

Review

Non-Fungible Tokens (NFT): A Systematic Review

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Abstract: Non-fungible tokens (NFTs) are gaining in popularity and are already extensively implemented. New use cases for NFTs are constantly developing. NFTs may prevent counterfeiting since each token carries the owner's digital signature and is thus unique. For the usage of NFTs to progress in an institutional environment, the potential for using NFTs must be investigated in detail. This discovery prompted a comprehensive examination of NFTs developed between 2012 and 2022. The scope is confined to the journal and the keywords "Blockchain", "Block-chain", "Non-fungible Token", and "NFT" are used. Also excluded are studies based on interviews, articles in the press, non-English articles, reviews, conferences, book chapters, dissertations, and monographs. This evaluation includes 34 papers from the last decade. This research examines the current state and development trends of NFT. In addition, the gaps and difficulties in the related literature have been explored, with an emphasis on the limits. These results highlight many unsolved research questions and potential future research avenues that would likely be beneficial to academics and professionals.

Keywords: non-fungible tokens; blockchain technology; NFT; systematic review

1. Introduction

A non-fungible token (NFT) is a "cryptographic asset on a blockchain containing unique identifying information and codes that separate them from one other," as defined by Peres et al. [1] in an editorial. Even though CryptoKitties, a game based on the Ethereum network, initially attracted attention to NFT goods in late 2017 [2], the rapid expansion of the whole business is intimately tied to the birth of COVID-19. After the World Health Organization identified a global epidemic, bitcoin market liquidity jumped dramatically, according to existing research [3]. Simultaneously, investors flocked to numerous cryptocurrency marketplaces, including NFT, as a result of the sharp decline in global market interest rates [4]. Significantly, the pandemic lockdown measures increased internet interaction and further drove the expansion of NFT. In addition to attracting extensive interest from fans and investors, there has been a steady emergence of academic studies on NFT.

However, surprisingly little research has been conducted on NFTs compared with the extensive literature on Bitcoin and other cryptocurrencies [5]. NFTs are still in their infancy, with both great potential and uncertainty; this suggests that there is insufficient research material or data to enable a significant number of projects. However, it is partially because NFTs is a multidisciplinary field of study. It necessitates a greater collection of information and comprehension in different domains. Similar to cryptocurrency research, there are three primary fields of NFT study: computer science, economics and finance, law, and other disciplines [6].

Research on NFTs is essential in light of the lessons learned from the evolution of cryptocurrencies. The capability of decentralized, distributed ledgers is seen to be even more fully exploited by NFT, which is why some academics predict it will expand at a comparable pace and to a similar degree as cryptocurrencies [7]. Given the current trajectory of scientific inquiry, NFTs are widely expected to have a particularly radical effect on the financial and economic sectors. To begin with, NFTs enlarge the potential uses of blockchain technology [8]. This is because it introduces digital scarcity, which makes digital assets



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more valuable via a new form of ownership [9]. Second, NFTs contribute to developing a brand-new economic ecology, which inspires content producers. It not only lowers the barriers to entry into new markets where content creators can make money off of things such as images, music, and artwork, but it also allows them to fine-tune contracts with existing markets or minimize the number of third parties involved, improving efficiency and decreasing overhead costs [10]. Finally, regulatory policymakers have seen an increase in issues including speculation, fraud, and excessive volatility as a result of NFTs [11].

The objective of this paper is to review the current status of the NFT literature in a way that will help emerging researchers catch up on the development of the field and give guidance for enhancing the quality of future studies. To be more precise, this research does a comprehensive literature evaluation of previous work on NFT. Moreover, we want to identify gaps in knowledge and promising avenues for future study. Here, are the specifics of the research questions (RQs):

- A. RQ1: What is the current state of the area of study?
- B. RQ2: What is the direction of NFT's evolution?
- C. RQ3: What are the common challenges that NFTs must overcome?
- D. RQ4: How will NFTs evolve in the coming years?

The present research is organized as follows. The second section covers in detail the research methodology used to locate, screen, and choose the literature. The third part covers the NFT literature, presenting the most-cited papers, discussing their relevance, and highlighting some of the major issues in this subject. The section finishes with a discussion of forthcoming developments. The conclusion is addressed in the last portion of the report.

