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Abstract

Technology has become a fundamental part of our environment, yet the borders between the physical and virtual realms become even more blurred. The introduction of the Metaverse is one of the most recent and notable innovations. It, just as any other technological advances, adapts to evolution in user needs serving as a link between the real and digital realms. While people can buy goods and services with a certain currency in the physical realm, cryptocurrencies and non-fungible tokens (NFTs) are used for transactions in the Metaverse. NFT provides customers a certificate of ownership, which means that their virtual commodities or assets such as lands or objects cannot be replicated. They may also be used to represent social standing, just like tangible goods and services. It has become increasingly common to come across museums displaying artworks or artists who sell their artworks as Non-fungible tokens (NFTs) on digital platforms such as Rarible, Mintable or OpenSea. This research discusses the 3D printability of NFTs and proposes a framework in order to create a hybrid experience for 3D printed NFT artworks. The results have shown that 3D printing of NFTs provided users/customers a hybrid experience in both realms, maintaining the artworks' uniqueness and rarity, proof of ownership, as well as physical copies in hand. Moreover, the artists who were afraid of publicly displaying their artworks for the concern of being copied have created 3D printable designs that enabled them to easily and safely promote their designs to the public.

Keywords

NFTs, 3D printing, digital fabrication, Metaverse

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ABSTRACT

Technology has become a fundamental part of our environment, yet the borders between the physical and virtual realms become even more blurred. The introduction of the Metaverse is one of the most recent and notable innovations. It, just as any other technological advances, adapts to evolution in user needs serving as a link between the real and digital realms. While people can buy goods and services with a certain currency in the physical realm, cryptocurrencies and non-fungible tokens (NFTs) are used for transactions in the Metaverse. NFT provides customers a certificate of ownership, which means that their virtual commodities or assets such as lands or objects cannot be replicated. They may also be used to represent social standing, just like tangible goods and services. It has become increasingly common to come across museums displaying artworks or artists who sell their artworks as Non-fungible tokens (NFTs) on digital platforms such as Rarible, Mintable or OpenSea. This research discusses the 3D printability of NFTs and proposes a framework in order to create a hybrid experience for 3D printed NFT artworks. The results have shown that 3D printing of NFTs provided users/customers a hybrid experience in both realms, maintaining the artworks' uniqueness and rarity, proof of ownership, as well as physical copies in hand. Moreover, the artists who were afraid of publicly displaying their artworks for the concern of being copied have created 3D printable designs that enabled them to easily and safely promote their designs to the public.

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ملخص

أصبحت التكنولوجيا جزءًا أساسيًا من بيئتنا، ومع ذلك أصبحت الحدود بين المجالين المادي والافتراضي أكثر ضبابية. يعد إدخال الميتافرس أحد أحدث الابتكارات وأبرزها فهو تمامًا مثل أي تطورات تكنولوجية أخرى، يتكيف مع التطور في احتياجات المستخدم ليكون بمثابة رابط بين العالمين الحقيقي والرقمي. بينما يمكن للأشخاص شراء السلع والخدمات بعملة معينة في المجال المادي، تُستخدم العملات المشفرة والرموز غير القابلة للاستبدال في المعاملات في الميتافرس. توفر الرموز غير القابلة للاستبدال للعملاء شهادة ملكية، مما يعني أنه لا يمكن نسخ سلعهم أو أصولهم الافتراضية مثل الأراضي أو الأشياء. يمكن استخدامها أيضًا لتمثيل المكانة الاجتماعية، تمامًا مثل السلع والخدمات الملموسة. أصبح من الشائع بشكل متزايد العثور على متاحف تعرض أعمالًا فنية أو فنانين يبيعون أعمالهم الفنية كرموز غير قابلة للاستبدال على منصات رقمية مثل Rarible أو Mintable أو OpenSea. يناقش هذا البحث قابلية الطباعة ثلاثية الأبعاد للرموز غير القابلة للاستبدال، ويقترح إطار عمل من أجل إنشاء تجربة هجينة لأعمال الرموز غير القابلة للاستبدال الفنية المطبوعة ثلاثية الأبعاد. أظهرت النتائج أن الطباعة ثلاثية الأبعاد للرموز غير القابلة للاستبدال وفرت للمستخدمين أو العملاء تجربة مختلطة في كلا المجالين، مع الحفاظ على تفرد الأعمال الفنية وندرتها، وإثبات الملكية، بالإضافة إلى النسخ المادية في متناول اليد. علاوة على ذلك، فإن الفنانين الذين كانوا خائفين من عرض أعمالهم الفنية علنًا من أجل القلق من نسخها، ابتكروا تصميمات ثلاثية الأبعاد قابلة للطباعة تمكنهم من الترويج بسهولة وأمان لتصميماتهم للجمهور.

