A Consortium Blockchain System for Verifying Digital Contents on Traditional Costumes

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Abstract. Many countries and organizations have an archive database for the digital preservation of cultural heritage. As recording cultural heritage data becomes more common, the importance of a reliable database is emphasized. However, if the verification of the produced digital heritage content is not correct, continuous errors are yielded in their applications and cultural heritage is misinterpreted. In this paper, we propose a consortium blockchain system for verifying digital cultural heritage contents. Blockchains, which have been applied to various fields recently, are a distributed data storage technology proposed by *Satoshi Nakamoto*. Blockchains are attracting attention as a technique for creating and storing reliable records owing to its property that it cannot be arbitrarily changed. We propose a verification system that is organized by three expert groups for assessment: researchers, curators, and artisans. The three expert groups review the digital heritage content and finally approve the content via a consensus process. To this end, the approved digital content is created as a block and stored in a blockchain record. We expect that the proposed consortium blockchain system will obtain efficiency and reliability in the screening process by leaving a reliable record of the digital content.

Keywords: Consortium blockchain · Digital contents of cultural heritage
Verification system · Smart contract

1 Introduction

Many countries and institutions have archived their cultural heritage digitally for preservation and opened it up to the public [1, 2]. The most important role of digital heritage is for it to be shared to satisfy the public interest for heritage of humanity. For example, the Smithsonian museums in the United States provide 3D digital content on cultural heritage in their collections [3]. Europeana is a digital library project in Europe that provides digital content from libraries, museums, art galleries, and archives throughout Europe [4]. The government of South Korea conducted a project for discovering and digitizing a cultural heritage and provided it to the public via the web [21].

The shared digital cultural heritages are widely used for cultural archetypes and applications, but not all contents are verified correctly. The cultural heritage registered

M. Ioannides et al. (Eds.): EuroMed 2018, LNCS 11196, pp. 437–446, 2018.
https://doi.org/10.1007/978-3-030-01762-0_38

in the digital archive must clearly verify the uncertainties that may arise in the reconstruction and recording of the contents, and then transmit them to the user [5]. The unverified digital heritages yield severe errors in their application contents. Based on this awareness of the problem, the need for the verification of digital contents via selected experts has been raised.

Since the produced digital contents of cultural heritage have historical significance in society, it should strive for long-term preservation without changing its data [8]. Long-term preservation should be associated with the integrity of the data. This is possible through the establishment of reliable databases and institutionalized standards [7].

Recently, blockchains [9] have received close attention as a reliable distributed data storage technology. The blockchain is a technique for storing and distributing replicated data to all nodes participating in the system without using a central server. It is almost impossible to make any changes to the records because the blockchain compares the data of each node from time to time to find the changed part. Thus, the blockchain guarantees the integrity of the data and can maintain a permanent record. Some researchers are aware of their potential as a reliable database and are actively conducting research on this [10]. In addition, smart contracts built into the blockchain enable automated work processes.

However, it is difficult to utilize it in a system that needs to be controlled because of the features that are open to unspecified individuals. The consortium blockchain [15] has been presented to solve this problem. The consortium blockchain is a system that gives promised organizations and individuals the authority to participate in the system and ensures the validity of the agreed contracts. It uses a restricted network, so it is easy to control the system and it can process data quickly. This can therefore be useful for trading platforms or government agencies that require approval.

Until now, the blockchain has been recognized as an efficient data validation system that guarantees integrity. In digital cultural heritage content verification, the blockchain can be used as an important system. Most digital archives currently in use have guidelines for verifying digital content, but without separate protocols. However, content verification through guidelines is inefficient because there are time and location constraints. The system proposed in this paper is quick and efficient because it can execute the protocol online using a smart contract. In particular, the cultural heritage expert agreement system using blockchain for content verification is a newly proposed in the field of cultural heritage.

In this paper, we propose a consortium blockchain system for verifying digital content on traditional costumes. Traditional costume contents should be considered in a comprehensive historical and empirical context. The consortium for the verification of digital heritage content is divided into three groups. The reason for organizing the reviewers into three groups is to avoid the consequences of biased reviews. The three groups are divided into researchers, curators, and artisans (shown in Fig. 1). Each expert group consists of individuals who are officially certified in their research fields. Afterwards, the correctly verified digital contents from experts are registered in the blockchain system. This system ensures the integrity of data and creates reliable content through a review process involving the consensus process of experts.