2. Research Methodology—Systematic Literature Review

2.1. Planning the Review

This study synthesis aimed to assess the present status of NFT. This investigation was conducted with the greatest seriousness by thoroughly reviewing all current relevant literature. Utilizing organized RQs, databases, and techniques for locating and evaluating material is integral to the review approach. Certain elements of the specified reporting items for systematic reviews were selected to give a clear, quantitative, and thorough assessment of NFT. The entire plan comprises the following important steps:

- I. Analyzing the state of the field at the moment.
- II. Understanding the evolution trends of the study.
- III. Determining the field's difficulties and potential future paths.
- IV. A summary of the investigation's results.

2.2. Research Strategy

A holistic review of the literature necessitates an inclusive perspective. Before the search, a sufficient number of databases were chosen to enhance the likelihood of locating highly relevant articles. Throughout the study, Scopus sources are examined.

2.3. Search Criteria

To ensure that the information presented here is comprehensive, relevant databases were exhaustively examined. However, not all great works of literature have been included in the search criteria for a variety of reasons. To achieve this goal, a complete literature search was performed. Approximately 127 Scopus results have been examined, published before November 2022. Thirty-four were deemed significant (Figure 1).

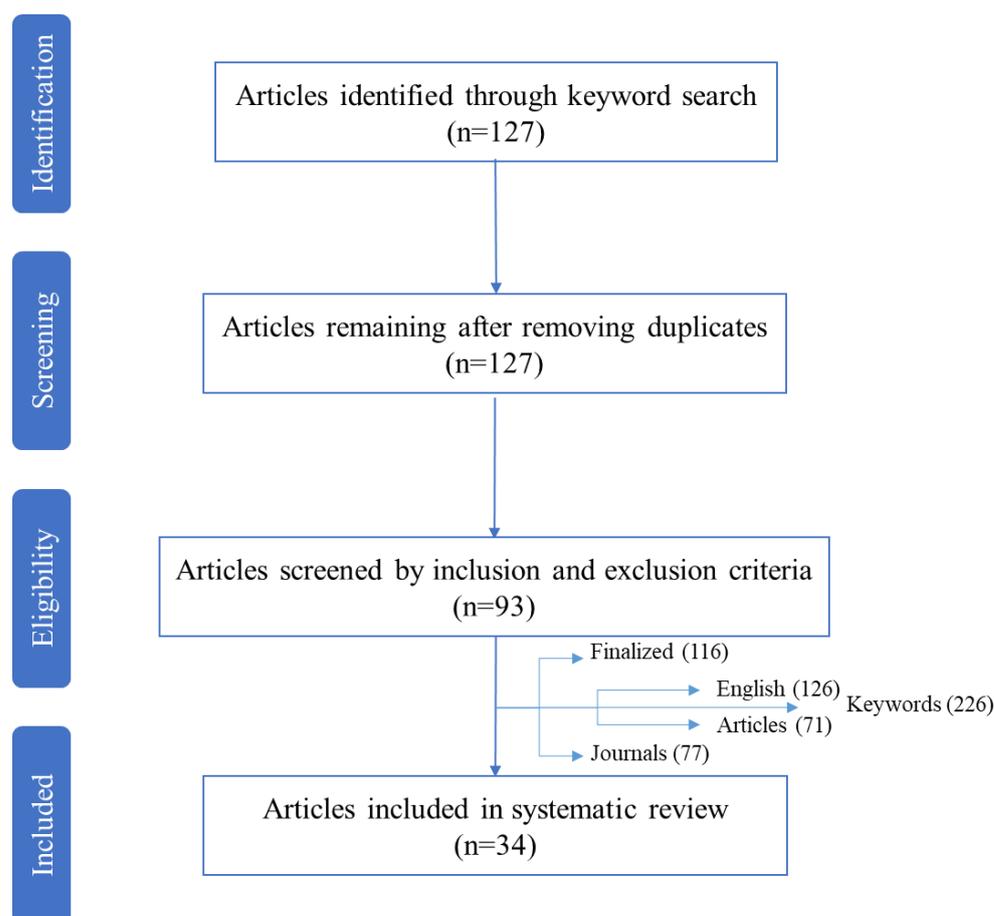


Figure 1. Diagram depicting the selection of studies for a systematic review.