الكلمات المفتاحية: الرموز غير القابلة للاستبدال، طباعة ثلاثية الأبعاد، تصنيع رقمي، الميتافرس.

1. INTRODUCTION

In 2021, an NFT (Non-Fungible Token) was sold as a digital file in JPEG format, which everyone can access and copy for free, was sold for $ 69.3 million (NYTimes, 2021), which attracted the attention of the whole world to these assets. Using blockchain technology, NFTs are crypto assets that authenticate to the uniqueness of virtual assets and are certified with their developer. A new age in the blockchain ecosystem, which at first exclusively contained cryptocurrencies, has started with NFT (Vidal-Thomas, 2022).

While one of the most recent and noteworthy innovations, Metaverse, acts as a bridge between the physical and digital worlds, most of the artists are discouraged to use digital platforms for displaying or selling their artworks due to the fear of unauthorized reproduction. This case is also valid in creating, sharing and trading the digital artworks since the authorship and uniqueness of the digital assets become questionable.

2. BLOCKCHAIN TECHNOLOGIES AND NFTS

The companies such as Meta acknowledge the huge upheaval that humankind is undergoing and have developed innovative solutions. The idea of a Metaverse dates back to 1992 Neal Stephenson's science-fiction novel Snow Crash in which he fictionalized a virtual world. Later on, similar concepts were developed in numerous science-fiction books and movies, notably Steven Spielberg's movie Ready Player One in 2018. Although the concept was introduced decades ago, the notion of the Metaverse has become popular in the last few years since we are in the midst of a huge cultural transformation. It is more than simply a virtual realm or online surfing; it also has its own economy and currencies based on blockchain technologies.

Many attempts have been made long before the emergence of blockchain technology, in order to establish a digital currency with global validity on the internet (Liu et al., 2022). However, these initiatives had to be ended due to the problem called “double spending” (Zheng et al., 2021). The same digital currency could be used in two different trading transactions by causing the sabotage/fraud of one of the sellers (Pinzon and Rocha, 2021). All digital files that can be stored on the Internet are a string of data bits and are relatively easy to copy (Akbar et al., 2021). For example, a pdf document is sent to another person. When sent, a digital copy of the document is sent to the recipient and the original remains with the sender. Sending the document to another person will not prevent the person from accessing it. This situation gives users insecurity and trouble. Although the system provides the opportunity to reproduce digital information and share it with other people, it was a critical security problem for digital currencies. It has the nature to cause a deficit in transactions (Pisa and Juden, 2017).

Blockchain is considered secure and basically refers to a distributed digital database (Liao and Katz, 2017). A digital ledger is an electronic record of data kept on a computer (Franks, 2020). Distributed refers to the simultaneous processing and storing of records among a number of computers connected to a network. The blockchain departs from conventional centralized databases, where data is processed and saved on a single server (Gururaj, 2020). The distinction between a centralized and decentralized (distributed) computer network is depicted in the Figure 1 below, where the dashed lines signify the data flow.

