UDC 004.75
DOI https://doi.org/10.32689/maup.it.2023.3.7

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Bibliographic description of the article: Kresyanpol, L., Novachevskyi, S., Hranovskyi, M. (2023). Zastosuvannia blokchein – tekhnolohii dlia zberezhennia ta poshyrennia kulturnoi spadshchyny cherez NFT [Application of blockchain technologies for preservation and dissemination of cultural heritage through NFT]. *Informatsiini tekhnolohii ta suspilstvo – Information technology and society*, 3, 54–62. DOI: https://doi.org/10.32689/maup.it.2023.3.7

Бібліографічний опис статті: Крестьянполь, Л., Новачевський, С., Храновський, М. (2023). Застосування блокчейн – технологій для збереження та поширення культурної спадщини через NFT. *Інформаційні технології та суспільство,* 3, 54–62. DOI: https://doi.org/10.32689/maup.it.2023.3.7

APPLICATION OF BLOCKCHAIN TECHNOLOGIES FOR PRESERVATION AND DISSEMINATION OF CULTURAL HERITAGE THROUGH NFT

Abstract. *Non-fungible tokens (NFT) represent one of the most important technologies in the space of Web3. Thanks to NFTs, digital or physical assets can be tokenized to represent their ownership through the use of smart contracts and blockchains. The first generation of this technology, called NFT 1.0, considers static tokens described by a set of metadata that cannot be changed after token creation. The static nature prevents their wide spread as they do not support any meaningful user interaction. For this reason, its evolution, called NFT 2.0, has been proposed to make tokens interactive and dynamic and enhance user experience, opening the possibility to use NFTs in more ways and scenarios. Cultural heritage assets are in danger of extinction or damage due to lack of publicity and financial problems. Technological advances can play a role in their preservation and promotion.*

The preservation and dissemination of cultural heritage is a serious challenge, especially in the age of digital technologies. Non-fungible tokens (NFTs) offer a promising solution for managing and authenticating digital assets. Using blockchain technology, NFTs can help preserve and promote the visibility of these important cultural artifacts.

This research aims to create a blockchain-based cultural heritage protection system. Cultural assets are transformed into unique digital items using NFT technology. An autonomous working system is provided by smart contracts. Supporters of the project make donations to receive their share of the rights to protect and maintain cultural heritage sites.

The use of NFT in this field raises important issues of preservation, digitization, and promotion of Ukrainian culture. The purpose of the article is to analyze the blockchain technology used for NFT, developing a unique collection of digital assets and publication it on the marketplace.

Key words: *Non-fungible token, blockchain technology, cultural heritage of Ukraine, digital assets.*

ЗАСТОСУВАННЯ БЛОКЧЕЙН – ТЕХНОЛОГІЙ ДЛЯ ЗБЕРЕЖЕННЯ ТА ПОШИРЕННЯ КУЛЬТУРНОЇ СПАДЩИНИ ЧЕРЕЗ NFT

Анотація. *Незамінні токени (NFT) представляють одну з найважливіших технологій у просторі Web3. Завдяки NFT цифрові або фізичні активи можна токенізувати, щоб представляти їх власність за допомогою смарт-контрактів і блокчейнів. Перше покоління цієї технології під назвою NFT 1.0 розглядає статичні токени, описані набором метаданих, які неможливо змінити після створення токена. Статичний характер перешкоджає їх широкому розповсюдженню, оскільки вони не підтримують жодної значущої взаємодії з користувачем. З цієї причини була запропонована його еволюція, яка називається NFT 2.0, щоб зробити токени інтерактивними та динамічними та покращити взаємодію з користувачем, відкриваючи можливість використовувати NFT у більшій кількості способів і сценаріїв. Об'єкти культурної спадщини знаходяться під загрозою зникнення або пошкодження через відсутність публічності та фінансові проблеми. Технологічний прогрес може зіграти певну роль у їх збереженні та просуванні.*

