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A Research Agenda for NFTs

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***Abstract*— Non-Fungible Tokens (NFTs) sit at the crossroads of emerging technologies and the digital transformation of our economy and society. While cryptocurrencies are mainly about decentralizing financial services and currencies, NFTs offer decentralized asset ownership, enabling a new, possibly profoundly transformative approach to managing assets and resources across our society. As a result, NFTs could potentially have a broader transformational effect than mere blockchain because it challenges the traditional notions of ownership and is, therefore, a more fundamental challenge to our established economic and social structures. However, several issues need to be solved regarding NFTs for this to become a reality. This paper provides a systematic review of the NFT literature outlining the research opportunities for NFTs.**

■ **NFTs** have increased in popularity since their appearance in 2014 [5], driven partly by their functionality and the development of standards such as ERC-721 [1]. While cryptocurrencies such as Bitcoin and Ether (the currency of the Ethereum network) were designed to be fungible – meaning that one Ether or one Bitcoin can be used interchangeably with one another - an NFT is instead designed to be non-fungible. NFTs are unique and cannot be replaced or exchanged on a one-to-one basis. NFTs can therefore be determined by uniqueness and scarcity.

NFTs are built using the smart contract capabilities of Ethereum. An NFT is created or "minted" from digital objects representing tangible and intangible items. Current use cases include arts and collectibles, enabling artists to maintain the scarcity of their creations, gaming, and metaverse goods, where NFT games allow for the persistence of assets [2], or DeFi and Services, for example, with Ethereum Name Services. In addition, NFTs protect original physical and digital work [2,17,18]. Most papers have focused on NFTs within the financial services sector. However, NFTs hold the potential for a more significant impact on our world. This paper provides a systematic literature review of the existing work on NFTs and provides a brief research agenda for this topic.

NECESSITY FOR DIGITAL TRANSFORMATION AT SOCIETAL LEVEL

Our institutions, organizations, and supply chains are artifacts of 20th Century modes of operation. Reliant on large-scale structures, globalized standards

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with meetings that require thousands of people to meet in person, homogenous products that reduce local diversity, and rely on massive supply chains that crisscross the globe; Covid 19 has illustrated in numerous ways just how brittle these systems are. It is time to create a more loosely coupled globalization that benefits from a globally connected world but does not create the brittle connections we are currently experiencing. This requires resilient technology, economic, and social systems –blockchain and NFTs can play a fundamental role in this space by forming new structures that provide humanity with new means to interact and engage in a resilient fashion. Decentralization and NFTs may help us with this.

The recently IPCC6 report in October 2021 and COP27 in November 2022 highlighted the necessity for action - with new estimates of reaching or crossing the global warming level of 1.5 degrees in the next 20 years [3]. This will cause intensifying of the water cycle (intense rainfall, flooding, and more intense drought), continued sea-level rises throughout the 21st century (extreme sea level events that previously occurred once in 100 years could happen every year), amplification of permafrost thawing, melting of glaciers, ocean warming, marine heatwaves, ocean acidification; "Stabilizing the climate will require strong, rapid, and sustained reductions in greenhouse gas emissions, and reaching net zero CO2 emissions. Limiting other greenhouse gases and air pollutants, especially methane, could have benefits both for health and the climate," said report author Zhai.

STATE OF THE ART

To fully embrace the potential of NFTs, both industry and research community need a good understanding of the attributes and existing applications of this technology, as well as possible gaps. Our paper outlines a systematic review of the work in IEEE conferences and journals directly related to *NFTs*, rather than blockchain. Previous surveys have focussed on the different application areas of NFTs; our survey and review of the literature differ from [7] by focusing on the attributes of NFTs themselves rather than the application domains that NFTs are applied into, enabling a research gap analysis to be completed more fully.

METHODOLOGY

A systematic review of the NFT literature helped us identify current gaps in the IEEE literature. Our search strategy was based on the PRISMA Framework [20] and structured in three main phases (see Figure 1). The following sections detail the identification, exclusion criteria, and analysis procedure.