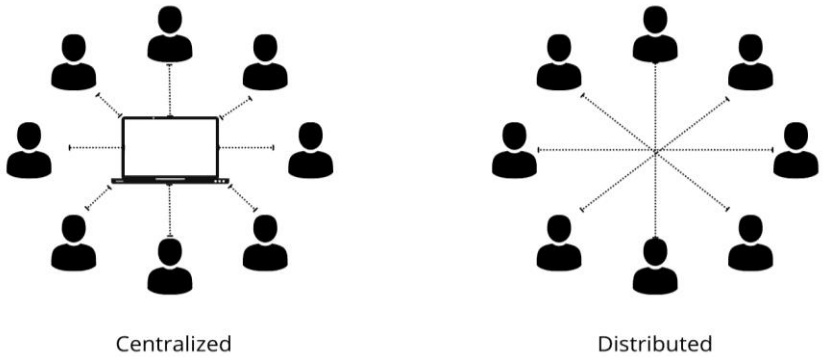

Fig.1: Centralized and distributed network.

As you can see, a centralized network uses a single primary server to handle and store all of the data. All of the data will be exposed if this system is compromised or hacked. On the other hand, each computer, or node, in a decentralized network processes and stores data. Each blockchain node that receives a copy of the full ledger is able to include new records to it. Before new transactions can be included in a block, the majority of nodes must acknowledge that they are authentic (Wright and Serguieva, 2017). As a result, the blockchain becomes safer since it would take a successful breach of more than 50% of the network to compromise the data. Because the ledger's data is visible to everyone on the network, it also encourages accountability and transparency.

Another significant parameter of emergence of blockchain technology is that the blockchains are designed to be decentralized since the creators of this technology intentionally did not want any one individual, company, bank, organization, local authorities, or country to monitor or supervise a blockchain (Atzori, 2017). Instead of looking for security and trust in the full faith and credit of a government or the financial resources of a large bank, members of the blockchain community of users, investors, and developers find security and trust in a peer-to-peer network of users that each contain a full copy of the blockchain as well as in the blockchain's encryption technology, which enables transactions without the interaction or supervision of counterparties or custodians (Murray, 2022).

In the current "proof of work" model of blockchain formation, a person can retain the right to add a new block by downloading the entire blockchain and completing a series of difficult mathematical calculations known as cryptographic "hash" processes (Sobti and Ganesan, 2012). This person is referred to as a miner or minter. As mentioned above, the blocks created by mining and minting under the proof of work model could contain bitcoin, tokens (NFTs), or other collections of data. The blocks are created using hash calculations and attached to the blockchain.

Forging or minting, as opposed to mining, is more likely to be used to describe the creation of an NFT when the "proof of stake" approach is applied. A consensus mechanism will be chosen from this group to forge the block, and the other participating nodes will decide to validate the block. This technique requires those who wish to be qualified for the bonuses of creation to stake cryptocurrency in a wallet in order to acquire the right to be a validator.

An NFT (non-fungible token), a particular class of blockchain-based cryptographic token, is utilized to identify digital assets. Due to how simple it is to replicate digital data, NFTs specifically offer a mechanism to demonstrate the ownership and validity of digital assets, something that was not truly achievable before. In this way, the digital assets are protected to a high level. This is mostly important for the artists who display their artworks in digital platforms as digital assets in different formats. A simple copy and paste or screenshots would be enough for “having” the artwork however an authenticity can only be provided through tokenization today.

As previously mentioned, the NFT logs a minting transaction that is integrated into a block, encrypted, and attached to a blockchain. There is a conscious effort to limit the amount of data (i.e., the file size) of the assets that are to be identified into the NFT since blockchains typically use a proof of work model for creation of blocks and the most popular chain for art NFTs, Ethereum, enforces gas fees for the formation of NFTs. In simple terms, the bigger the file, the longer it will take a minter to detect a matching address for the block and the more gas will be used to attach the block to the chain. Therefore, the block must have a very small graphic file size if it is to include an actual artwork file such as a.jpeg, .gif, or .png. For example, CryptoPunks are able to be directly coded into their NFT and transferred on the chain due to its small file size, extremely low resolution, and huge pixelation (only 24x24 pixels, or 24 dpi resolution or 0.001-megapixel resolution) (Murray, 2022).

