

NON-FUNGIBLE TOKENS (NFT) MARKET: INVESTIGATION AND PROSPECTS

Marija ILJINAITĖ^{ID*}, Nijolė MAKNICKIENĖ^{ID}

*Department of Financial Engineering, Faculty of Business Management,
Vilnius Gediminas Technical University, Saulėtekio av. 11, 10221 Vilnius, Lithuania*

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Abstract. The financial markets are undergoing rapid transformations that raise fundamental questions about the effectiveness of traditional investment models and strategies. Nowadays, investment options are incomparably wider than ever before, and one of the areas of this global financial transformation is alternative investments, so the question is what might be the trends of one of these alternative investments, non-fungible tokens (NFT). The object of the study is alternative investments, such as NFTs. The article intends to reveal how NFTs might impact the valuation and trade of digital assets, as well as to identify the key advantages and risks associated with NFTs for investors and creators. The research will carry out cluster analysis of NFTs, which will help to better understand the NFT market, learn about possible prospects and developments, possible advantages and disadvantages, as well as the level of risk.

Keywords: non-fungible tokens (NFT), alternative investments, blockchain, cryptography, digital art, unique digital assets.

JEL Classification: G11, O30, P44.

1. Introduction

In modern times, when global economic dynamics and technological development are visible, the financial markets are facing extremely rapid transformation that raises fundamental questions about the effectiveness of traditional investment models and strategies. Investment opportunities are now incomparably wider than ever before, and one area of this global financial transformation is alternative investments. Non-fungible tokens (NFTs) have become increasingly popular among investors and are understood as a new asset class. So, for instance, according to Zion Market Research (2023), the valuation of the global NFT market was recorded at USD 36.12 billion in 2023 and is projected to soar to USD 217.07 billion by 2032, marking a compound annual growth rate of about 22.05% from 2024 to 2032. The benefits of these new investments are related to the unique characteristics of assets, such as the value of fine art, real estate, collectable stamps or wine, which add more diversity and opportunity to an investment portfolio. For this reason, alternative

investments are becoming increasingly important to diversify investment portfolios away from traditional investments such as stocks, bonds and mutual funds and thereby reduce the level of risk (Kong & Lin, 2021).

The dynamic shift in investment preferences and technological innovation is of great interest to investors and the public, so understanding these emerging asset classes is critical. Featuring a unique digital representation of property, NFTs are changing the way we value and trade assets in the digital age. In addition, the rapidly changing regulatory environment for these assets requires in-depth analysis to identify potential pitfalls and opportunities.

Despite the rapid growth and popularity of non-fungible tokens in today's financial markets, there is still little empirical research on their long-term impact on financial systems, investment strategies, and the creative economy. In addition, the question arose: What are the prevailing trends within this market, and how do they resonate with the digital audience at large? This article addresses this question by leveraging cluster analysis to delve into the market's intricacies, thereby shedding light on the potential trajectory of NFTs in the digital age.

* Corresponding author. E-mail: marija.iljinaite@stud.vilniustech.lt

The object of the research is non-fungible tokens (NFT).

This article aims to investigate potential trends in the NFT market and assess its relevance among internet users, utilizing cluster analysis as a key methodology for this exploration. To achieve the goal, the following tasks are set:

1. To analyse the theoretical aspects of alternative investments, such as NFT;
2. According to the examined literature, prepare a research methodology for NFT clusters analysis, detailing the clustering technique and describing how the clusters will be interpreted to identify market trends and segments;
3. Perform NFT cluster analysis.

The first part of the article analyses the theoretical aspects of alternative investments, such as NFT, their principles of operation, advantages and disadvantages, as well as examines the peculiarities of investment, its policy and risk level. The second part of the article presents the methodology for conducting the research. The third part of the article carries out a statistical cluster analysis of NFT.

2. Theoretical aspects of alternative investments

Alternative investments such as non-fungible tokens are new and innovative financial concepts that are rapidly invading the investment world and transforming traditional financial models. These investments are related to the use of cryptocurrencies and blockchain technology, including in the gaming industry, not only inspire consumers and investors due to their uniqueness and potential but also redefine notions of ownership, value, and exchange in the digital age (Faqir-Rhazoui et al., 2021; Longshak, 2022).