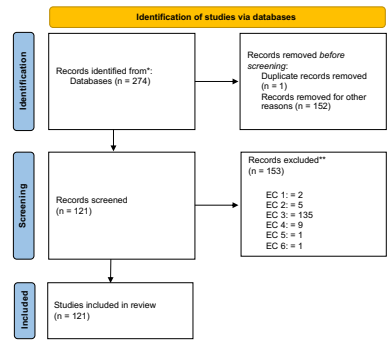

Figure 1: Identification, screening, and inclusion procedure following the PRISMA framework

Identification

The identification was performed according to the following criteria:

Database: the analysis was focused on searching the IEEE Explore database. This database was chosen for the quality of its contributions and its comprehensive database of IEEE activity in this space.

Data filter: the search was restricted to a 5-year period of articles published between January 2018 and January 2023. This was viewed as sufficient due to the novelty of the NFT topic

Key terms: this review focuses on the fields of NFTs, rather than just blockchain solutions. Therefore, we focused our query on the term "NFT" and associated phrases – "Non Fungible Tokens" and "Non-Fungible Tokens".

The database was last searched on February 10th, 2023, to give the most up-to-date results possible. The search resulted in 274 items, which were screened for eligibility.

Exclusion Criteria

Eligibility assessment was conducted considering the following exclusion criteria:

EC 1: The item is a review article, doctoral dissertation, book, book chapter, demo, or not peer-reviewed (2 articles)

EC 2: The article is not publicly available online (5 articles).

EC 3: The abbreviation "NFT" has a different meaning (135 articles).

EC 4: The work presented in the article does not qualify as NFT research (9 articles). For example, the key phrase "NFT" is mentioned in passing rather than the main focus of the work.

EC 5: Article relates to a standard rather than a research article (1 article)

EC 6: The article has the same author(s), results, and methodological approach as another paper already included (1 article).

At the end of the screening process, 121 articles remained for analysis.

Analysis Procedure

The 121 papers selected were summarized, and metadata was extracted into a spreadsheet containing the article's title, author(s), publication venue and year, keywords, methods, and domain (e.g., security, data provenance, economic aspects), as well as a summary of the research question(s), the context of the application, and primary research contribution(s)/outcome(s).

Each paper was then analyzed through the following questions:

Q1: Does the research target NFTs as a central issue?

Q2: What is the area of research related to NFTs?

Q3: What are the research gaps?

These questions served as a framework to determine how the research described in the article contributes to the overall agenda around NFTs within the IEEE community and enabled us to assess the research gaps in a structured fashion. In examining the corpus, attention was given to how the authors framed the research question. If research questions were not straightforward, we screened the problem context - i.e., the main issue(s) being addressed – and the focus on the paper regarding NFTs. If NFTs were part of a solution description, we captured how NFTs were used in the solution rather than the solution itself, e.g., NFTs were used to provide provenance and traceability, or the research proposed security solutions. The second author conducted the analysis.

RESULTS

Our screening resulted in 121 papers that satisfied the inclusion criteria. Articles included in the corpus were mapped to analyse how NFTs are being approached in the IEEE community. We first provide a summary of the results from the mapping exercise. Second, we present and discuss emerging trends.

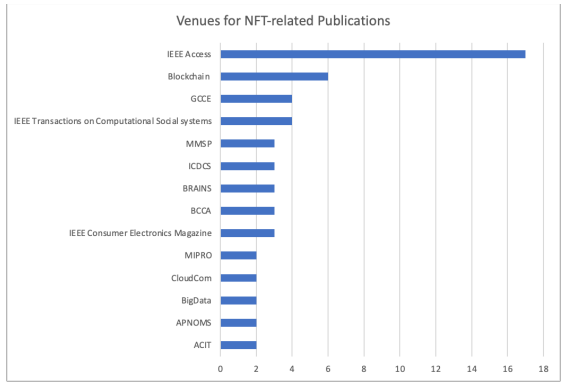

Figure 2: Distribution of the 121 papers of the corpus per venue (top 14 venues)