A smart contract (your certificate of ownership) that refers to a bundle of metadata, amongst many other things provides access to your NFT file, is what you actually purchase when you purchase an NFT (Malsa et al., 2021). To enable customers to clearly identify what their purchase rights them to, NFT markets generally show token metadata on the transaction page. The token metadata presented on a listing from the Mintable.app marketplace is shown in the Figure 2.

In any case, the encouragement due to the authorship protection in NFTs has become critical in terms of both trading digital artworks and experiencing artworks in digital display media without a concern about the authorship. However, the gap between the digital artwork and the owner does not shrink since the ownership exists fully on the digital platforms as a stored data. Although the one who pays for the artwork gets to own the artwork, the preview images for example can still be downloaded even if no authorship can be claimed. Therefore, this paper proposes a framework in which the NFTs can be materialized through 3D printing. In this way, 3D printing of NFTs can provide a hybrid experience in both realms, maintaining the artworks' uniqueness and rarity, proof of ownership, as well as physical copies in hand. Moreover, the artists who were afraid of publicly displaying their artworks for the concern of being copied can create 3D printable products that help them to easily and safely promote their arts to the public.

Token Metadata


```
{
 "symbol": "Mintable Gasless store",
 "image": "https://d1iczm3wxxz9zd.cloudfront.net/c92a4640-3852-
4686-b629-c80405f258da/000000-
0000000000/67608894499395172137109624386848315321739481272832542
 "animation_url": "",
 "royalty_amount": 500,
 "copyright_transfer": false,
 "address": "0x8c5aCF6dBD24c66e6FD44d4A4C3d7a2D955AAad2",
 "tokenId":
 "67608894499395172137109624386848315321739481272832542522197035
 "resellable": true,
 "original_creator":
 "0x957947392EEF123ACb103925dfE8E3784177BBF2",
 "edition_number": 1,
 "description": "<p>I am relaxing</p>",
 "auctionLength": 0,
 "title": "Do not disturb",
 "url":
 "https://metadata.mintable.app/mintable_gasless/676088944993951
 "file_key": "",
 "apiURL": "mintable_gasless/",
 "subtitle": "Do not disturb",
 "name": "Do not disturb",
 "auctionType": "Fixed",
 "category": "Art",
 "edition_total": 1,
 "gasless": true
```


Fig.2: Token Metadata on Mintable.com.

3. METHODOLOGY AND FRAMEWORK

An NFT has a huge potential for 3D printing since the design and execution files are already stored as digital artifacts. That is, these files are readily included into an NFT, directly or by a third-party hosting site that stores the data. Therefore, a framework (Figure 3) is proposed in which the NFT enthusiasts have access to the related folder labeled with the NFT code. There are several files in this folder, including print settings instructions and a tutorial on how to assemble the separate components into the full model. The methodology is divided into four main steps: Collaboration with NFT artists for creating a network and database; Creating STL files and uploading on GitHub; Minting NFT artworks on a Ethereum blockchain based trading platform; Tracking the transactions. This framework aims to provide a transition from digital to physical where experiencing both media become possible.

In order to create an NFT artist network, several accounts on social media were contacted and their NFT accounts are reviewed. The specifications regarding the printability were discussed and a database was constructed. After the creation of the database, a private GitHub profile was created in order to upload STL files and the data in the profile was restricted in order to seal the identity of parties of transactions. Then, 2D vector-based NFTs were extruded in the modeling platform and the 3D files were refined. The NFTs were uploaded to Mintable, a free trading platform based on Ethereum blockchain. A preview image, item description and listing details were entered and the GitHub link was inserted into private/unlockable content. After listing the NFTs, a number of auctions were received and the NFTs were sold. After each transaction, the GitHub page was checked and the number of download values were recorded.