Study domain and research topics affected the development of the search string. By searching “NFT” AND “Non-fungible token” pertinent information was identified and collected.

(I) Inclusion criteria (IC).

1. Research published at any point between 2012 and 2022.
2. The keywords include “Blockchain”, “Block-chain”, “Non-fungible Token”, and “NFT”.
3. The research scope is restricted to the journal.

(II) Exclusion criteria (EC).

1. The elimination of articles in the press.
2. Articles that are not in English.
3. Exclusion of reviews, conferences, book chapters, dissertations, monographs, and works based on interviews.

3. Results and Discussion

The results of answering the RQs given in the preceding systematic review are as follows. This study seems to substantially advance the use of NFTs. This section describes NFTs and their foundations, variations, development teams, platforms, and consensus procedures. The importance of employing NFTs will be discussed in further detail in the future.

Selection Results

In total, 93 of the 127 items that this search produced were screened. This systematic review includes 34 articles. Below is a list of the papers that were chosen, along with explanations of the general categorization findings. The review process’s limitation is that the database is mainly Scopus.

A. RQ1: What is the current state of the area of study?

This systematic analysis examines the collected descriptive data on the different articles published each year, the publishing source, and the annual average number of citations that research publications receive. The examination of NFT research papers published between 2012 and 2022 is completed in this systematic review. The number of referenced research articles is shown in Table 1 along with the relevant journals.

Table 1. Several articles across different journals.

Journals	Number of Publications
IEEE Access	5
Finance Research Letters	4
Mathematics	3
Scientific Reports	2
Sensors	2
Applied Sciences Switzerland	1
Automation In Construction	1
Buildings	1
Business Horizons	1
Computer Communications	1
Crime Media Culture	1
Economics Letters	1
Energy Research and Social Science	1
Fashion Style and Popular Culture	1
IEEE Transactions on Green Communications and Networking	1
Information Processing and Management	1
International Journal of Environmental Research and Public Health	1
International Journal of Innovative Computing Information and Control	1
International Journal of Law and Information Technology	1
International Review of Financial Analysis	1
Journal of Business Venturing Insights	1
Journal of Cultural Economics	1
Operational Research	1

The number of articles produced for each topic area from 2012 to 2022 is shown in Figure 2. The main subject areas are Computer Science (14 articles) and Engineering (12 articles). Other subjects include Economics, Econometrics and Finance (7 articles), Materials Science (7 articles), Mathematics (5 articles), Social Sciences (5 articles), Business, Management and Accounting (4 articles), Physics and Astronomy (3 articles), Biochemistry (2 articles), Genetics and Molecular Biology (2 articles), Chemistry (2 articles), Decision Sciences (2 articles), Energy (2 articles), Multidisciplinary (2 articles), Arts and Humanities (1 article), Chemical Engineering (1 article), Environmental Science (1 article), Medicine (1 article), and Psychology (1 article).

