, including Goal Management, Token Management, and Work Management. In Section VII, we conduct an empirical study to validate our proposed model in a real-world scenario. Finally, we conclude our contribution and discuss our further work in Section VIII.

I. BASIC TECHNOLOGIES

A. Blockchain

Blockchain is an emerging decentralized architecture and distributed computing paradigm which is first used with success in Bitcoin [14]. It is a highly anticipated new technology that can achieve consistency in P2P networks among the mutually trustless entities. It realizes a decentralized trust system without any trusted third party. It can guarantee privacy-protected, traceable, and tamper-resistant data access. The infrastructure model of blockchain is illustrated in Fig.1. Generally speaking, the blockchain system consists of the data layer, network layer, consensus layer, incentive layer, contract layer and application layer [10]. It provides strong non-repudiation, unforgeability and traceability relying on the hash function, the signature scheme and the encryption technology involved in the data layer, so that it can help improve the security of the organizational management and trace the history of data. Multiple applications of blockchain have been extended to networking, intelligent manufacturing, supply chain management, digital asset trading and so on [15, 16].

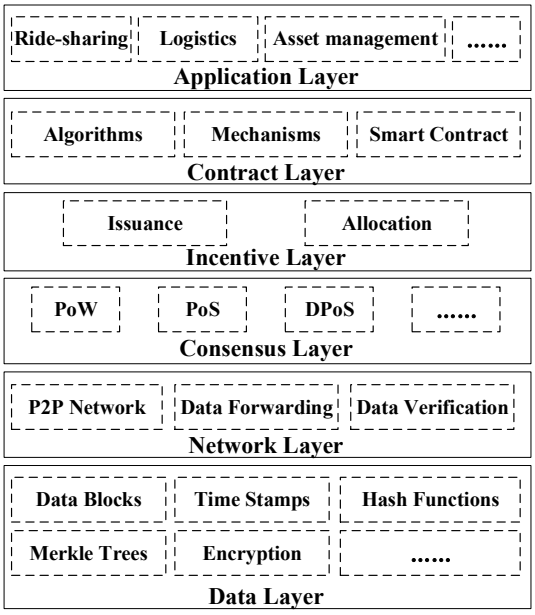

Figure 1. The infrastructure model of blockchain

B. Smart Contract

Smart contract was firstly proposed by Nick Szabo, defined as the implementation of the contract computerized transaction protocol [17]. Although Bitcoin supports a small range of programmable logic to be executed by the blockchain, only a limited range of smart contracts can run on it. It was not until the appearance of Ethereum [18] in 2014 that the first Turing-complete decentralized smart contract can be realized, which is referred to as a section of code that can be executed automatically like a distributed intelligent robot. Then, smart contract begins to attract more attention and to be widely used in different kinds of fields in information systems [19].

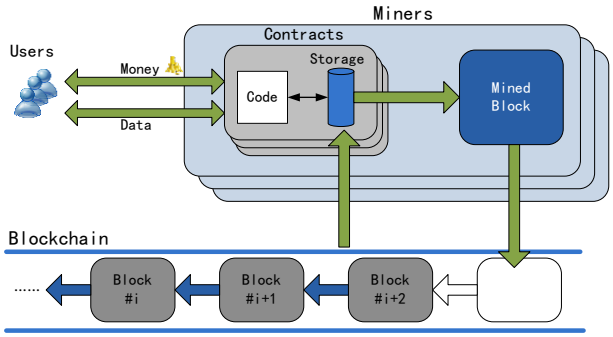

Figure 2. Schematic of smart contracts based on blockchain

Fig.2 shows the schematic of a decentralized system with smart contracts, as illustrated by Juels et al. [20]. A smart contract's state is stored on the blockchain. A smart contract program is executed by a network of miners who reach consensus on the outcome of the execution, and update the contract's state on the blockchain accordingly. Users can perform two types of transactions, whose difference is whether or not to transform tokens. It can reduce the manual operations and enhance the security by presetting the triggers of all operations in the contract.

C. PDCA Cycle

PDCA cycle is a well-known model for continual process improvement that is followed by the quality management. It is proposed by Shewhat, the father of statistical quality control and also known as the Deming circle [21]. PDCA is a combination of words Plan, Do, Check and Action. And PDCA cycle is fully managed in the order of P-D-C-A and continues to circulate. PDCA cycle is made up of four steps.