The following are the contents to be presented in this paper. In Sect. 2, we provide background knowledge about historical research on Korean traditional costumes and blockchains. In Sect. 3, we present the blockchain-based verification system. Finally, in Sect. 4, we refer to the conclusions and the direction of future research.

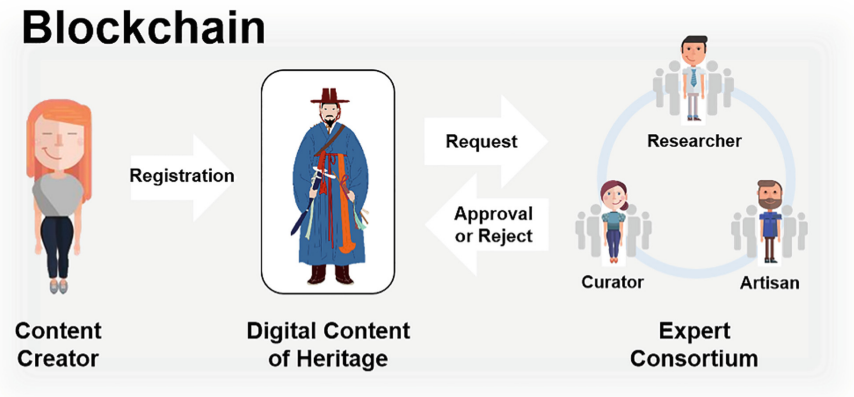

Fig. 1. Overall consortium blockchain for verification of traditional costumes.

2 Background and Related Works

2.1 Blockchain Systems

As e-commerce developed, the central system made transactions possible by guaranteeing individual identity. However, the central system had some drawbacks. The data managed by the central system can be changed by malicious manipulation or hacking. In addition, the system was inefficient because the management costs were high and the transaction stage was complex [16]. As a solution to this problem, *Satoshi Nakamoto* devised the blockchain system in 2008 [9].

The blockchain is a decentralized data distribution storage system. Anyone can participate in the system, and all nodes participating in the system share the same data. It is possible to trade without going through the central server, and it is difficult to arbitrarily manipulate the data. The main characteristics of the blockchain can be summarized as follows [17].

First, the blockchain has a distributed structure. The verified transaction information is generated as a block and stored in the blockchain. At this time, the data is replicated and stored in a distributed node, not in a central server. Since all nodes have the same data, it is possible to trade directly between individuals without going through a central server.

Second, it is difficult to change registered data. Blocks are linked together with the hash value of the previous block. If the data is arbitrarily changed, the hash value of the connection block will change and not be recognized in the system. Therefore, it is almost impossible to change the data because all nodes have to change data at once.

Third, smart contracts enable automation and efficient work processes [11]. The user can make the application through the simple creation of a script embedded in the blockchain. Since it is possible to complete the contract online, it is efficient because it can overcome location restrictions and replace the document and signature required for the contract with a code. Above all, if the condition of the pre-written code is satisfied, the contract is automatically executed so that the business can be processed quickly.

The blockchain can be divided into three types according to the degree of authority granted to the participants: public blockchain, private blockchain, and consortium blockchain [15].

1. Public blockchain: An open-type blockchain. Anyone can participate and anyone can be the operator. Because it gives fair authority to participants, it is mainly applied to virtual money such as Bitcoin or Etherium. However, there is a disadvantage that the system is slow because an unspecified number participates in the system.
2. Private blockchain: A centrally controlled blockchain. One organization operates the platform with blockchains. Only the subject who operates the blockchain creates and approves the contents of the transaction. It is often used in stock markets or financial institutions that do not want their transaction data to be disclosed. The system is fast because one organization participates.
3. Consortium blockchain: A mixed-type blockchain. It is a combination of the public and private blockchains. Only the participants authorized by the system participate and derive a consensus according to certain rules, such as the smart contract. It is used by trading platforms or government agencies that require an agreement between participants. The system is fast because only the participants authorized by the system participate.