The meaning of NFT is unique and widely known in today's digital world. This technology goes beyond the concept of traditional ownership and provides a unique way to mark, store and trade the content and objects in the digital space. The main meanings of NFT are as follows Xia et al. (2022):

1. Immutability: NFTs are immutable – they have a unique identification and cannot be exchanged for other items. This lends authenticity to artwork, collectibles, or other content.
2. Proof of ownership: NFTs enable identification and proof of ownership in the digital world. They confirm that the person is the official holder and can prove it publicly on the blockchain.
3. Transparency: NFT transactions are public and stored on the blockchain, making them easily viewable and verifiable. This, for instance, provides transparency and ensures that NFT real estate ownership is real and immutable.
4. Creative and economic potential: NFT expands the opportunities for creators and artists to enter the global market and receive rewards for their work.

They also provide collectors with the opportunity to purchase unique assets and participate in digital collecting.

5. Innovation: NFTs are part of a rapidly growing digital ecosystem that includes blockchain and cryptocurrencies. This opens the door to new possibilities and experiments that change the traditional concept of property and culture.

The value of non-fungible tokens can also be financial, as they can have a market value. Some NFTs fetch high prices at auctions, and their value can fluctuate depending on collectible value and demand. However, NFTs have more value than just financial. They are changing the way people understand ownership and authenticity in the digital world, providing new dimensions of creative and economic community. This is an example of how blockchain technology is becoming integrated into our daily lives, transforming traditional industrial sectors and creating new opportunities (Alizadeh et al., 2023).

The development of NFTs is interesting and its rapidly developing phenomenon is associated with digital assets and blockchain technology. Although the beginning of NFT can be dated back to 2017, it was largely popularized by the ERC-721 standard of the Ethereum network, which was officially implemented in 2018 (Mazur, 2021). This standard allowed for the creation of unique digital values that cannot be changed or replaced by others. This has opened the door to the sale and exchange of digital collectibles, artwork, music and other digital content with clear authenticity. In the early days of NFT, they were mostly about artists and collectibles. Selling artwork as NFTs has allowed artists to bypass traditional middlemen, such as galleries or art dealers, and directly connect with collectors and buyers. This direct access to the market has revolutionized the relationship between artists and creators, giving them more control over their work and the ability to monetize it independently. Artists interested in selling their work as NFTs typically sign up with a marketplace and mint digital tokens by uploading and validating their information on a blockchain. Some popular NFT marketplaces include platforms like OpenSea, Rarible, and SuperRare. Some artists have found significant success in selling their art as NFTs, with high-profile auctions and substantial sales attracting attention from mainstream media outlets. But the real wave of NFT exaltation started in 2020 and continued into 2021, when it captured particularly high public attention (Bao et al., 2023). According to the NFT Market Quarterly report, NFT trading volume exceeded 277 million US dollars and the average price was more than 4.5 thousand US dollars in 2022 in the first quarter (NonFungible, 2022). Celebrities have entered the world of NFTs this year, including sports stars, musicians, prominent businessmen and more. This has attracted attention not only from cryptocurrency enthusiasts but also from the general public. The field of NFTs has expanded in various areas, including (Xia et al., 2022):

1. Art: Artists began to create and sell their work in NFT format, attracting collectors.

2. Music: Music artists and bands have started releasing music albums, concert tickets and even master recordings of famous recordings in NFT format.
3. Gaming: Games and gaming items have become popular choices for NFTs. This allowed players to have unique items that could be sold and traded.
4. Real estate: Some projects are experimenting with real estate, where NFTs can represent ownership rights, for example, a piece of real estate.

To gain a deeper understanding of NFTs also requires an understanding of the infrastructure in which they are created, bought and sold. Blockchain is a decentralised digital technology that allows transaction data to be stored and managed across various computer networks called “nodes”. The main feature of this technology is that the information is not stored in a centralised server or database, but is distributed among many nodes that all have a copy of the same chain. Each transaction is added as a new block to the chain, and all blocks are stored chronologically, forming an immutable transaction history. The most important feature of the blockchain is its resistance to alteration and fraud since data is constantly verified and updated at all chain nodes. This also provides transaction transparency, as all nodes can view the chain’s contents. Concepts of blockchain technology include decentralisation, persistence, anonymity, and verifiability, common characteristics that apply not only to mainstream blockchain applications but also to NFTs (Flick, 2022; Phumphuang & Jareevongpiboon, 2023; Renduchintala et al., 2022; Proelss et al., 2023).