In terms of venues (see Figure 2), the most popular was IEEE Access (17 articles), followed by Blockchain: IEEE International Conference on Blockchain (6 articles), GCCE: Global Conference on Consumer Electronics (4 articles), IEEE Transactions on Computational Social systems (4 articles), MMSP: International Workshop on Multimedia Signal Processing (3 articles), ICDCS: International Conference on Distributed Computing Systems (3 articles), BRAINS: Blockchain Research & Applications for Innovative Networks and Services (3 articles), BCCA: International Conference on Blockchain Computing and Applications (3 articles), IEEE Consumer Electronics Magazine (3 articles), MIPRO (2 articles), ACIT: International Arab Conference on Information Technology (2 articles), APNOMS: Asia-Pacific Network Operations and

Management Symposium (2 articles), BigData: International Conference on Big Data (2 articles), CloudCom: International Conference on Cloud Computing Technology and Science (2 articles). A further 64 venues published 1 article each, including flagship publications such as IEEE Computer, IEEE Network, IEEE Transactions on Green Communications and Networking, IEEE Transactions on Information Forensics and Security, IEEE Transactions on Network Science and Engineering, IEEE Transactions on Systems, Man, and Cybernetics, and IT Professional.

Spread of Topics

The spread of topics that the articles covered varied, but several main areas of interest concerning NFTs were evident, as illustrated in Table 1. Themes were selected by addressing the areas outlined by the authors or in the solution description.

Context	Count
Data Provenance	32
Economics	16
Security	14
Other	9
Network Architectures	8
Gaming – Digital Asset Ownership	5
Incentive	5
Marketplace	5
Overview	5
Data Provenance / Models	4
Network Analysis	4
Survey	3
Artwork Production	1
Copyright	1
Digital Objects	1
Digital Twin	1
Environmental	1
Metaverse	1
Performance of NFTs	1
Repository	1

Table 1: Summary of Topics Covered in Corpus

Most papers in the corpus (32 articles) target the application of NFTs to data provenance. NFTs (Non-Fungible Tokens) can help solve data provenance by providing a unique digital identifier tied to a specific asset. NFTs use blockchain technology to create a permanent, tamper-proof record of the ownership and transfer of a digital asset, including any information about its creation, history, and authenticity. This allows for transparent tracking of the asset's ownership over time and makes verifying the asset's provenance easy. Another related area is data provenance applied to the complex area of models – both 3D and otherwise (4 articles). The data provenance and proof of ownership attributes of NFTs were applied in various areas – e.g., publishing or diamond tracing. A critical area of provenance proved to be tracking and tracing digital assets within gaming (5 articles).

NFTs can help 3D models by providing a secure and verifiable way to track the ownership and provenance of digital 3D assets enabling the protection of intellectual property and transparency and improving market efficiency through NFT-based licensing models. With NFTs, 3D models can be unique and indivisible, and their ownership can be easily transferred and tracked on a blockchain.

The second highest-ranked topic of papers (16) was the economic implications of NFTs – using big data analytics to measure the impact of different pricing strategies and provide algorithms to ensure the profitability of NFT funds. Incentive management (5 articles) was highlighted as a robust application area, where NFTs were used to ensure optimal outcomes for all participants in various contexts. Finally, a handful of papers referred to the marketplace aspects of NFTs (5 articles).

A clear area of interest in the corpus is the application of NFTs within or as contributions to technical architectures, including Network Architectures, code repositories and other architectural

solutions. In addition, the security issues associated with NFTs were highlighted.

Finally, we found only one article that covered the potential for a positive environmental impact of NFTs, and this can provide a fruitful research agenda if addressed correctly.

DISCUSSION

In this section, we discuss some of the attributes of NFTs that enable new solutions and illustrate some use cases.

Fractionalized Ownership / Collateralisation

A crucial benefit of NFTs for certain types of assets over physical artefacts is support for (decentralized) royalty deals, "where a fee is collected by the initial creator of a digital collectable every time its NFT is sold to a new owner." [15]. The use of NFTs for fractionalization of ownership of assets is often presented as a breakthrough in ownership models. The ability to fractionalize assets into multiple digitalized pieces provides shared ownership. It enables various new revenue models for data provenance, data supply chains, and digital twins, as outlined in Table 1.