This paper proposes a verification system using the blockchain. This system uses the characteristics of the blockchain that store unchanging data and support an efficient transaction protocol. Participants in the system can be divided into content creators and reviewers. This system is best suited to the consortium blockchain because the participants are limited and have to reach a certain consensus. In the next section, we will examine the verification system process in detail.

2.2 Traditional Costumes in Joseon Dynasty

Joseon was the last dynasty of Korea, which lasted from 1392 to 1910. Joseon was a status-driven society based on a strict exemplum. The costumes of the Joseon Dynasty were changed and institutionalized according to the times. The attire regulations were finely organized based on laws and institutions. It is difficult to reproduce the costumes of the Joseon Dynasty because the specific regulations differed according to the situation and ritual.

For example, the *yung-bok* was the official activity attire of the king and officials. The *yung-bok* was worn by distinguishing the color of the clothes and ornaments according to the situation. The regulations on the *yung-bok* of the king and officials appear in *Sang-bang-jeong-rye* and *Sok-dae-jeon*, published in 1750 and 1746, respectively. *Sang-bang-jeong-rye* is a regulation on royal attire. *Sok-dae-jeon* is a

legal code compiled in the late Joseon Dynasty to revise and supplement early Joseon Dynasty laws. The legal code includes the rules on the officials' attire.

According to *Sang-bang-jeong-rye*, the king used red-painted official hats made of horsehair (namely, *ju-rip*). The king's official robes (namely, *cheol-lik*) were red and expressed his authority with round patches embroidered with a dragon (namely, *hyung-bae*) on the front and back and both shoulders (shown in Fig. 2).

In *Sok-dae-jeon*, *yung-bok* attire is divided into two categories: *dang-sang-gwan* and *dang-ha-gwan*. *Dang-sang-gwan* was for high-level officials, who closely aided the king, and *dang-ha-gwan* was for lower-level officials. The *yung-bok* attire of *dang-sang-gwan* included red official hats and blue official robes (shown in Fig. 3). The *yung-bok* attire of *dang-ha-gwan* consisted of black official hats (namely, *heung-nip*) and blue-gray official robes in the palace (shown in Fig. 4, left). However, during the royal procession, they had to wear red official robes (shown in Fig. 4, right). Both the king and the officials wore black boots that covered their ankles (shown in Table 1).

In the case of Joseon Dynasty costumes, it is necessary to conduct diverse studies with reference to regal codes, literature, paintings, and relics to reproduce the contents properly. However, content that lacks historical research may be registered in the database. Therefore, it is necessary to verify the contents through the examination of experts in each field for database registration.

Table 1. The *Yung-bok* attire corresponding to social status.

Status	King	A high-level official	Low-level official
Official hats	Red	Red	Black
Official robes	Red	Blue	Blue gray/Red
Footwear	Black	Black	Black
Figures	 **Fig. 2.** The king's yu*ng-bok* [18] (Color figure online)	 **Fig. 3.** A high-level official *yung-bok* [19] (Color figure online)	 **Fig. 4.** A low-level official *yung-bok* (left): when inside the palace [19] (right): when outside of the palace [20] (Color figure online)

3 Proposed Consortium Blockchain for Verification

The process of the digital contents of the digital heritage verification system is shown in Fig. 5: (i) The content creator registers the digital content on digital heritage and (ii) analyzes the metadata of the content and finds the reviewers in each group and request; (iii) the reviewers send the results of the verification and perform an agreement, (iv) "Three rejections" or "One approval and Two rejections"; they send the modifications and review them again "Two approvals and one rejection"; they review them again or approve them after consultation (v) "Three approvals"; and a block is generated with metadata in the blockchain.