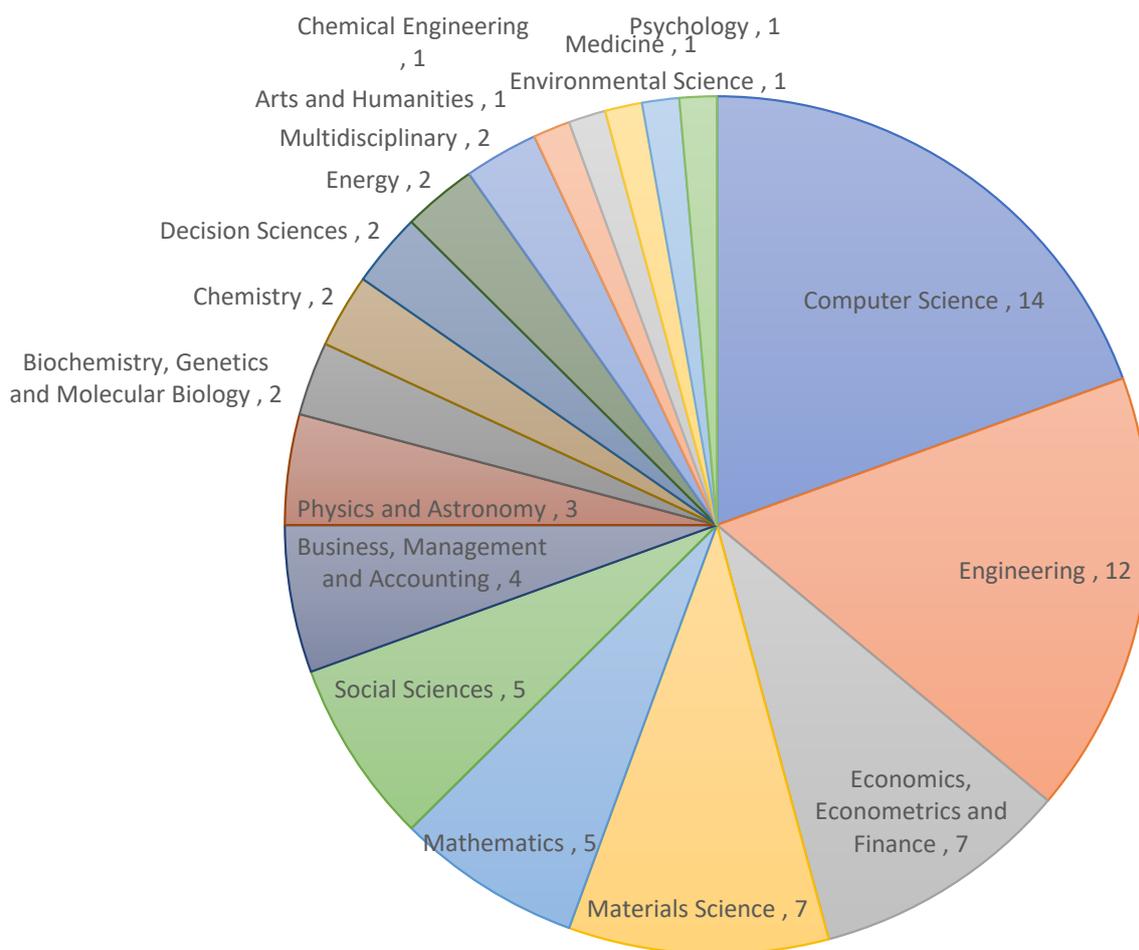


Figure 2. The number of papers written based on the subject area between 2012 and 2022.

Kevin McCoy created the first NFT in 2014 and dubbed it Quantum on the Namecoin blockchain [1]. Dermody and his colleague founded Counterparty in 2014, a peer-to-peer financial platform and an open-source, distributed internet protocol based on the bitcoin blockchain. Throughout the process, an increasing number of projects and assets were created, including a trading card game (2015) and a meme trading game (2016) [2]. With the Ethereum blockchain and what constitutes an NFT today, real NFTs migrated to Ethereum only after 2017. Between 2012 and 2022, Figure 3 depicts the number of articles published year. There is no accessible material from 2012 to 2019. Between 2018 and 2021, there is a gradual increase in public awareness of NFTs, followed by an adoption explosion in early 2021. In 2020, only a single paper was published. The quantity of articles has grown from 2020 to 2022. There were 5 articles published in 2021, followed by 28 articles in 2022 (almost 82% of total articles). In 2022, the number of publications has expanded substantially.

Figure 4 shows the proportion of writers by nationality. China has the greatest number of writers. The United States, Ireland, Australia, and the United Arab Emirates, among others, followed.

