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**A Review of Non-fungible Tokens Applications in the Real-world
and Metaverse**

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Abstract

The growth of the popularization of blockchain technology has caused new concepts to emerge. Non-Fungible Token (NFT) is one of these concepts introduced based on blockchain technology in 2017. As newly-emerged concepts, NFTs have rapidly become a popular technology in industry and academic research. NFTs currently have various applications in the industry, which are reviewed in the present study. They have also attracted a broad spectrum of research. Metaverse is another exciting blockchain-based technology that enables people to connect with digital avatars in a virtual universe. The importance of this study is to identify new applications of NFTs in the Metaverse making NFTs more applicable. Assisting with identity management and ownership right of digital assets are examples of NFT applications in the Metaverse that are explained in this study in detail. Ultimately, this study presents some future directions of NFT applications in industry and academic research.

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1. Introduction

Traditional internet (Web1.0) and interactive internet (Web2.0) are popular well-known technology. Most people currently use Web2.0 for their daily work and enjoy internet-based services [1, 2, 3]. Relying on internet technology, several attractive services have been proposed, such as internet-based centralized finance (CeFi) and the mirror world (centralized Metaverse). The mirror world was firstly offered by N. Stephenson in 1992 as a virtual reality (VR)-based world interconnected by the internet [4]. A Mirror world is also a digital world indicating real-world things in cyberspace and enabling users to interconnect virtually.

In 2008, an anonymous author launched the practical version of blockchain technology as the Bitcoin project's infrastructure [5]. Blockchain technology was first used only for cryptocurrency infrastructures [8, 21]. Then, the concepts of assets tokenization and decentralized finance (DeFi) were proposed relying on blockchain technology

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[6, 7]. As a new type of blockchain-based token that certify uniqueness, the concept of NFT was launched in 2017. This type of token differs from previous tokens so that no two similar NFTs are equal [9, 10]. NFTs rapidly found their places in industry and academic research in such a way that they attracted a broad spectrum of developers and business people in numerous fields.

Recently, Web3.0 was introduced as another blockchain-based exciting technology, which can cause a revolution in internet-based communication. The primary idea of Web3.0 was to provide blockchain-based internet to protect the internet security by the whole of connected users. Based on Web3.0 technology, a new type of mirror world was implemented on blockchain technology using Web3.0 technology called Metaverse [11]. The Metaverse provides a Web3.0-based digital world where users can join with their self-avatars and interconnect with other users.

With the broad area of applications, NFTs have been applied in the Metaverse, where NFTs currently are beneficial in the Metaverse [12]. Using NFTs as digital assets ownership rights (e.g., lands, cars, houses, etc.) and their application to prove users' identities are examples of NFT applications in the Metaverse [13]. It is predicted that NFTs will play significant roles in the Metaverse and attract numerous people in both the real and digital worlds.

Motivation and contribution: With the increasing popularity, NFTs have been used in various fields of technology so that several IT leading companies and numerous newly-emerged companies invested in this field or provided NFT services. This study addresses NFTs' applications in the two following aspects:

1. *Real-world-based NFTs:* These NFTs are connected to real-world (physical) things and accumulate information from real-world oracles (e.g., NFTs as tickets, artworks, or car ownership right). These NFTs applications are directly dependent on material things. Moreover, they will have no value if the mentioned things are destroyed. Most reviewed applications in this aspect have been offered based on the uniqueness of NFTs.
2. *Metaverse-based NFTs:* In this aspect of NFT applications, it is assumed that NFTs are purely digital (only in the Metaverse) and link to no real-world object or individual (e.g., virtual airplane ownership rights, issued certificates by a virtual academy, or Metaverse-based houses). These NFTs do not lose their value and are always applicable since their basic objects are never disappeared/destroyed. The presented applications in this aspect are suitable for Metaverse-based people's daily lives.

Outlines: The remainder of this paper is organized as follows. Section 2 addresses the paper's preliminaries. As the main part of this study, Section 3 reviews well-known applications of NFTs and then presents new applications of NFTs in the Metaverse. Section 4 discusses about application of NFTs. Finally, Section 5 concludes this study and identifies future academic and industrial works directions.

2. Preliminaries

This section presents the paper's preliminaries in detail.