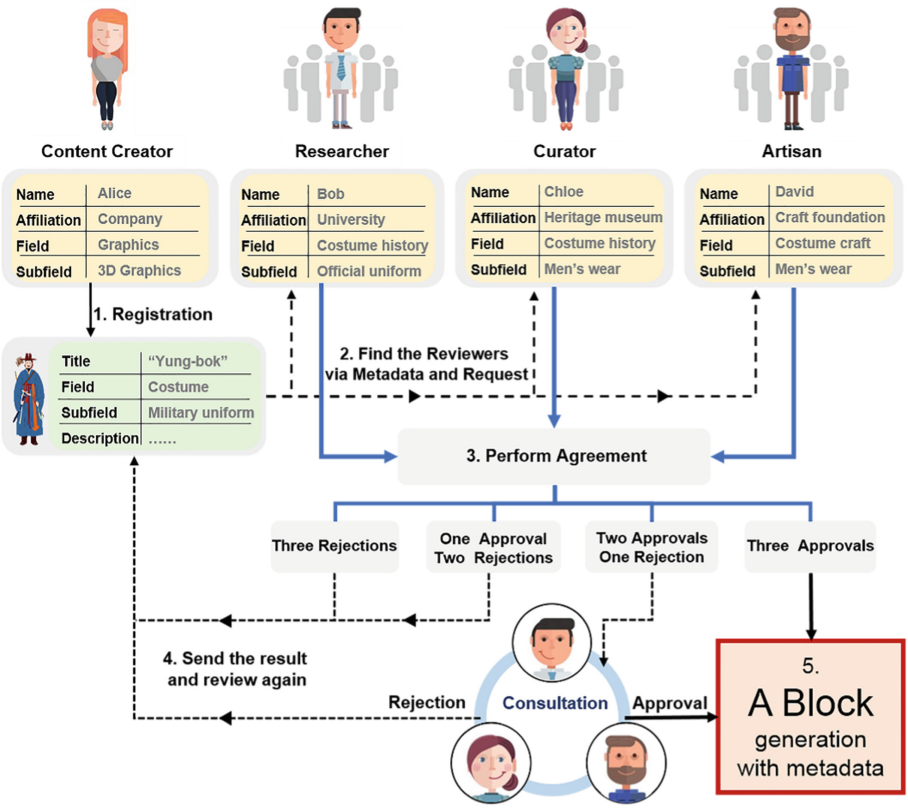

Fig. 5. The proposed consortium blockchain for verification.

Step 1: Register participants and digital contents

Participants (i.e., content creators and reviewers) join the system [13]. The content creators create digital content on heritage and register them in the system. They could be a company or an individual. When joining the system, they select the classification

of the participant and enter details such as name, affiliation, field, and subfield (shown in Table 2).

The content creator uploads digital content on traditional costumes to the system for review. Then, they enter the metadata for the content. The items are title, field, subfield, and description. The content name should show the characteristics of the content most clearly, and the relevant fields and subfields should be entered so that it can be connected with the metadata of the reviewers [6]. Finally, a description of the content should be entered so that it can be referred to in the content review (shown in Table 3).

Table 2. Examples of participant information

Classification	Content creator	Reviewers		
		Researcher	Curator	Artisan
Name	Alice	Bob	Chloe	David
Affiliation	Company	University	Heritage museum	Craft foundation
Field	Graphics	Costume history	Costume history	Costume craft
Subfield	2D graphics	Official uniform	Men's wear	Men's wear

Table 3. Metadata of digital contents on digital heritage

Digital content	Item	Substance
	Name	High-level officials' *yung-bok* attire
	Field	Traditional costume of Joseon Dynasty
	Subfield	Official uniform, Men's wear
	Description	A detailed description of the content

Fig. 6. High-level officials' *yung-bok* attire [21]

The reviewers are qualified experts who verify the content registered by the content creators. The reviewers are divided into three groups: researchers, curators, and artisans. The researcher group contains researchers who conduct research in each field. The curator group comprises museum curators who are in charge of exhibiting and managing artifacts directly, and the artisan group is composed of nationally certified artisans. The reviewers set up the group to which they belong at the time of sign-up, select the participant classification, and input information including the name, affiliation, related field, and subfield (shown in Table 2).

Step 2: Find the reviewers via metadata and requests

The system finds the best reviewers based on the metadata of the reviewers and digital contents and automatically requests a review. For the sake of fairness in the

review, the information on the content creator is not included when the contents are delivered to the reviewer. The method of passing on contents for review uses a public key infrastructure (PKI). By using the PKI, information on the reviewers and creator is protected from other system users [12]. The digital contents to be reviewed are encrypted and transmitted by the public key of the selected reviewer. First, the reviewer checks the metadata of the content and determines whether it can be reviewed. If the reviewer is willing to review it, they decrypt it with their private key; otherwise, they send it back to the content creator.