- Plan: to establish the goals and processes according to the requirements of the customer and the policy of the organization.
- Do: to execute according to the plan to achieve the goals.
- Check: to check whether the results are consistent with the expected results and analyze the problem during the process.
- Action: to deal with the problems and standardize the activity plan.

Not all problems can be solved in a PDCA cycle, and the legacy problems will automatically turn into the next PDCA cycle, in order to reduce error operation and improve management quality [22].

II. The Platform Framework

A. The Application Background

Technological innovation is the core driving force of social and economic development, and at the same time the emergence of new technologies brings new challenges to organizational management. With the rapid development of the Internet, social media platforms, such as WeChat, have been witnessed to play a key role in employee management for organizations, enabling individual or groups of employees to express their viewpoints or report their works in a real-time fashion. Social media has drawn closer relations between managers and employees, and the flattening trend of the organizational structure has become increasingly evident. The resulting Cyber-workspace in social media, which exists in parallel with employees' physical workspace, has the potential of greatly changing the forms and functions of the organizations. The behavior data of the employees in the Cyber-workspace is particularly important. With the help of software-defined robots, which represents "knowledge automation" [23, 24] of the cutting-edge intelligent tools, virtual workspace can be achieved using in-depth mining. At the same time, the problems of tampering data and over-reliance on manual implementation within the organizational management are increasingly prominent. The blockchain and smart contracts, widely known as one of the disruptive technologies emerged in recent years, also bring new opportunities to organizational management.

B. Analysis and Framework

Based on the blockchain and smart contracts, combined with a framework that incorporates robots and software-defined surrogates using the ACP-based parallel systems theory [25], this paper proposes the construction of PDCA closed-loop management ecosystem. It's an organizational management solution to instantiate the PDCA cycle with software-defined robots powered by blockchain and smart contracts. It can be logically divided into three levels, including the data layer, the business layer and the presentation layer. The blockchain is the most basic infrastructure of the data layer to support distributed storage and the operation of smart contracts. Currently, blockchains are not efficient to support some scenarios, such as the difficulty of querying by content. Therefore, according to the business logic, the data with little relation to blockchains is supported by the traditional database, so as to keep the operation of the system in a combination of on-chain and off-chain. The data layer includes data access components which are in charge of data accessing. Smart contracts tools are responsible for validation, compiling and deployment of contracts. As the system needs to access some third-party data, it's helpful to build a service proxy to obtain the external data. The business layer is composed of Goal Management, Token Management and Work Management. The business logic of the previous two subsystems is mainly described in the smart contracts. The presentation layer consists of rich user interfaces, such as wallet, web, app, etc. It can provide users with a good interactive experience. The platform architecture is shown in Fig. 3.

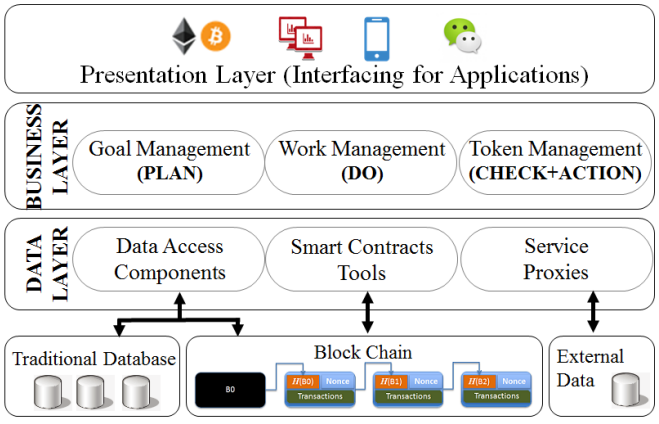

Figure 3. PDCA closed-loop management ecosystem architecture

III. Goal Management Model

The prediction market utilizes reasonable incentive mechanism to help participants express their judgment of the future events in real time. By collecting and integrating the confidence of all parties involved in the same event, the prediction and guidance of the future results of the event will