2.1. Blockchain

S. Nakamoto proposed the practical version of blockchain in 2008 [5]. Blockchain is a transparent and distributed ledger that records immutable strings and codes. The blockchain blocks including data strings are linked to the previous block(s), and each change/modification during each previous(es) block(s) appears in the current/next block(s). Therefore, the recorded data are tamper-proof, and their changes are detected easily. For recording data on public blockchains, each submitting data needs to be accepted with the consensus of the majority of blockchain nodes [14]; otherwise, the submitting data is rejected by the blockchain recording process.

In the last decade, blockchain has been one of the state-of-the-art technologies in industry and academia and applied in many technology fields.

2.2. Blockchain-based Assets

This section introduces three main assets recorded on public blockchains.

2.2.1. Cryptocurrency

Cryptocurrency is the most popular type of blockchain asset and a well-known application of blockchain technology. It is a type of digital currency empowered by distributed ledger and cryptographic algorithms. Bitcoin, the first distributed cryptocurrency, was launched based on its blockchain by S. Nakamoto [5]. Subsequently, other cryptocurrencies, generally called altcoins, have been proposed in their specialized blockchains [8, 15].

2.2.2. Token

Tokens are altcoins without specialized blockchains and released on other blockchains [15]. Therefore, they will be out of access if their blockchain as their infrastructure is interrupted.

2.2.3. Non-fungible Token (NFT)

The practical idea of NFTs was first proposed in 2017 and implemented due to *ERC – 721* on the Ethereum blockchain. NFTs are immutable blockchain-based tokens/codes that certify uniqueness [9, 16]. They are known with the following main properties [17]:

1. *Uniqueness*: It refers to one-of-a-kind items that may be digital or not.
2. *Immutability*: This feature is mainly dependent on the security of the blockchain so that no individual is able to erase, destroy, or manipulate the recorded data.
3. *Non-interchangeability*: It is understood from the acronym of NFTs. NFTs are not replaceable by another even if a high-similarity is found between them.

The attractiveness of NFTs has caused them to be applicable rapidly in several fields, firstly for digital art and collectible cards (the first application). Recently, NFTs are also used for digital lands in the Metaverse (other applications of NFTs will be explained in Section 3).

Providing services related to NFTs (e.g., creation, trading infrastructure, buy, sell, exchange, etc.) is a newly-emerged job in the blockchain area. Thus, these services are provided by several famous companies such as OpenSea, Rarible, ZORA, Teia, and Marketplace.

2.3. Metaverse

Unlike the mirror world, the Metaverse is a blockchain-assisted virtual world controlled by no central authority [11, 13]. As a brief definition of the Metaverse, the Metaverse is a virtual internet-based world, which is implemented distributedly to interconnect the users. The users join Metaverse using VR glasses and other interfaces for interacting together and experiencing natural senses in a virtual world.

The concept of the Metaverse has recently become popular so that IT leader companies (e.g., Meta, Google, NVIDIA, Microsoft, Apple, Amazon, etc.) provide Metaverse-based services and several newly-emerged companies launched their metaverses (such as Decentraland, Sandbox, Upland, etc.). Additionally, numerous great companies in various areas have developed their services or invested in metaverses (e.g., Adidas, Nike, JP Morgan, Coca-Cola, etc.).

Notwithstanding the exciting and user-friendly features of the Metaverse, it has several advantages and disadvantages [18]. Among its advantages are *i*) providing an effective method for assisting people to experience what they cannot in the real world (e.g., traveling and observing far-distance exhibitions), *ii*) enabling companies to better interact with customers and have a more efficient advertisement, *iii*) optimizing social media platforms with better connectivity and more advanced features, *iv*) supporting online meetings, job interviews, etc., and *v*) assisting physically-disabled people in daily activities. However, *i*) addiction to the use of Metaverse, *ii*), decreasing overall physical activity of people throughout the whole day, *iii*) decreasing efficiency and lack of focus due to long screen timing, and *iv*) requiring a high-speed and secure internet connection without lags or low response delays are examples of the Metaverse disadvantages.

3. NFT Applications

Considering the uniqueness of NFTs as the main feature, they can be assumed equal to a digital version of any unique thing. Therefore, NFTs are very popular and applicable in each digital world (e.g., Metaverse). In this section, first well-known applications of NFTs are reviewed and then new applications for NFTs in Metaverse are defined in Fig 1.