As for non-fungible tokens, this is a new way for blockchain technology to certify the ownership and tradable rights of digital assets. Unlike traditional cryptocurrencies such as Bitcoin or Ethereum, which are generally identical and exchangeable, immutability is a key feature of NFTs, symbolising the uniqueness of cryptocurrencies, which cannot be exchanged for similar ones (NFTs have no exchange value and are the only ones of their kind). This means that each non-fungible token has a unique identification provided by the blockchain (Wilson et al., 2022). NFTs have gained much popularity in the art, collectibles and gaming industry. They allow creators to release unique digital creations that can be paintings, music, videos, or even virtual game items. NFTs enable the author to prove the authenticity and ownership of the work, and they enable collectors to purchase rare and unique assets (Mikalajūnas, 2022).

Although the development of NFTs has brought many innovations and opportunities for developers and investors, it is also inseparable from certain risks (Meyns, 2022):

1. Price volatility: NFT price volatility can be extremely high, leading to rapid asset value changes. Some NFTs can shoot up overnight and then suddenly fall. This may force investors to quickly buy or sell NFTs to avoid losses.

2. Counterfeit NFTs: The NFT market is not immune to fraud and counterfeiting. Although blockchain technology ensures authenticity and traceability, there is still the possibility that nefarious persons may attempt to sell counterfeit or illegal NFTs. It is necessary to verify the origin and authenticity of an NFT before purchasing it.
3. Legal and copyright issues: NFTs that represent copyrighted content may raise legal and regulatory issues. Creators may be subject to legal protection if their work is sold on NFTs without their consent. In addition, some NFTs may involve controversial content that may lead to legal disputes.
4. NFT market volatility: The NFT market is not mature and volatile, so its future and long-term stability are uncertain. This can mean that a long-term investment in NFTs can be unpredictable.
5. Technological risks: The value of NFTs can also be affected by technological risks such as breaches, security holes or bad behaviour of the blockchain network participants.
6. Platform dependency: Most NFT trading takes place through certain platforms. Investors must depend on the reliability and security of these platforms. If the platform runs into problems or goes out of business, it could affect investors.
7. Market bubble: Due to the rapid development of NFTs, there is a risk that the market may be oversold and prices may be inflated to unrealistic values. This can lead to the bursting of a market bubble and huge losses for investors.

To minimise these risks, investors should perform due diligence and source analysis before investing in NFTs, and use reliable NFT trading platforms.

Investors can take advantage of NFT investment opportunities in several ways. First, they can buy non-fungible tokens hoping that their value will increase in the future. Several NFT projects have already achieved cult status and have become very expensive for collectors (Karjus et al., 2023). In addition, one can speculate in the market by trying to buy NFTs at a lower price and sell them at a higher price, which is a risky but potentially profitable activity. Another way to invest in NFTs is to build your asset values or invest in NFT projects (Babel et al., 2022). NFTs are used in a variety of industries, including the gaming industry, the art world, and even real estate. Investors can create NFTs related to their passions or collaborate with talented developers to create unique digital assets (Trček, 2022). In addition, many NFT projects invite people to invest in them by promising a share of the projects’ profits (Zauchka & Agur, 2023). This is a rapidly developing market that can offer not only financial potential but also a unique opportunity to join the world of digital art and innovation. Therefore, NFT investment opportunities are attracting more and more people looking for alternative investments.

To successfully invest in NFT it is important to understand the pros and cons of these investments, assess your risk tolerance and make informed decisions based on your financial goals and capabilities. This analytical approach can help maximize profits and reduce risk in alternative investments.

The Table 1 shows the pros and cons of non-fungible tokens. Arguably, the advantages of NFTs include uniqueness, developer rights, transparency, and the ability to make money for both developers and investors. Also, NFT can be used as a diversification tool in an investment portfolio. However, it is important to note that the NFT market faces significant risk aspects, including market volatility, risk of fraud, high transaction fees and regulatory opacity. Technological challenges and liquidity risks can also affect the value of NFTs (Sestino et al., 2022; Urom et al., 2022).