be generated. The goal management subsystem is responsible for the first step "Plan" in PDCA cycle and is a distributed prediction market platform. It is supported by the blockchain infrastructure and is driven by smart contracts. As we know, intrinsic distributed mechanism of these technologies ensures that the predictive results cannot be manipulated, and also provides an effective infrastructure that can guarantee the diversity of information and the decentralization of organization. Its logic is almost represented in the format of smart contracts to accomplish organizational goal set by managers and employees. After these smart contracts have compiled by "Smart Contracts Tools" of data layer, we can get Contract ABI (Application Binary Interface) which is a bridge between presentation layer and business layer. When smart contracts have been deployed on blockchain, the front-end can interact with them by JSON RPC API. The business logic consists of the management of target, arbitration, account and settlement. This subsystem model is shown in Fig. 4.

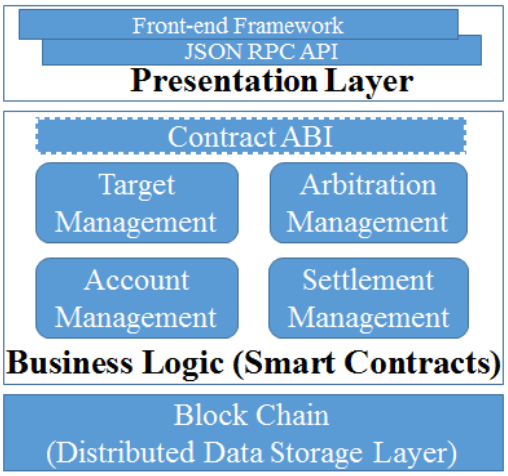

Figure 4. The model of goal management

First, a target should be created. A target means an event that might happen in the future of an organization. Then, employees can contribute their own experience and wisdom to anticipate this bet with token. Token means a negotiable encrypted digital right certificate, issued by the token management subsystem. The amount of tokens participating in prediction represents the confidence to accomplish this goal. Once the agreed conditions are met, which can be self-tested or voted by credible arbitrators, the contract will be executed automatically and the tokens will be reassigned. Tokens are the medium of organizational rewards and punishment mechanism, which can guide employees and correct mistakes in organizational management.

IV. Work Management Model

Software-defined robots are the agents of employees in the virtual space. We used the robots to collect and analyze the behavior of employees within daily work. It's helpful to quantify work behaviors of employees and get the contribution scores according to the outcome. It's the carrier of blockchains and smart contracts to implement PDCA cycle.

The model of work management is depicted in Fig. 5.