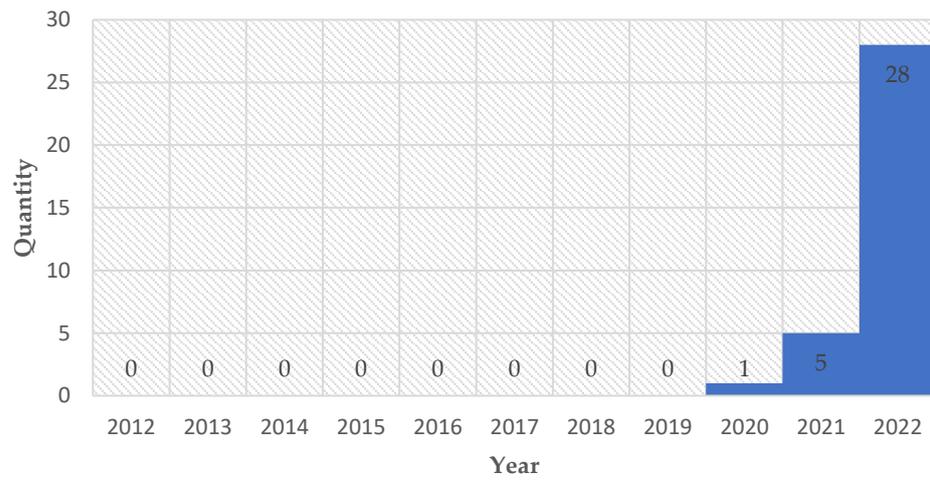


Figure 3. The number of publications published year between 2012 and 2022.