The reviewer uses their professional knowledge to verify that the digital contents have been reproduced correctly. If the content is reproduced correctly, the reviewer encrypts it using their own private key and sends it to the system, including the public key. On the other hand, if the content is not reproduced correctly, the reviewer attaches the modification, encrypts it with the content creator's public key, and sends it to the system.

Step 3: Perform agreement

The system involved the following consensus process by combining the received results [11].

1. *"Three rejections" or "One approval and two rejections"*: This process includes two cases. The first is three rejections, and the second is one approval and two rejections. The system transmits the result of the review encrypted by the public key to the content creator. The content creator decrypts with the private key and checks for modifications. The contents can be requested to be reviewed again after revising and supplementing them.
2. *"Two approvals and one rejection"*: This process works when two reviewers approve and one reviewer rejects. The system suspends judgments on content and allows the reviewers to exchange their verification results. The reviewers derive a consensus on content through a consultation. If the result of the consensus between the reviewers is rejected, the content can be reviewed again. In contrast, if approved, it creates a block and registers it in the blockchain.
3. *"Three approvals"*: When content is approved by three reviewers, content verification information is generated as a block. The blocks include time stamps, content information, and the content creator and reviewer's private key (shown in Fig. 7). The generated block is registered in the blockchain and becomes the verification data of the digital contents [14].

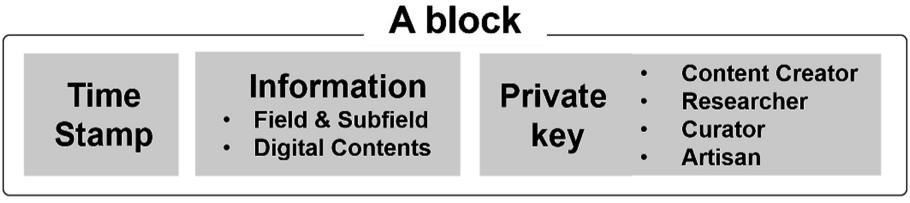

Fig. 7. Elements of a block

In this chapter, we have discussed how to configure a consortium blockchain and verify the digital content of traditional costumes within the system. The digital content verified through this system generates a block and is registered in the blockchain, and the digital heritage contents ensure reliability.

4 Conclusion and Future Works

UNESCO has set up guidelines for the selection of digital content for long-term digital preservation [2]. The purpose of these guidelines is to find preservation value for digital cultural heritage and establish a policy for preserving selected digital heritage. However, it is not easy to distinguish whether the generated digital contents of cultural heritage are worth preserving. Most institutions lack expertise in the historical research of digital content, so they need help from external agencies or experts. The system derives a consensus among the reviewers through smart contracts. The final results are stored and propagated to the blockchain. Information stored in the blockchain cannot be changed intentionally, so information about content authentication remains indefinitely.

Therefore, the content creator is motivated to produce high-quality contents, and copyright can be protected at the same time as the verification. In contrast, those who verify the contents will be cautious about content verification because the authentication information about the work remains. The digital cultural heritage reproduced as a result is expected to have correct historical research and improve the quality of contents.

Thus far, we have discussed the process of digital content verification system based on the consortium blockchain. What has not been covered in detail in this paper will be elaborated in further research. The future research will proceed as follows.

First, when the verification system becomes deadlocked, the system should allow reviewers to share their opinions and draw a consensus. We will construct a detailed consensus protocol on this part in subsequent studies.

Second, regarding the reward problem of the reviewers, after the content review, compensation should be given to the content creator and reviewers. The proposed system in this paper generates a block when all three reviewers approve of the content. However, even if the content is rejected and does not generate a block, compensation for the review should be given. Therefore, it is necessary to research the compensation problem of the reviewers and content creators.

The blockchain is an innovative system that has emerged to solve the trustworthiness problem of information. By applying it to the field of cultural properties, we intend to improve efficiency in preserving and managing cultural properties. Through future research, we expect that the blockchain will be used in various cultural heritage fields.

Acknowledgements. This research is supported by 2018 Support Project for Academic Research in Korea National University of Cultural Heritage.

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