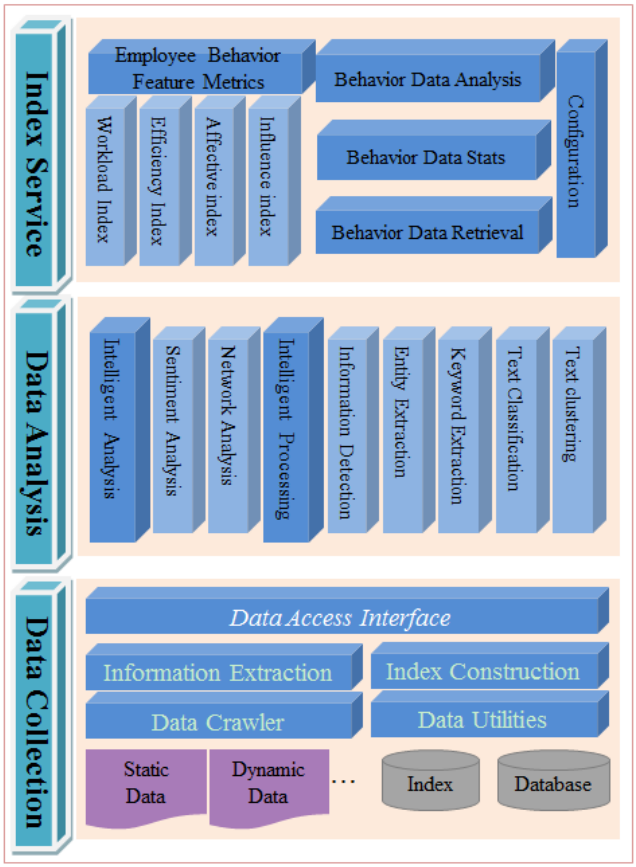

Figure 5. The model of work management

A. Data Collection

The information of employees can be divided into static data and dynamic data. Static data generally refers to structured data stored in an information system of the organization, with a long updating cycle. Dynamic data refers to the real-time data flow in the daily work of employees, generated in social media platforms, such as WeChat. This kind of data is typically short, unstructured and fast-updating, but it can accurately reflect the real-time work content of employees and is the basis for quantifying organizational behavior. Thus we use the crawler technology to achieve the efficient data collection of work related information generated in the Cyber-workspace. Then, we use the information extraction, integration and indexing to make data available and formally-defined. Finally, the unified data access interface is abstracted for efficient and convenient read and write operation.

B. Data Analysis

In order to achieve the in-depth development and intelligent mining of employees' behavior data, we conduct two-level analysis. The one is basic intelligent processing work based on Classification, Clustering, Entity Extraction and other knowledge acquisition technologies. The other focuses on quantitative analysis of the emotion and the group cooperation. Sentiment Analysis helps us capture special events that cause mood swings during daily work. Network

Analysis is especially useful to understand and master the pattern of each group, such as who is the core of this group and how many pairs of close partners.

C. Index Service

Considering the uncertainty, diversity and complexity of the employees' behaviors, a single feature or model cannot accurately describe the behavior entity. So we produce metrics to support behavioral profiling for analyzing and better understanding employees, with the input of large amounts of real-time collected data generated by employees' daily reported works on social media [26]. These metrics, including Workload Index, Efficiency Index, Affective index and Influence Index, describe the individual and group behavior characteristics of the organization from four dimensions of work intensity, work efficiency, job satisfaction and work importance, as depicted in Fig. 6. All metrics can be weighted to compute a contribution score for each employee. By establishing a relationship between contribution and tokens, we can quantify the employee's job performance and contribution to the organization in terms of the amount of tokens the employee receives per day.

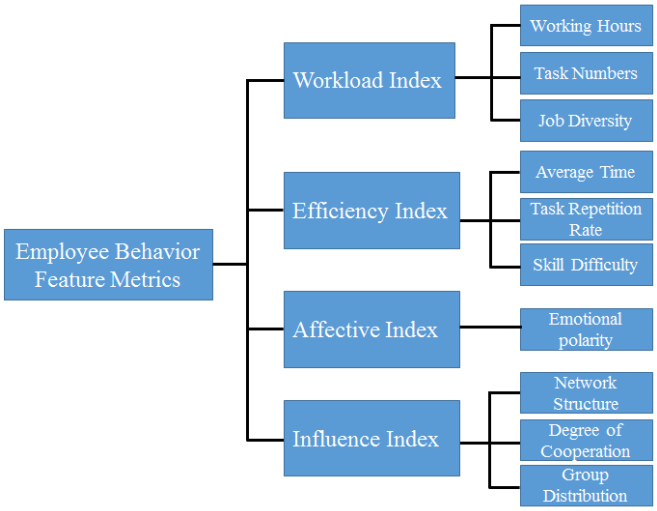

Figure 6. The employee behavior feature metrics

V. Token Management Model

The token management subsystem provides the operational media for quantifying organizational management, and effectively concatenates PDCA cycle. The model is shown in Fig. 7. The token management subsystem is constructed based on blockchain, which is similar to a coupon system, including the issuance, circulation and trading of coupon-like assets. The token is generated during the creation of the block and is managed by the issuance component. Employees can obtain tokens according to their contribution to the organization. Settlement component is responsible for circulation. In the process of goal setting, both managers and employees need tokens for participation. The implementation of smart contracts will also lead to the redistribution of tokens. The incentive mechanism of tokens constrains and guides the participants in specific scenes in the organization management, promotes the achievement of organizational goals and guides the organizational management.