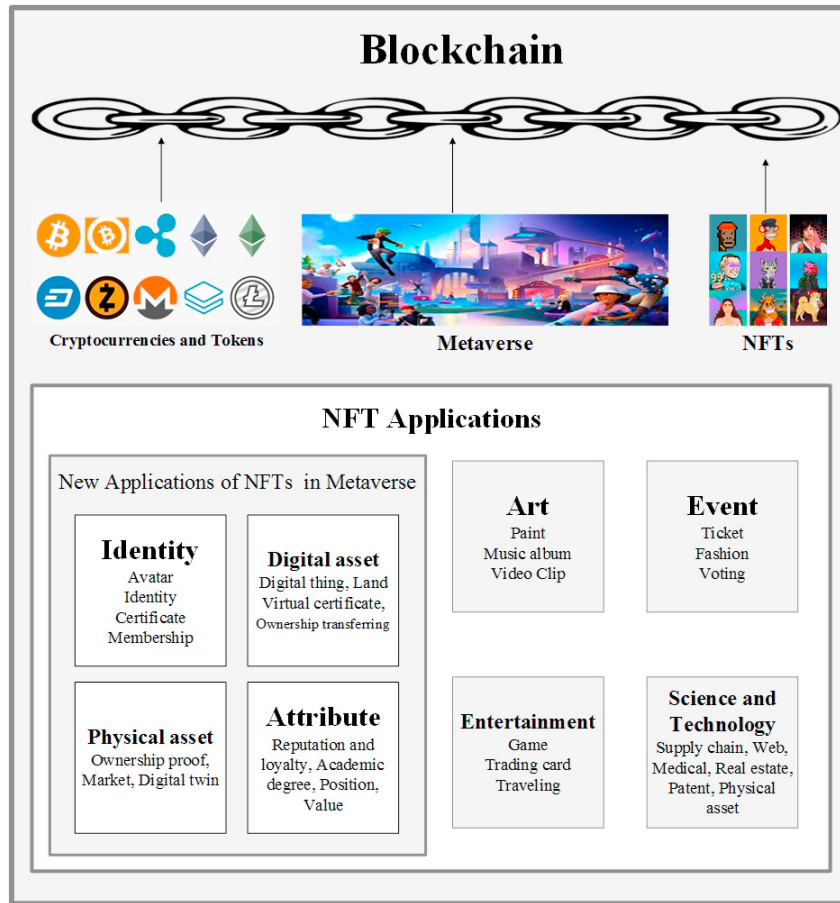


Fig. 1. General Applications of NFTs and New Applications in Metaverse

3.1. A Review of Well-known Application

This section reviews the general applications of NFTs [10, 17], and categorizes them into the four groups "Art", "Event", "Entertainment", and "Science and Technology".

3.1.1. Art (for artists)

This category is one of the most popular types of NFTs and even the most valuable forms (as an example of the evaluability, the "Everydays: the first 5000 days" of Beeple was sold for 69 million Dollars). NFT-looking artworks can be involved in some subgroups as follows:

- *Paint*: Digital paintings or drawings in the form of NFTs could be sold.
- *Music album*: By selling music albums, music artists can benefit from reaching their fans without preparing for concerts or festivals.
- *Video clip*: It is the motion type of digital painting or drawing. NFT-based video clips are usually loop-videos (e.g., *.GIF) or memorable moments as short videos.

3.1.2. Event (for companies and governments)

Digital events are mainly favorable for companies or those who want to provide internationally large gatherings or exhibitions [19]. The following applications are assumed for these types of NFTs:

- *Ticket*: Entry tickets or discounts on sports matches, concerts, exhibitions, and events could be sold in NFT forms.

- *Fashion*: Fashion NFTs, mainly as exhibitions of cloth, dresses, etc., are assumed in the two below aspects:
 1. Digital clothes for virtual life, and
 2. Selling unique real-world clothes,

So that NFTs are considered ownership rights of them.

- *Voting*: Vote to NFT and voting by NFT (NFT-based voting) are two different aspects of this item that rely on the uniqueness of NFTs. Unique NFTs can be assumed candidates for collecting submitted votes, or each user linked to a unique NFT can be considered a voter.

3.1.3. Entertainment (for fun)

The audiences of this category are those who use internet-based entertainment [20]. Some applications of NFTs in this category will now be addressed below.