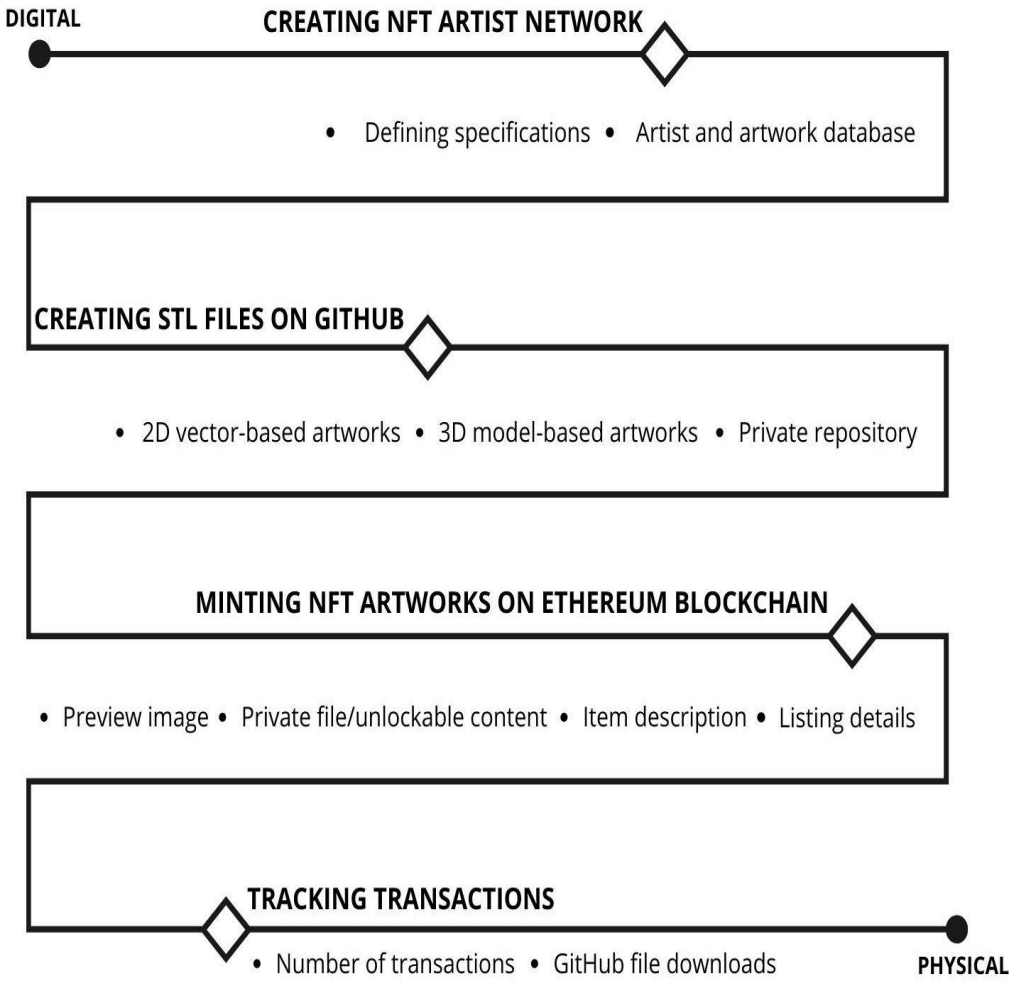

Fig.3: Methodology of the framework

4. APPLICATION AND RESULTS

The proposed system was conducted with the NFT artist XXX as the starting point to validate the overall system. Four of the artworks have been converted to STL files through modeling on Rhinoceros 3D/Grasshopper, using Image Sampler and the optimized forms were 3D printed (Figure 4). Two of the artworks were 2D drawings originally so they were converted into lines, and their extrusion (Figure 5) provided a possibility of printability. The other two files were already in 3D format; however, they were not printable due to the mesh topologies. Therefore, the 3D forms were optimized and their mesh faces were reduced in order to be able to print them. At the end of the printing, each artwork was used as a decoration or as a product such as a painting on the wall or a keychain, in which they have found their way of engagement with their audience in the physical realm.