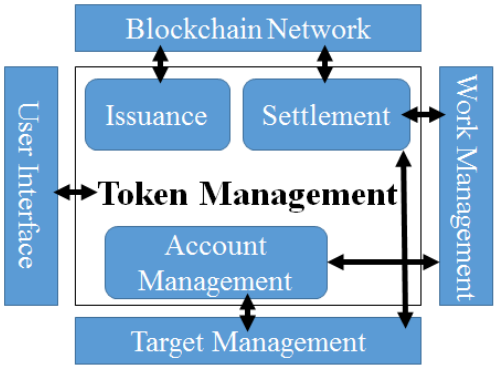

Figure 7. The model of token management

VI. An Empirical Study

In what follows, we conduct an empirical study to validate our proposed model in a real-world organization of China, where employees can use our model to report their daily works and discuss work-related topics in WeChat. A set of rules or policies are formulated to encourage and regulate the postings of group members, especially the daily work reporting.

The PDCA closed-loop management ecosystem infrastructure has been built in our use case. A private blockchain built by Geth keeps running to support token issuance and redistribution. Large amounts of real-time data generated by employees on WeChat will be collected and analyzed in a real-time fashion. Each employee has a corresponding robot agent in the paralleled virtual workspace.

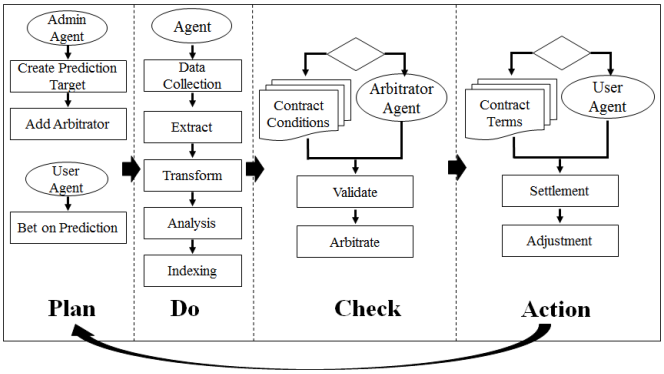

Figure 8. The PDCA process of the use case

In the first step of "Plan", an Admin Agent typically representing a high-level leader creates a target. Then, another role for arbitration would be chosen by Admin Agent. Arbitrators should be credible and reliable. And common employee can take part in this betting with tokens. Each employee's agent plays an important part in the next step of "Do". After a series of data processing and analysis, we can obtain quantitative indicators of employee behavior. The work of employees will be quantified by the corresponding number of tokens. When a milestone is reached or a preset

condition is met, we will enter the "Check" step. In this step, we support decentralized and traditional arbitration. The former is executed by smart contracts automatically and the latter is realized through voting by the chosen arbitrators. Finally, we take the "Action" step. Similar as the "Check" step, it can be implemented in two ways. The one is auto-execution according to contract terms, and the other is by manual operations. In this step, we can find the deviation from the predetermined target and find out the problem, do some necessary adjustments and re-launch the new round of PDCA cycle. The entire process of this use case is shown in Fig. 8.

VII. CONCLUSIONS AND FUTURE WORKS

Blockchain is an emerging and fast-growing decentralized architecture and distributed computing paradigm. Its key advantages include time-series data, tamper-resistant, as well as programmability in the form of smart contract, which is capable of auto-executing or self-enforcing. Thus, it is particularly suitable to solve the increasingly prominent problems of tampering data and heavy reliance on manual implementation within the organizational management. In this paper, we proposed an organizational management solution to instantiate the PDCA cycle with software-defined robots powered by blockchains and smart contracts. First, we introduce the basic technologies, including blockchain, smart contract and PDCA cycle. Then, we describe our "PDCA closed-loop management ecosystem" which is designed to collect employees' daily work behavior data, compute contribution scores through quantitative analysis, and guide the participants in PDCA cycle supported by blockchain and smart contracts. Then, we explain the core framework of this ecosystem in detail, including Goal Management, Token Management, and Work Management. Finally, we conduct an empirical study to validate our model and describe the entire process of a use case in a median-size organization of China.

This paper represents our preliminary study and work on the emerging blockchain and smart contract area, and our main purpose is to achieve a secure and efficient organizational management system deployed on blockchain. In our future work, we are planning to analyze employees' behavior using a Long Short Term Memory (LSTM) model to build a personalized behavior model for each employee, and we are also planning to improve our ecosystem using Parallel Blockchain [27], which offers the key capabilities including computational experiments and parallel decision-making to realize the effective blockchain management and decision-making with descriptive intelligence, predictive intelligence and prescriptive intelligence.

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