Digital assets are also becoming interesting as an asset class for institutional investors – and the service and product offerings in this space are expected to grow over the following years. New products and services must be built around them to enable NFTs to be used as non-passive (i.e., buy and hold) investments.

A newer set of NFT products and services are being developed around collateralized NFTs. NFTs can be used as collateral for loans – this can streamline the lending process by reducing counterparty risk and provides capital efficiencies for trade participants by accelerating clearing and settlement to real-time.

While it is still relatively early in the innovation cycle for NFTs, only a tiny fraction of the use cases take advantage of NFTs for a broader incentive than financial gain. Even those projects that have been proposed around using NFTs for sustainability [3] [4] have mainly used NFTs as a fund-raising mechanism rather than for more innovative purposes.

Data Provenance

As our corpus illustrated (see Table 1), the role of NFTs in data provenance is a key area of research. Within the broader industry, however, the uptake of large-scale data supply chains (DSC) has been an area of increasing concern as data-driven companies such as Meta, Amazon, TikTok, and many others have used data from individuals to power their revenue streams. A DSC enables the collation of multiple data streams from several sources, such as Devices and IoT sensors, to open data, mobile networks, or corporate databases. These data are then connected through a company's data production processes, as illustrated in Figure 3.

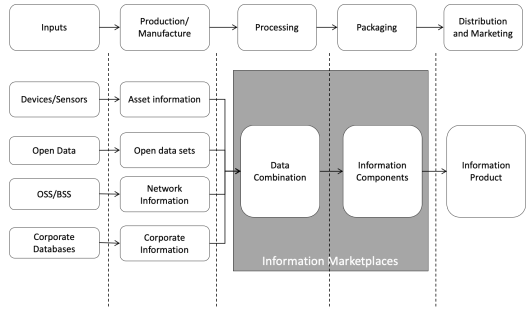

Figure 3: Data Supply Chain

A vital aspect of this process is to ensure trust in the data flows – i.e., data being used in the creation of an information product:

1. is from whom it says it is from (data provenance)
2. has not been manipulated in transit (data integrity)
3. is the correct data to use in this process (data value)

Within DSCs, it is essential to develop trust in the data used within them – otherwise, incorrect decisions can be made due to the wrong input of data, or people may not use DSC. Many proposed solutions for the ownership, trading, and access of data rights fall short of the correct levels of "traceability, transparency, audit, security, and trustful features." [14]. As a result, there are several proposed uses of blockchain and NFTs to assure the integrity and, in some cases, monetization of not just the data but the Artificial Intelligence (AI) models themselves; NFTs can "protect the ownership rights of the AI assets and their chain of original creators and contributors to prevent users from falsely claiming rights over others' works… are a powerful mechanism that sits on top of the blockchain network and provides a means to represent assets as unique tokens that are associated with their appropriate owners" [14].

Integrity in the Metaverse

Due to the heavily digital nature of the Metaverse, NFTs and Metaverse are often presented as a powerful combination. Within the Metaverse, for example, different companies are building shopfronts that enable various users to engage within them in a new, fully digitalized manner. The 'real estate' of the Metaverse could, therefore, in theory, also be tokenized and assured with NFTs. For example, users could be assured that they were going to the Tiffany store in the metaverse, not a fraudulent but extremely well-executed limitation, by checking the data associated with Tiffany's NFT.

Furthermore, in the metaverse, identity management will become critical for people to trust it for commercial, social, and other emergent types of interactions. Successfully proving who you are in the Metaverse will become vital in an environment where everyone is an avatar – proving who you are irrefutable will enable a trustful environment [7].

Charitable Fundraising

NFTs can support and sustain fundraising and donation campaigns. Examples include the Ocean Collective "Museum of Extinction," which allows users to buy an NFT of an endangered species with proceeds to reduce CO2 in the ocean, while Moss.Earth attempts to help individuals and organizations offset their carbon by tokenizing carbon credits. In theory, NFTs can be used to raise funds, e.g., for scientific studies that turn genomes into NFTs [6], to use donations of heritage NFTs to sustain and restore them [4].