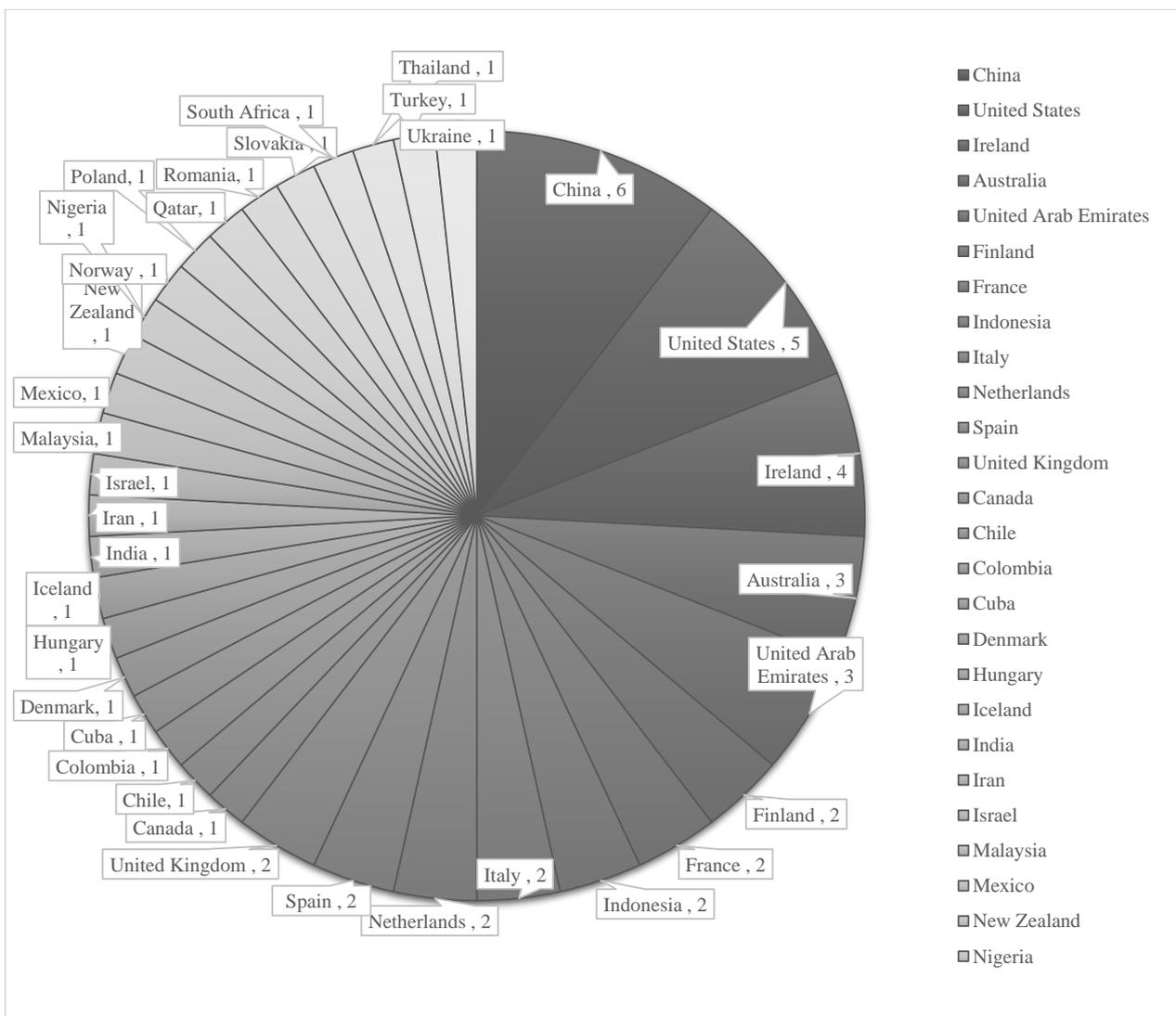


Figure 4. Author distribution by nation.

B. RQ2: What is the direction of NFT's evolution?

Already in 2012–2013, hashes of files or other data were added to the Bitcoin blockchain to authenticate their existence or legitimacy at a certain moment [12]. This development served as the foundation for the creation of “Colored Coins,” tokens that are uniquely identified by introducing metadata to Bitcoin transactions, and “Namecoin,” a separate blockchain that uses tokens to establish an alternative, decentralized top-level domain name system by deploying tokens for domain name registration [13]. Counterparty, is another attempt, offering enhanced capabilities for more generalized uses of NFTs on the Bitcoin blockchain and the first blockchain-based trading cards [14].

The projects and businesses grew and diversified their activities even more in 2018 [15]. The markets and supporting infrastructure grew enormously, fueled by venture finance, cryptocurrency investments, and buzz [16]. As a consequence of this growth, music songs, physical things, academic papers, and a great deal more have been included in NFTs. In some cases, these were only experiments, in others, the founders or investors were searching for their niche, while others assert that this tokenization process would result in a new property system.

As change has progressed, the art world has been lured into partnerships between established art world organizations such as Art Basel and technological firms. The proponents of cryptocurrencies promise enhanced artist compensation, disintermediation, and better compliance with impending anti-money-laundering rules as business reasons for these collaborations [17]. The top 10 papers that were mentioned the most between 2012 and 2022 are shown in Table 2.

Table 2. Top 10 publications between 2012 and 2022 in terms of citations.

	Objective	Year	Cited by	Source
1	Is the price of NFTs determined by cryptocurrencies?	2022	44	[18]
2	Setting a price for NFTs in fertile LAND	2022	43	[19]
3	Charting the NFT revolution: visual characteristics, trade networks, and market developments	2021	34	[20]
4	Robotic reality capture and blockchain-enabled smart contracts for automating construction payments.	2021	29	[21]
5	Spillovers across asset classes and NFTs: Lessons from the COVID-19 epidemic	2022	24	[22]
6	A transaction system based on blockchain with both fungible tokens (FTs) and NFTs for a community-based energy infrastructure	2021	14	[23]

Table 2. Cont.

	Objective	Year	Cited by	Source
7	Secure I and blockchain integration by physically attaching IoT devices to non-fungible smart tokens via physical unclonable functions	2021	14	[24]
8	Intellectual property assets and patents as NFTs; important technologies and issues	2022	13	[25]
9	Mortality, climate change, and blockchain: policy interventions to minimize net-zero consequences, mortality, and carbon emissions of Bitcoin and NFTs	2022	12	[26]
10	Why Are NFTs Getting All the Attention?	2022	9	[27]

C. RQ3: What are the common challenges that NFTs must overcome?

The major pressing issues raised by NFTs are the uncertainties surrounding the legal rights and financial benefits provided by NFTs and the environmental effects of the underlying blockchain.

The ease of creating “digital editions” of art or collectibles on an open, economically liquid, value-transfer network has created new income streams for artists, museums, and businesses. In addition, some supporters contend that NFTs “may be able to democratize art” [28] since they enable a wide range of individuals to share the born-digital art and are paid for doing so. In contrast to promises made by NFT initiatives, however, there is little proof that it, compared with other online monetization types, helps artists’ problems in earning a livelihood [29].