Збереження та поширення культурної спадщини є серйозним викликом, особливо в епоху цифрових технологій. Невзаємозамінні токени (NFT) пропонують багатообіцяюче рішення для управління та автентифікації цифрових активів. Використовуючи технологію блокчейн, NFT можуть допомогти зберегти та сприяти видимості цих важливих культурних артефактів. Це дослідження спрямоване на створення системи захисту культурної спадщини на основі блокчейну. Культурні активи перетворюються на унікальні цифрові елементи за допомогою технології NFT. Смарт-контрактами забезпечена автономна робоча система. Прихильники проекту роблять пожертви, щоб отримати свою частку прав на захист і підтримку обєктів культурної спадщини.

Використання NFT у цій сфері ставить важливі питання збереження, оцифрування та популяризації української культури. Метою статті є аналіз технології блокчейн, яка використовується для NFT, розробка унікальної колекції цифрових активів та розміщення її на маркетплейсі.

Ключові слова: *невзаємозамінний токен, блокчейн технолгія, культурна спадщина України, цифрові активи.*

Introduction.

The use of non-fungible tokens (NFTs) to preserve and disseminate Ukrainian cultural heritage is an innovative and promising approach that can improve the visibility and accessibility of these important cultural artifacts, as well as raise funds for the restoration and rehabilitation of cultural sites damaged during the Russian-Ukrainian war. Non-fungible tokens (NFTs) have emerged as a way to collect digital data as well as a means of investment. Despite being popularized only recently, NFT markets have witnessed several high-profile asset sales and a huge increase in trading volumes over the past year [1]. The study of the NFT phenomenon, the study of key concepts and principles related to the metaverse, blockchain, decentralized programs and user interaction, and the analysis of NFT trading platforms are described in [2]. An interesting approach to analyzing the market dynamics and security issues of the multibillion-dollar NFT ecosystem is described in [1]. The author examines the NFT ecosystem and identifies three main participants: markets, external organizations, and users.

Literature review.

Non-funny token (NFT) is a data unit stored in the blockchain. From the technical point of view, we can find that art is facing unprecedented virtual and realistic problems [3, 4]. Through the discussion of digital identity, fair trade and gameplay, this paper regards NFT art as a Metaverse pointing to the future, and discusses the generation and evolution of NFT as a digital mechanism from the creation and acceptance of NFT art.

Public attention towards NFTs has exploded in 2021, when their market has experienced record sales, but little is known about the overall structure and evolution of its market. In in the article [5] made analyse data concerning 6.1 million trades of 4.7 million NFTs between June 23, 2017 and April 27, 2021, obtained primarily from Ethereum and WAX blockchains.

Interesting approach in investigate the predictability of NFT sales using simple machine learning algorithms and find that sale history and, visual features are good predictors for price described in works 5-6.

Undoubtedly, the digitization of cultural heritage is the next step in the digitalization of people, society, and the state, and the use of blockchain technologies in this area will significantly accelerate this process. In In paper 7-9 provided an overview of this technology in the sale of digital art and how it influences both the process itself and what are the challenges and risks of using it today.

Based on the value co-creation theory, in paper [10] studies the motivation of adopting gamification in art NFT, analyzes its connection with user engagement, loyalty and self-brand connection, and provides a theoretical basis and future development direction for the development of gamification in art NFT.