- *Game*: Game-based assets and tools (e.g., weapons, cars, bikes, avatars, passed levels, etc.) are represented as NFTs and linked to the game's main character. Recently, *Rockstar Games* has informed that they will apply blockchain and related technologies (e.g., NFTs) in the last version of their most popular product, "Grand Theft Auto" (GTA VI).
- *Trading card*: Security and uniqueness of accumulated concession in trading or valueability of trading cards is a property that is satisfied by NFTs.
- *Traveling*: Traveling is one of the worldwide people's fun that computer science products can improve its quality. Providing NFT-based services to passengers by travel companies is a smart idea that enables these companies to trace passengers, collect and analyze customers' situations, and help increase service levels.

3.1.4. Science and Technology (for researchers, scientists, and industries)

Data protection, ownership, sharing, and tracing of products situation are critical items in science and technology. Text-based NFTs, as most well-known in these fields, have greatly assisted scholars and people in businesses. Other subgroups of these NFTs are itemized as follows:

- *Supply chain*: Tracing products from the manufacturer to the end user (consumer), fraud-resistance, and ensuring physical integrity are critical issues in product management, and supply chain [22]. NFT-based supply chain as a state-of-the-art idea greatly assists product managers.
- *Web domain*: Web domains are valuable assets for companies, which should be unique, immutable, and support provable ownership. Applying NFTs is the best choice to provide these properties simultaneously. Moreover, these features are assured by linking web domains to specialized NFTs.
- *Real estate*: Uniqueness is the primary feature of houses or other types of estates traded by real estates, for which digital monitoring is critical. Therefore, creating an NFT for each estate makes monitoring and data collecting easier for real estate owners [23]. NFTs also guarantee estate ownership and provide a simple method for ownership transfer.
- *Patent and intellectual property*: Patents and their intellectual property are valuable for scientists as it depicts their long-term works and studies [24, 25]. Additionally, their integrity protection, ownership proof, and the possibility of transfer are significant properties that could be supported by NFTs.
- *Medical record*: Similar to previous arguments, healthcare information of people and patients should be protected from each modification, but updatable [26]. Therefore, NFTs can carry these properties and be linked to a specific individual as healthcare document records.
- *Physical (real-world) asset*: It is the extended type of the first generation of NFTs (in digital arts). As with some applications mentioned earlier, such as digital arts, gaming, product tracing, real estate, etc. [17, 19], real-world assets are also allowed to link to NFTs to benefit from the NFTs' attractive features.

3.2. New Applications in Metaverse

This section, as the main section of the present study, addresses the applications of NFTs in Metaverse [12] and offers new applications. Those mentioned applications are represented in the four following groups:

3.2.1. Identity (related to virtual people)

Similar to the real-world, identities, in the Metaverse, the items are also used for users' authentications, which should be unique and fraud-resistance for each user. The below aspects are considered for NFTs as Metaverse-based identities:

- *Avatars (visual identity)*: Avatars are used for profile picture (PFP) collections, which need to be unique among thousands of avatars. Metaverse-based avatars and 3D avatars, matched to real faces of people, are considered the most identifying items in the public Metaverse. Therefore, uniqueness is a critical property of avatars that are satisfied by NFTs. Some known avatars are *Bored Apes*, *CryptoPunks*, and *Lazy Lion*.
- *Identity (e.g., name)*: It is the primary requirement of each entity, including users, objects, and other digital things, in the Metaverse. Linking users' unique real identities to their NFT-based identities in the Metaverse provides several excellent features such as identity management, access control, adding/removing from Metaverse-based communities, monitoring, and controlling. Therefore, creating NFTs based on users' real identities is a critical issue for Metaverse-based people (virtual people).
- *Certificate*: Similar to the real world, certificates can be issued in the Metaverse (e.g., for Metaverse-based courses), and they should prove validity and ownership. Creating NFT-based certificates for virtual people by Metaverse-based agencies/colleges/academies is an exciting idea making Metaverse-based courses and training more popular.
- *Membership*: By creating and linking NFTs to users' real identities, Metaverse-based communities are simply created by adding/removing NFTs instead of virtual people in Metaverse-based groups, societies, and gatherings.