A critical issue, however, is how to connect the physical world with digital – how do you save the ocean by owning an NFT of an endangered species? How can you connect the purchase of an NFT with genuine CO2 reduction? Many solutions rely on an ex-ante reward model rather than an ex-post one, leading to further environmental damage as the reward is earned before the positive impact is achieved.

Another issue is that the use of NFTs means that the items become one-off sales – the NGO or, more importantly, the recipient of the funds from the NFT cannot receive extra funds from the NFT. Therefore, a reusable model of NFTs is needed – one that could enable a subscription NFT connected to an ex-post value, but also enabling a perpetual income from the NFT for the affected parties. A final open issue associated with this type of NFT is that they are directly linked to the notion of property rights in and of itself. So, when used in this manner, they reinforce the foundations of today's environmentally damaging version of capitalism.

Identity Management

Non-fungible tokens (NFTs) can be used in identity management by providing a unique, digital representation of a person's identity stored on a blockchain. NFTs can contain information about an individual, such as their name, date of birth, address, biometric data, and more. This information can verify the individual's identity and provide secure access to various services and platforms, which may be helpful to enable countries with many unregistered people to give them government identities. Example projects already underway include a digital ID system in Papua New Guinea that links biometric data as fingerprints with digital assets. However, this approach leads to broader issues – namely, how to ensure real-world assets are correctly represented in NFTs.

Transforming Real-World Assets onto NFTs

Transforming real-world assets is one of the applications inherent to NFTs, but also fraught with challenges. For many assets that need to be digitalized, however, there are some intrinsic difficulties: For example, items in the real world can be transformed, and the NFT will no longer match them, e.g., if a diamond necklace is transformed into earrings, the original NFT associated with the pendant is no longer usable.

Merely transforming an item into a photograph does not create enough robustness to ensure that items cannot be easily forged or that replacement NFTs cannot be easily made. If the NFT is based on images, it is straightforward for someone to create a similar image (and consequently an NFT) and claim it is the original. Some innovative methods have been proposed to overcome this. For example, 3D optical scanning and modelling technology [15], LIDAR sensors, and spectrum analysis in frequency domain transforms [16]. Once a unique fingerprint can be created that is directly tied to the actual physical properties of the object in question, e.g., the occlusions

in a diamond or the shape information of a 3D CAD file encoded as a superposition of frequencies, a hash can be created and linked to an NFT that is difficult to forge or re-use without permission.

FUTURE USE CASES

Decentralization – and NFTs – can play a role in assisting humanity move towards a more loosely coupled globalization – where local communities can respond and adapt to significant climate shifts while maintaining the overall benefits of global interconnectivity, knowledge, and cultural exchange, as well as trade where appropriate.

NFTs as investment vehicles for the delivery of Critical Infrastructure (CI) roll-out

A more complex use case is applying NFTs as a means for delivering CI – this use case demands in-depth thinking about the links between large-scale civil and digital infrastructure.

Traditionally, CI has approached the same way in all nations – using the same large-scale 'mega-engineering' that has been successful in the higher GDP countries. This approach, however, has severe limitations – it is costly to finance, roll- out and maintain, and is fossil fuel-intensive to operate [10]. Despite having large amounts of private-sector investment and government subsidies, this approach to large-scale CI suffers from a lack of flexibility when large-scale weather events hit – for example, in Texas and the UK, large numbers of the population were left without power due to centralized energy infrastructure. In other nations – especially those without established infrastructure – there is often little private sector involvement due to investor unwillingness to assume the commercial, financial, and political risks of such large-scale undertakings. Over the last decade, governments have sought to attract private investment by offering support to investors through grants, soft loans, or guarantees. These programs have failed to deliver the genuinely flexible type of infrastructure required as they promote dependency (generally on a foreign entity) and do not create significant empowerment or employment opportunities locally. World Bank loans are also complex for them to manage as they can undermine borrower country ownership and restrict policy space. Very often this can lead to harmful impacts on the lives and livelihoods of people, especially the world's poorest and most vulnerable. The European Network on Debt and Development found 506 conditions found in 53 Development Policy Operations (DPO) – 9.6 conditions per operation on average. On the other hand, community-owned and community-built infrastructure for water, sewerage, and energy have shown great promise in solving the delivery of CI for such communities; most of these have been decentralized but have failed to create a scale of delivery. Digital technologies can help with achieving this scale.