The study [11] describes the construction of a cryptographic method of interaction Museum Art Exchange Protocol (MAXP) for museum digital collections based on blockchain technology. Using this method, a digital collection exchange system on Ethereum is created to implement an online exchange of digital collections between two museums. Blockchain technology also has a significant impact on the transportation of cultural heritage, offering dynamic real-time remote control for the transportation of cultural relics [12, 13, 14], as well as providing regulation of the exchange of transportation of physical collections. Traditionally, there are three ways to use blockchain technology to record copyrights. The first is to record copyrights for off-grid design schemes [15], using a decentralized data management structure to protect user privacy. The second is to control the copyright

of user data protocol records under a master-slave paradigm [16] to realize digital copyright management. The third is a copyright-aware encryption algorithm [17], which uses digital watermarking technology to enhance the reliability of the encryption algorithm, creating a digital copyright blockchain management scheme. Although a number of digital copyright schemes for museums have been proposed based on blockchain technology, the regulatory mechanism for sharing digital collections is not ideal. Three typical methods are relatively mature in blockchain regulatory technology research: a blockchain transaction tracking mechanism [16], a blockchain address collection mechanism [18], and a blockchain certificate management mechanism [19, 20].

Problem statement. Preserving and disseminating Ukrainian cultural heritage is a serious challenge, especially in the digital age. Non-fungible tokens (NFTs) offer a promising solution for managing and authenticating digital assets. Using blockchain technology, NFTs can help preserve and promote the visibility of these important cultural artifacts. The use of NFTs in this area raises important issues of preservation, digitization, and promotion of Ukrainian culture.

The purpose of the study. The purpose of the article is to analyze the blockchain technology used for NFT. Development of NFT tokens for the preservation and promotion of the cultural heritage of Ukraine.

Anatomy of the NFT.

Non-fungible tokens (NFTs) are digital representations of data that contain digital authenticity and ownership and support the creation of intangible assets. NFTs are recorded on a blockchain, but not all NFTs are the same in terms of how they are stored. In this article, we will take a deeper look at the technical side of NFTs and how they are stored. Generally, content such as files and metadata can be stored on or off the blockchain. While it is a common understanding that blockchain technology allows NFTs to be immutable and permanent, this is not entirely true for all NFTs. This is where the difference between on-chain and off-chain NFTs becomes important. Before we begin, there are a few important concepts we should take into account.

A server is a computer or computer program that manages access to a centralized resource or service on a network. NFTs are sometimes stored on servers. Nowadays, it is more common to place them on IPFS or Arweave.

Hosting is the storage of a website on a server or other computer as a service for accessing it via the Internet.

Metadata is a set of data that describes and provides information about other data. Metadata helps servers find, process, and host data more efficiently. In the case of NFTs, metadata provides more information about the characteristics of the digital asset, such as the token name, the token description, and any special properties the creator wants to add (e.g., size, color, etc.).

A hash is the result of applying an algorithmic function to information to transform it into a random string of numbers and letters. This acts as a digital fingerprint of that information. Hash is commonly used to encrypt data in an efficient and verifiable manner.

Smart Contracts – A smart contract is a contract in which the terms of the agreement between the parties are directly written into code. The code and the terms of the contract stored there exist on a distributed, decentralized blockchain network. The lines of code ensure execution, and transactions are traceable, transparent, and irreversible. Without the need for a central authority, legal system, or external enforcement mechanism, smart contracts allow for trusted transactions and agreements. NFTs are minted and exchanged using smart contracts.

On-Chain NFT. NFTs exist entirely on the blockchain and have all the metadata and smart contracts stored on the chain. This means that the data of these NFTs is stored on the blockchain.

On-chain NFTs include two important data components:

– metadata, which is the basic information of a particular NFT – the name of the token, special properties of the NFT, where the digital copy is stored, etc. Since this metadata is integrated with networked NFTs, the information itself also lives on the blockchain.

– smart contracts that can generate digital assets on the network.

Since the metadata, smart contract, and NFT are stored on the blockchain, we eliminate the need to rely on external systems or a third party. Therefore, if the blockchain is up and running, the NFT collection will always be available. However, storing entire image files requires significantly more computer memory. It is therefore extremely expensive and therefore not yet widespread.