NFTs are publicly available and do not function to support many artists financially from a copyright viewpoint; therefore, those who can build a following (particularly among crypto natives) and previously known artists tend to fare better [30]. Anything capable of being digitized can be converted into an NFT. However, there is a growing interest in NFTs from the copyright perspective, in part because many of the works being traded as NFTs, such as works of art, are copyright-protected, and also because there is a lack of clarity regarding what exactly is acquired when purchasing an NFT. NFTs are not subject to digital rights management, unlike other well-liked material such as streaming services, and may thus be accessed by anybody and many users at once. NFT supporters view these pieces of information as the beginning of a new economic system and the release of artists and their work from the grip of the art market, while detractors and skeptics see it as capitalism in overdrive as a consequence of the commoditization and securitization of art. Commoditization is seeing art as just another tradeable item rather than a valuable object in and of itself. Securitization is the process of converting anything into a financial instrument for use in financial speculation, which also permits fractionalizing (dividing an item into shares). NFT opponents decry widespread fraud and speculation and assert that the economic models used by NFT initiatives do not provide any non-capitalist incentives, such as a more equitable economic structure.

Regarding environmental issues, the majority of NFTs now in use are proof-of-work blockchains, which are criticized for their high energy requirements for security and operation. To lessen the environmental effect, there are second-layer systems or blockchains based on proof-of-stake that are either currently available or under development. However, as with many public blockchains, the amount of energy needed is now a major argument against NFTs [31].

The disappearance of connections (also known as “link rot”) and accusations of money laundering and fraud are further technical and socio-legal difficulties brought up by NFTs. “Link rot” is a serious issue since many NFTs merely provide a link to the tokenized text. This phrase refers to the circumstance in which a hyperlink no longer directs users to their intended destination because the relevant hosting provider no longer provides access to it. A decentralized storage system such as IPFS relies on users sharing data through their nodes or purchasing “pinning” as a service [32].

D. RQ4: How will NFTs evolve in the coming years?

NFTs are immutable digital assets that reflect works of art, musical compositions, and other real-world artifacts that reside on a blockchain. The market for non-fiat currencies is resilient and dynamic, increasing the number of NFT transactions and users. Future studies will further include NFT material that was omitted from this analysis but is of significant value, particularly theoretical publications and common knowledge from the cryptocurrency industry, proposing many broad areas for future NFT research.

NFTs as immutable digital assets represent physical items such as songs or paintings on a blockchain. NFT transactions and users continue to rise as a result of the market’s resilience and vitality. Many broad topics for future NFT research have been proposed, including research into the excluded NFT content that is of substantial worth, such as common knowledge and theoretical articles from the bitcoin sector.

I. Tokenomics

Tokenomics is a system of economics based on tokenization comprising token characteristics, monetary policy, and user incentive mechanisms [33]. In tokenomics, everyone receives tokens as compensation for their participation and uses those tokens to buy goods and services. The term “tokenomics” refers to the token allocation method’s economic behavior in comparison to the market economy’s mechanism for allocating resources. There are three major categories of tokens based on their intended use [34]. The first kind includes payment tokens, also known as coins, such as Bitcoin and Ethereum. In contrast to FTs, which are distinct and divisible, these tokens do not adhere to the NFT principle. Utility tokens are the second kind of token, and they’re meant to provide users with digital access to a certain app or service. The third kind, Asset tokens, has seen a huge expansion in use thanks to the advent of NFT. Tokenomics studies have so far focused on the development, distribution, and management of token ecosystems. All of the results that were presented from this sample were designed for tokens that may be used several times. Howell et al. [34] argue that, if conducted properly, token issuance has the potential to outperform conventional financial instruments in terms of safety, liquidity, and transparency. Tokens are introduced to decrease the effective carry cost of completing platform transactions, which speeds up the adoption of productive platforms, as shown by Cong et al. [35], who give one tractable dynamic equilibrium framework of token price and platform adoption. Except when the platform expects high cash flows, has big funding needs, or confronts serious agency conflicts, Gryglewicz et al. [36] show that token financing is preferable to stock financing. Future research on NFTs may continue in this paradigm by drawing parallels to FTs. Research potential is increased by focusing on the theoretical application and impact of NFTs. For example, NFTs have led to remarkable growth in the digital market and incentives for individual producers, but questions regarding how to build a more efficient marketplace remain unanswered [20]. Furthermore, NFTs are considered an integral part of the Web3.0 and metaverse [37], but there is a lack of state-of-the-art theoretical research on how to build NFT-based ecosystems.