Decentralization, therefore, has a vital role to play in delivering inclusive infrastructures through creating innovative financial instruments for the entire life cycle of CI so grass-roots communities can self-fund and, in some instances, self-build their infrastructure, which has been shown to bring greater empowerment to communities, opportunities for employment and better educational outcomes. In some cases, the use of localized currencies can even help create better financial resilience – localized currencies linked to inclusive infrastructure can help to create localized flourishing economies that can survive economic and other types of shocks better than those relying on traditional, brittle, centralized financial and civil infrastructure development methods. The key is the combination of the Internet of Things (IoT) devices with NFTs to provide reliable infrastructure.

The development lifecycle of CI to create resilient infrastructures across the entire lifetime of a project is illustrated in Figure 2. The role of cryptocurrencies and blockchain can be applied through the whole lifecycle of the CI - from conception, proposal, tender, development, installation, and financing. In addition, we place the socio-technical aspects of the system at the center of our analysis to develop the best technical solution possible, as well as the governance aspects of both the technical aspects (DAOs, NFTs, etc..) and the overall solution itself. Different parts of the governance mechanisms will be highlighted, developed, and communicated at each point of the life cycle.

Figure 2: A Framework for NFTs for CI

Within this framework, we can see numerous areas where blockchain and NFTs can play a role in the delivery of critical infrastructure:

Infrastructure projects can allow the crypto community to invest in financial products with bond-like risk levels while the expected return is still respectable. Looking at small-scale PPP, the investments are typically longer-term, starting at three years and going up to 15 years.

NFTs can be used for effective maintenance notifications as they allow machines to authenticate the data from various parts of the infrastructure, e.g., water pumps.

Greater security can be obtained by, e.g., automatically minting NFTs to certify that devices are functioning and trustworthy.

As illustrated in the previous section, NFTs may have a powerful impact on the ability of our world to manage/handle climate change, as well as several other transformational effects on our economy and society.

BRIEF RESEARCH AGENDA

In this section, we summarize some of the leading open issues that need to be progressed to ensure that the positive impacts of NFTs can be harnessed for society's benefit.

Security Research Areas

Security remains a critical open area of research, including contract size, quantum computing and the emerging concepts of Economic Security.

NFT Contract Size

The EIP-170 standard was the first to introduce a contract size limit of 24576 bytes to prevent denial-of-service (DOS) attacks [9]. As NFT use cases are expanding, the number of features in contracts is increasing, so this limitation may be reached at some point. For example, ERC1400, a security token standard, requires 27 functions and 13 events to be successfully deployed. Some solutions are proxy contracts and distributed linked contracts over the network. However, some developers may need related functionality in one contract only.

Some proposals have appeared to tackle this issue, such as EIP-2535 [11]. EIP-2535 "enables people to write smart contracts with virtually no size limit.", within this standard, a "diamond" is a contract with external functions supplied by "facets." "Facets" are separate and independent contracts that can store and share internal functions, libraries, and variables; the modularity idea is proposed to solve the problem with size limitations. However, someone implementing a contract using this standard may still need extra work to coordinate all the subcontracts ("facets"). Open research topics could include maintaining the same aspects that this "limitation" brings when introduced, like the prevention of Denial-of-Service attacks [8] [9].

Quantum Computing and NFTs

A new era of computing is rapidly emerging with quantum computing. While traditional computing uses bits with two possible values, 0 and 1, qubits can have several states simultaneously in quantum computing. As a result, deterministic and sequential processes can be dropped in favor of simultaneous and probabilistic ones. Quantum computers can solve mathematical problems that are currently unsolvable by traditional computers. For example, the Sycamore quantum processor solved a problem in 200 seconds [12]. The same situation would be solved in 10,000 years using a powerful traditional computer.