Off-Chain NFT. While on-chain NFTs exist entirely on the blockchain, off-chain NFTs do not. They exist in two parts – the smart contract and the metadata for the actual illustration. Most often, the smart contract of an NFT that is deployed on the blockchain does not store the digital work/image of the physical work or any metadata on the blockchain, but only stores a pointer to a storage location outside the blockchain, hence these NFTs are called Off-Chain. The pointer is basically a link that leads to a file containing the relevant metadata of the NFT. This metadata file contains, among other information, a link to an image file of the represented digital work or an image of the represented physical asset. The smart contract exists on the blockchain containing a set of rules that assist the transaction and serve as a digital description of the content. The smart contract also contains a link that points to a server that stores digital artwork, which may be stored offline rather than on

the blockchain. While such off-chain NFTs are currently the most common way to link NFTs to the assets they represent (e.g., an image file), this approach is technically quite risky. There is no guarantee that the file will not be replaced or overwritten by a file with the same name in the future. There is also the potential risk that the link leading to the work or even the metadata file will be tampered with, as the server hosting the image or metadata may no longer be operational. The record on the blockchain will still exist and the NFT holder will still own the NFT as it consists of the tokenID and the alphanumeric address of the smart contract. However, the NFT holder will only have the token ID, but will not have an image of the physical asset or metadata. In this case, the NFT will no longer fulfill its purpose and will not be able to associate the NFT with the represented asset.

There is indeed a risk of communication failure. This can happen if a web server company can no longer operate its servers due to bankruptcy or other reasons. Even today, there are links to NFTs that lead nowhere. To avoid the risks associated with this type of technical setup of an NFT, there are alternatives to linking an image to an NFT. For example, the NFT can point to an IPFS (Interplanetary File System) location. IPFS is a peer-to-peer network. This means that uploaded files are stored and shared on multiple computers, allowing the network to operate in a decentralized and secure manner. Each file uploaded to IPFS is assigned a unique URL, a "fingerprint" of the file. This means that pointing an NFT to a specific IPFS URL ensures that the asset behind the NFT cannot be modified (as the modified asset will be assigned a different IPFS URL). When using IPFS, any user can access a file and compare the hash value of the file with the hash value of the NFT. Therefore, anyone can verify that the NFT refers to the original file. Another solution is to use Arweave. At its core, Arweave is a decentralized storage network (DSN) that connects people who have extra available disk space with those who need more storage. It is designed to provide scalable, cost-effective, and persistent data storage, and it is built on a blockchain-like data structure called blockweave.

There are several other options for offline storage, such as Google Drive, AWS, iCloud, or centralized storage on a hardware server. However, there are some problems with this approach. First, we rely on the work of third parties, just like any centralized server or storage. Secondly, there is a security risk as these servers can be hacked and their information can be tampered with. Nevertheless, IPFS provides a more secure method of data storage because it is a P2P, distributed and decentralized storage network with no central point of failure. In the event that a storage location fails, it will be backed up by a peer. But if the NFT holder decides to delete the NFT file from off-chain storage, it will break the connection between the file and the blockchain.

Research results.

Using non-fungible tokens (NFTs) to preserve and disseminate Ukrainian cultural heritage is an innovative and promising approach that can improve the visibility and accessibility of these important cultural artifacts, preserve their digital copy, as the real object may be destroyed during the fighting in the Russian-Ukrainian war. Also, the digitization of cultural monuments and their conversion into non-fungible tokens (NFTs) allows for the creation of a certain ecosystem for the management and authentication of digital assets that can be used to restore and rebuild damaged and destroyed cultural monuments. The study by Dipanjan Das [1] considers the NFT sector as a certain ecosystem with markets, external organizations, and users. Users. NFTs are often used to sell digital collectibles and works of art. Users in the NFT ecosystem can fall into the following categories: content creator, seller, and buyer (Fig.1).