II. Metaverse

Metaverses are defined by an increasing number of interactions between users. To allow responsive engagement, the speed of the consensus mechanism must be considered. As compromise solution algorithms develop over time, it may become possible to examine metaverses in more depth. Metaverses provide more comprehensive data than internet history. Consequently, user information must be safeguarded in an especially secure way. To do this, an additional study must be conducted on user protection. Due to metaverses' decentralized control, entities such as the police or government may be required to safeguard users from harm [38]. This includes offensive material and fraud. How implementation may occur should be investigated further.

III. Regulation and risk

On the one hand, fraud is a significant factor to take into account when working with cryptocurrencies, and the price of NFTs may be subject to market manipulation or other dishonest actions [19]. Therefore, further study is required in the future or existing NFT market to warn or uncover the associated hazards. On the other hand, NFT mining and trading activities can provide unsustainable profits and skew investor expectations, ultimately exacerbating the market bubble caused by the enormous influx of fresh money. Concerns exist over the possible impact of NFTs on other financial markets and cryptocurrencies. The NFT business is currently small enough for politicians and regulators that legislation would impede its development and potential advantages, but its growth should be continuously monitored [11]. Traditional centralized regulatory frameworks have been affected by the cryptocurrency and NFT industry's emphasis on collaborative maintenance, self-management, and decentralization. Researchers must keep looking at and evaluating NFTs from the perspective of rule formation and mechanism improvement if they want to construct a model that is mutually beneficial and synergistic.

IV. Video games

The video game business has to determine whether NFTs are an improvement over traditional games. For instance, a USD 300 starter package is needed for the blockchain game Axie Infinity [39]. The high cost of certain NFT games raises the issue of whether or not the extra money is worth it for players, or whether or not the developers are just trying to maximize their profits. Since the blockchain video game industry grows, it is essential to establish whether scalability is sufficient, as the scalability and speed of a blockchain depend on the chosen consensus algorithm [40]. The video game business is fraught with peril that might lead to the destruction of valuable possessions. The video game business requires easy access; hence, the NFT concept has to be simplified. The potential risks to buyers must be communicated [41].

V. Asset valuation

Research in this area may be hectic right now, but there is room for greater output and clearer pathways to be developed. The first concern is whether or not there is a standard methodology for establishing the value of NFTs. Although it would be possible to do so with a single NFT market, others need further investigation [19]. Other factors might be investigated and added to the study [42], such as market sentiment, financial and economic policy uncertainty, pure volatility indices, and so on. The second goal is to define the link between NFTs and other cryptocurrencies, as well as the elements [18] that drive both markets, such as the Consumer Sentiment Index (CSI), the Consumer Confidence Index (CCI), economic policy uncertainty (EPU), and the Volatility Index (VIX) [22]. Since more and more investors are likely to start using NFTs, its impacts and links with a wider range of assets are likely to become an important area of study.

4. Conclusions

In recent years, NFTs have seen a rise in popularity, not only in research but also in clinical application. Using a blockchain, it is possible to limit access to digital commodities

and keep their value high. As a consequence of the fast progress, new use cases are becoming apparent. Notwithstanding, many contemporary businesses are still unaware of NFTs. Businesses must be made aware of the myriad possibilities presented by NFTs. Because of this insight, a comprehensive analysis of NFT articles published between the years 2012 and 2022, has been investigated. The present status of NFTs, their applications, and the potentially revolutionary impacts of their distinctive qualities are all topics that will be investigated in this paper. It has been brought to people's attention that there are issues and omissions in the relevant literature, in addition to the constraints and the consequences such constraints have on other fields. Overall, there were 34 different articles in this field that were taken into consideration for this evaluation. There is a growing amount of support and conviction in the potential of NFTs, but there is still considerable ambiguity over the future of NFTs. To approach NFTs as a new asset class that needs particular laws, on the other hand, would be a much superior strategy in the long term. The significance of forthcoming advancements in fields such as tokenomics, the metaverse, regulation and risk, video games, and asset pricing has been discussed and illustrated.

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