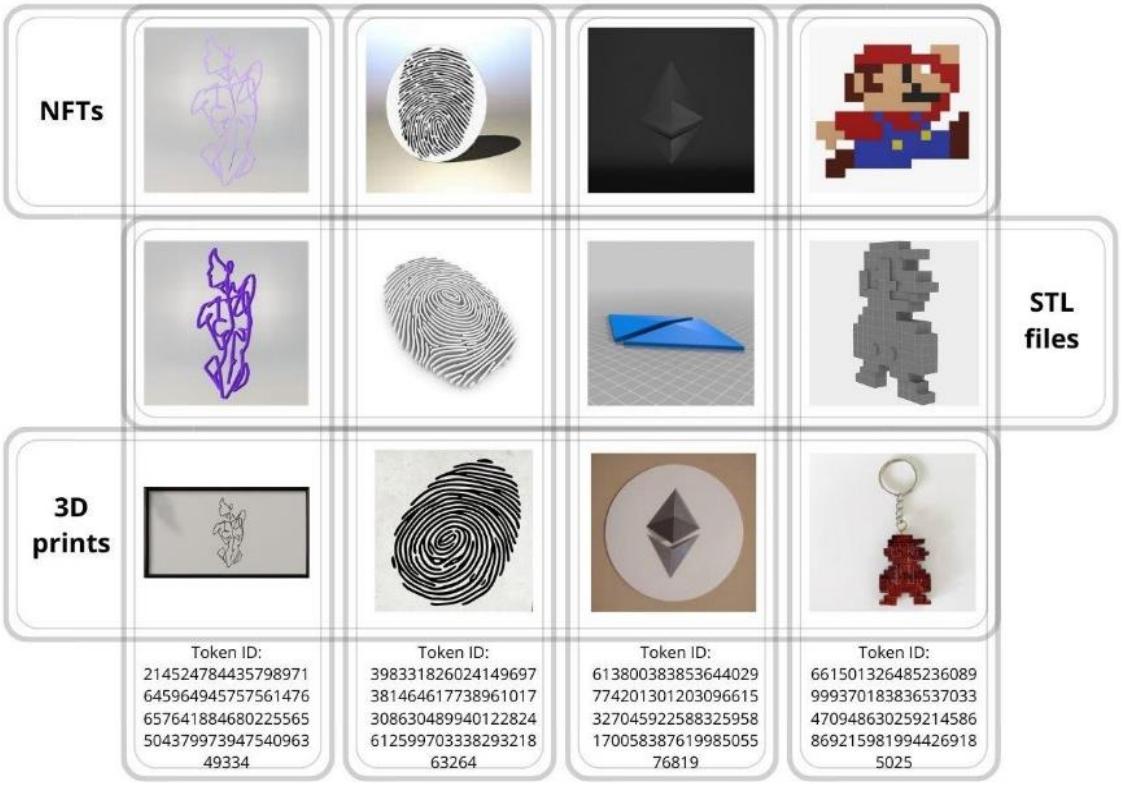

Fig.4: NFTs, conversion to STL files and 3D printing.

Fig.5: The 2D artwork transformation into 3D printable product

5. CONCLUSION AND DISCUSSION

It can be concluded that this framework has provided a hybrid experience for art enthusiasts. Although the number of downloads is trackable, whether the artworks get to be printed is still a question. The identity is undisclosed in blockchain systems and in such transactions, therefore, no one will be consulted and asked to reveal their identity.

Another challenge is that each STL file needs a separate unique download link on GitHub profile, however, it would be complicated and not feasible if the dataset increases. In future studies, the links should be generated automatically or other ways of providing links should be explored.

As a result, the findings have shown that 3D printing of NFTs provided users/customers a hybrid experience in both realms, maintaining the artworks' uniqueness and rarity, proof of ownership, as well as physical copies in hand. Moreover, the artists who were afraid of publicly displaying their artworks for the concern of being copied have created 3D printable artworks that enabled them to easily and safely promote their arts to the public.

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