This raises several problems regarding computer security, namely current cryptographic algorithms that take advantage of the "slowness" of current computers. For example, RSA keys are the product of two N-digit prime factors, assuming that "the opposite process of prime factorization, for which the computational time increases exponentially with N" [13]. Current computer systems are expected to have all security mechanisms violated by quantum attacks. This includes ledger systems like the blockchain where NFTs are housed, impossible (theoretically) to attack—blocks on the chain work with traditional and current hashes and encryption mechanisms. The basic assumptions of authenticity, integrity, and confidentiality can be broken with quantum computing.

Blockchains must evolve to protect against this new paradigm through harnessing quantum computers to build a new era of distributed systems using quantum cryptography mechanisms. Quantum cryptography is a promising start but must be embedded into the NFT frameworks and platforms to assure end-user security.

Economic Security

A key issue yet to be fully addressed in the literature is the difference between security types for NFTs. Most literature focuses on technical security – i.e., the security of the system or platform itself, rather than economic security – i.e., the security issues caused by the fact that NFTs and the DeFI world are implicitly *techno-economic* systems [19]. "Economic risks are inherently a problem of economic design and cannot be solved by technical means alone…even if all technical issues are sorted; we are often left with remaining economic problems about how to market equilibria could be manipulated over time to exploit protocols" [19]. To understand these issues in the NFT world, a better understanding of the markets within which they operate would be required – and from this improved understanding, new protocol incentive structures could be developed for NFTs. For example, in the case of using NFTs to raise loans for critical infrastructure, a critical part of the protocol would have to be ensuring that the 'debt' is serviced effectively and justly before implementing the incentive structure for the protocol. A key issue of economic security is the immaturity of NFT platforms themselves, as does the lack of experience of those running the platforms; e.g. OpenSea only patched holes in their security after it was "brought to their attention" [XX]. While [XX] suggests increased awareness of NFT risks and that owners must "be vigilant and take measures to ensure that their assets are not misused", removing the security burden from end users is an open research area that should be addressed.

ECONOMIC RESEARCH AREAS

Transaction Models

One key issue identified during the SLR is related to the lifetime of NFT tokens. Many of them are created, sold once, and then forgotten or unused further. Such transaction models where the creator is remunerated only at each transaction (resale) cycle can create a two-way problem - the creator stops receiving funds, and their owner stops receiving recognition for an up-to-date product (e.g., the latest NFT sponsoring an exhibit at a Museum), leading to a negative cycle. One solution for this problem is to create a temporary licensing model for NFTs (i.e., valid for a certain period). An example could be donations for museums – an NFT could be used as a subscription token for donations – enabling new assets to be created each year. Buyers would be tempted to buy the new NFTs, while museums could continue to have subscription revenues.

Copyright and NFTs

Within the literature, a clear limitation of NFTs is that while they help prove ownership and provenance, they do not solve copyright issues. For example, changing just one pixel in an artwork or a digital asset would change the hash and, despite no discernible difference for human viewers of the digital object or photograph, would be represented as a fundamentally different object. As a result, any owners of the original products would have to resort to traditional copyright law in any disputes that arose (e.g., with someone taking a copy of an artwork and minting a new NFT). One possible solution is creating NFT frames, where secure computing environments ensure that only the person with viewing rights can open the digital asset.

Unintended Consequences

NFTs have been used to fund various innovative products and services, including warfare. NFTs have been successfully used to fund the war in Ukraine, helping to raise over $6.7 million to buy equipment for the war [10]. NFTs are financing options that don't involve borrowing and are appealing since Ukraine is wary of dramatically increasing its debt load. However, similar techniques could be used to fund other types of warfare or terrorism if methods are not developed to ensure that NFT funding mechanisms are used within existing legal frameworks. An open research issue is how to stop NFTs from being used to fund activities prevented under internationally agreed regulations.

CONCLUSIONS

NFTs are an emerging technology that can help create significant transformative effects across our economy and society. The NFT area is not fully explored by the research community. Our systematic literature review identifies several areas of potential interest for the technical community.

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