3.2.2. Digital Asset (related to Metaverse-based assets)

Digital assets that only exist in Metaverse (i.e., they have no physical twin) should be represented and protected. The following types of digital assets (as some main examples, that are not limited to) should be linked to NFTs to satisfy those mentioned properties:

- *Digital thing*: There should be a mechanism to determine/assign any digital thing to a virtual person or group of virtual people in the Metaverse. Additionally, this issue should provide provable security and ownership. Therefore, this primary requirement is met by releasing an NFT for each existing digital thing in the Metaverse.
- *Land*: Buying/selling Metaverse lands is one of the newly-trended aspects of the digital world that has attracted numerous people. In this background, NFT as a land document plays the leading role (for land ownership proof, transferring to others, etc.).
- *Virtual certificate*: Metaverse-based certificates indicate and prove the skill of virtual people or passing a virtual course in the Metaverse. Using NFTs for certificate documents is the best choice for issuing Metaverse-based certificates.
- *Ownership transferring*: As with the real world, digital things ownership should also be transferable to virtual people. It is possible by existing digital documents as ownership proofs, for which NFTs can have critical roles and leading shares to satisfy.

3.2.3. Physical Asset (related to Metaverse-based version of real-world things)

Any physical asset can be tokenized and represented in Metaverse as NFTs. Creating digital versions of real-world things for displaying in the Metaverse involves various aspects, some important of which are presented below.

- *Digital twins*: The Metaverse development requires applying highly-accurate simulations of physical assets to make the most natural senses for virtual people (e.g., the material of the clothing, flexibility of objects, ease of use, etc.). To support this feature, digital twins as accurate simulations of physical objects are suggested to use in the Metaverse [27]. However, previous problems still exist, then, applying NFT-based digital twins in the Metaverse is the best solution.
- *Market (generally, each service provider)*: Markets are another Metaverse-based asset assumed to be similar to their real versions that provide services to virtual people (e.g., clothes shops, barbers, or restaurants). In

this regard, a principal (father) NFT should be launched and assumed as the Metaverse-based market. Sub-NFTs created based on the main NFT (child or children of the father, for who NFTs information should be written in their metadata) are assumed as services or purchased products' ownership.

- *Ownership proof:* As mentioned earlier, ownership is one of the most critical properties for physical and digital assets. Providing this feature solves many problems of the Metaverse, such as efficient buying/selling, ownership transfer, asset security, and asset management. In this study, it is believed that assuming ownership equal to an NFT satisfies those mentioned problems in addition to providing easy monitoring and data analytics.
- *Other examples:* As a conclusion and general aspect of this category, it is possible to tokenize all simulations or digital twins of real-world things (e.g., houses, cars, lands, malls, instruments, etc.) for use in the Metaverse and virtual people.

3.2.4. Attribute (related to virtual people's behavior)

Considering NFTs as an attributing item for Metaverse-based objects/users, the following issues can be linked to NFTs.

- *Reputation and loyalty:* The linked NFTs to virtual people can display people's loyalties in virtual communities and individual reputations in Metaverse.
- *Academic degree:* Assigning NFTs equal to certain academic degrees to virtual people who graduate from Metaverse-based academies/colleges/universities is a perfect method for representing virtual people's educational degrees. In this method, issued academic degrees are secure against cyber attacks.
- *Position:* Thus, virtual people's positions (e.g., boss, staff, etc.) can be considered equal to NFTs for their Metaverse-based lives.
- *Value:* Connecting everything (virtual people, components, entities, and things) enables managers to quickly analyze the Metaverse-based community's value and collect related information.

4. Discussion

As an emerging and exciting concept, NFTs have attracted millions of people in various fields worldwide. NFTs can improve virtual people's daily lives and assist them to have satisfying digital lives. Additionally, applying NFTs in cyberspaces, especially in the Metaverse, will enhance the usage and reliability of these types of environments and attract more people to benefit from NFTs' features and/or investment.

5. Conclusion

This study first reviewed the concepts of blockchain, NFT, and Metaverse. It then addressed the general application of NFTs major in arts, events, entertainment, and science. As the most crucial issue in this study, new applications of NFTs used in Metaverse, were presented including identities, digital and physical assets, and attributes.

Future directions: The NFTs' features provide beneficial opportunities in industry and academia for businessmen and scholars including:

- *Industry:* Services to link users' real identities to unique NFTs will be an attractive idea to be used as a Metaverse-based job. Metaverse-based certificate issuing, developing academies in the Metaverse, and services of digital assets tokenization in the Metaverse are other examples of NFT-based future directions, which can lead to high revenue for developers and businessmen.
- *Academia:* Providing specialized infrastructures for NFT-based services is a networking idea to support the mentioned application. Another idea for academics is to design NFT-based security protocols to provide security features for NFTs applications (e.g., NFT-based authentication, NFT-based anonymous authentication, NFT-based user reputation collector, NFT-based payments, etc.).

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