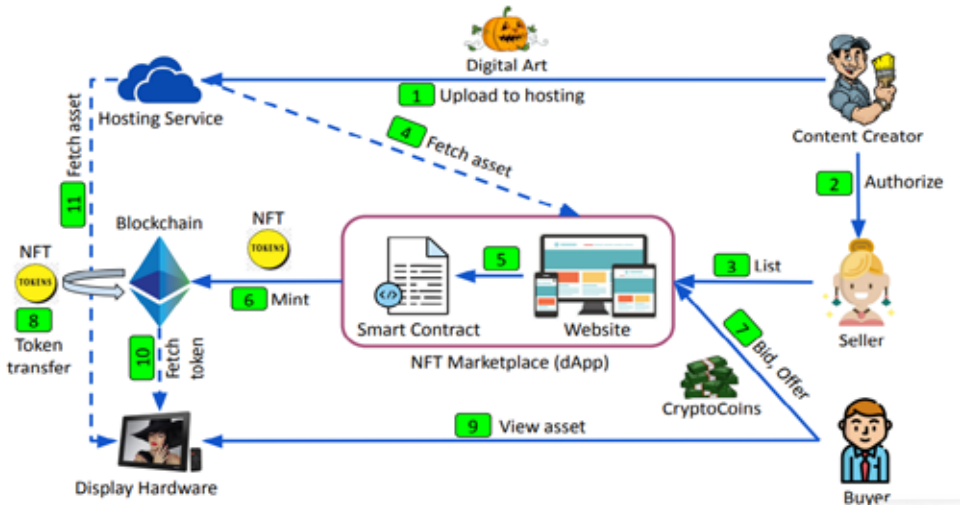

Fig. 1. Ecosystem of NFT functioning

Source: [1]

Content creators, in turn, create and upload artwork to hosting platforms where it is published and tokenized. In this ecosystem, hosting platforms play the role of external organizations that act as intermediaries between sellers and buyers. Hosting platforms are a combination of a web interface and smart contracts concluded between users.

Considering NFT as one of the tools for preserving and popularizing Ukrainian cultural heritage, we have developed a collection of NFT art aimed at preserving cultural and architectural monuments that were damaged or destroyed during the Russian-Ukrainian war. Similar projects have already been implemented and have shown their effectiveness. For example, the National Art Museum of Ukraine (NAMU), the oldest museum in Kyiv, created the NAMU NFT collections to support two goals: to raise funds for the NAMU and other museums in Ukraine that were affected by the war, and to promote Ukrainian culture around the world (Fig. 2). This project involved extensive consultation with Ukrainian cultural communities and included clear provisions to protect confidentiality and cultural sensitivity.

Fig. 2. Cossack Mamai as NFT at Patron-of-art NFT marketplace

Source: https://collect.patron-of-art.com/release/2

The collection we have developed includes 5 architectural monuments that have been damaged and need to be restored. In particular, the Holy Dormition Sviatohirsk Lavra, the first mention of which dates back to the 15th century as a monastery complex that began to form in these places during the period of settlement of the "Wild Field" by the Cossacks and the creation of the first watch fortifications (Fig. 2).

Fig. 3. NFT Sviatohirsk Lavra

Source: compilete by authors

The next project was the Donetsk Drama Theater in Mariupol (Fig. 4).

The center of cultural life and the only professional theater in Mariupol, which since March 16, 2022 has been a symbol of the humanitarian catastrophe caused by Russia. The theater became a mass grave for hundreds of people who hid within its walls from Russian shelling. The building of the Mariupol Drama Theater was built in 1956-1960 in the style of monumental classicism.

Fig. 4. NFT Donetsk Drama Theater

Source: compilete by authors

Fig. 5. NFT Regional Youth Library in Chernihiv

Source: compilete by authors

Regional youth library in Chernihiv. The neo-Gothic building was built in the late nineteenth century. It housed the premises of an orphanage and the Vasyl Tarnovsky Museum of Antiquities, which kept items from the Cossack era and Taras Shevchenko's personal belongings. Since 1978, the library has been housed here.

Fig. 6. NFT Local History Museum in Okhtyrka Sourse: compilete by authors

The building of the local history museum in Okhtyrka was built in 1861 and is a cultural landmark of local significance.

The manor was built in 1762 in the neoclassical style with Baroque elements.

Digital art in combination with blockchain technologies forms a specific cultural practice, depends on the development of technology, and responds to the Internet not only as a medium, but also as a technologically dependent, socio-cultural, political, and economic ecosystem that broadcasts cultural codes [11]. The developed collection History_Memory_and_Identity aims to preserve cultural and architectural monuments destroyed

during the war in the digital space. The proceeds from the sale of tokens are planned to be used for social projects to restore Ukraine's cultural heritage.

Fig. 7. NFT The estate of L.E. Koenig in Trostianets

Source: compilete by authors

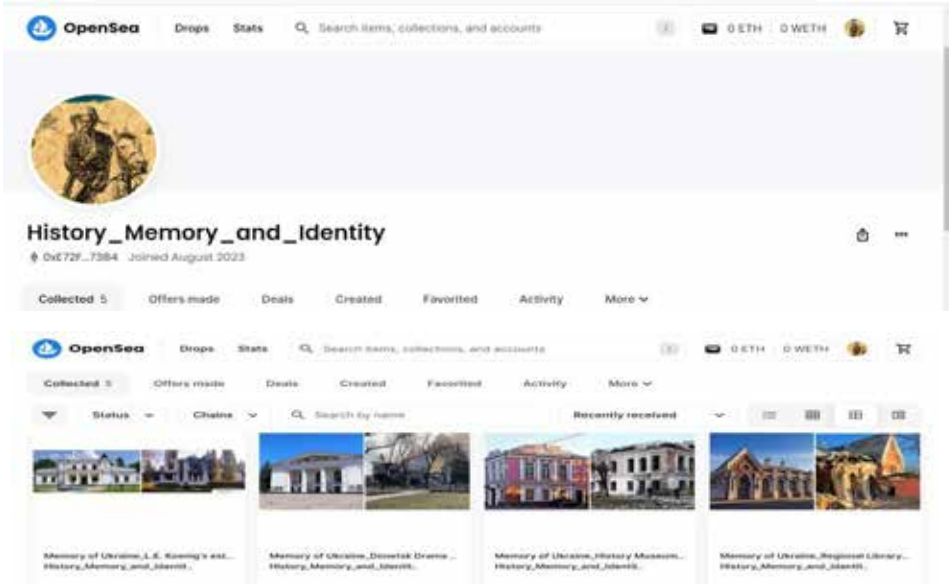

Fig. 8. The NFT collection is available on the OPENSEA marketplace

Source: compilete by authors

Conclusion.

Cultural heritage sites, especially monuments of architecture and urban planning, are of great importance and value as authentic documents of history. They are a source of information on history, cultural and socio-economic development, philosophy of perception of the world; they also convey the level of artistic and scientific thought of different generations. That is why the preservation of architectural and urban heritage sites is a very relevant issue for today, given the realities of today.

The introduction of digital blockchain technology is a promising area for the development of creative collaborations. The resource allows not only to preserve the cultural heritage object in a digitized form for future generations, but also opens up new opportunities, serves as a model for restoration work, helps to track the process of their loss, etc. The digital system is best suited for obtaining and registering rights to a digitized unique immovable object, its creation in the form of NFT tokens, and blockchain technology allows us to develop promising strategies for further interactive use of cultural heritage monuments. The available experience allows us to recognize the creation of NFT tokens based on a cultural heritage object as an act of popularization of Ukrainian castles and fortresses far beyond its borders, expansion of target audiences and involvement of those segments of the population that have never been interested in the topic of Ukraine's real estate heritage in general.

However, the problem raised requires further in-depth theoretical and practical research, in particular: the creation of a platform for digitized domestic immovable cultural heritage, a regulatory framework for the regulation of digital technologies and the crypto market.

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