Table 1. Advantages and disadvantages of NFTs (source: composed by the authors based on Sestino et al., 2022; Urom et al., 2022)

Advantages	Disadvantages
Uniqueness: Each NFT can be unique and unrepeatable, which gives it a unique value.	Risk: NFT markets are volatile and influenced by market demand, so there is a high risk of losing your investment.
Creator's rights: NFTs allow the holder to have unique ownership of a work, including artwork or music.	Risk of fraud: There are fraudsters and counterfeiters in the market who can sell fake NFTs.
Transparency: Blockchain technology ensures transparency and publicity in NFT transactions.	High transaction fees: Some NFTs may have very high transaction fees.
Monetization: Developers and game item traders can monetize by selling their works or assets as NFTs.	Regulatory risk: NFT markets are poorly regulated, which can lead to legal risks of opacity.
Diversification: Investors can use NFTs as a way to diversify their investment portfolio.	Technological challenges: NFT technology may experience technological disruptions or setbacks.
Support ecosystem: Many support and development projects in the NFT market aim to increase the possibilities of using NFT.	Liquidity risk: NFTs can be difficult to sell, especially if there is no demand.
Investment opportunities: NFTs allow investors to purchase virtual assets and online collectibles that can increase in value.	Uncertainty: NFT markets are still young and volatile, making it difficult to predict their long-term potential.

So, it can be said that NFT has both advantages and disadvantages. These investments offer unique ownership rights, transparency and profitability potential. However, these markets also have significant risks due to market volatility, regulatory uncertainty and the potential risk of fraud. In addition, liquidity risk may arise from the difficulty of selling certain securities.

The next chapter will present the methodology of alternative investment research.

3. Methodology

In order to discover the hidden relationships in the data related to alternative investments such as NFT, to gain insights into their underlying structure and to make a valid and reliable conclusion, this study's analysis is based on a quantitative approach using a multivariate statistical method – cluster analysis. For cluster analysis of publications related to NFTs, the Graphext software data analysis and visualization platform will be used (GRAPHEXT INC, 2024).

Cluster analysis, often referred to as clustering, is indeed a powerful statistical technique used across various fields to uncover inherent structures within data. By identifying groups or clusters of data points that exhibit similar characteristics or patterns, cluster analysis enables researchers and analysts to gain insights into the underlying structure of the data. This method is particularly valuable in scenarios where the natural grouping of data points is not immediately apparent or when exploring relationships among data points.

The process of cluster analysis involves partitioning a dataset into subsets or clusters in such a way that data points within the same cluster are more similar to each other compared to those in different clusters. There are several different clustering techniques, including hierarchical clustering, density-based clustering and K-means clustering (Han et al., 2011). The K-means clustering method will be used for this study, so this method will be described below.

The K-means algorithm is indeed one of the most popular clustering algorithms because it is fast and easy to understand. The algorithm works by randomly selecting initial cluster centers and then iteratively assigning each data point to its closest cluster based on some distance metric. After the assignment, the cluster centers are updated by computing the mean of all the data points assigned to each cluster. The algorithm continues until the clusters no longer change or until a set number of iterations is reached (Kassambara, 2017).

The main goal of K-means clustering is to partition a dataset into a specified number of groups or clusters. The value of K is pre-defined by the user or analyst, representing the desired number of clusters. The algorithm aims to group similar objects together into the same cluster, maximizing the intra-class similarity, while ensuring that objects from different clusters are dissimilar, minimizing the inter-class similarity (Kassambara, 2017).

In K-means clustering, each cluster is represented by its centroid, which corresponds to the mean of the data points assigned to that cluster. These centroids serve as the representatives of their respective clusters and are used to measure the distance between data points during the assignment phase (Kassambara, 2017).

The basic concept behind K-means clustering involves minimizing the total intra-cluster variation, often referred to as total within-cluster variation. The goal is to form clusters in such a way that the data points within each cluster are as close to each other as possible, minimizing the total sum of squared distances (sum of squared Euclidean distances) between data points and their respective cluster centroids (Kassambara, 2017).

Various K-means algorithms have been developed over the years to achieve this goal efficiently. One of the standard K-means algorithms is the Hartigan-Wong algorithm, introduced in 1979. This algorithm defines the total within-cluster variation as the sum of squared Euclidean distances between each data point and its corresponding centroid. Mathematically, it can be expressed as (Kassambara, 2017; Tang et al., 2022):

$$W(C_k) = \sum_{x_i \in C_k} (x_i - \mu_k)^2, \tag{1}$$

where: x_i – design a data point belonging to the cluster C_k ; μ_k – is the mean value of the points assigned to the cluster C_k .

Each observation (x_i) is assigned to a given cluster such that the sum of squares (SS) distance of the observation to their assigned cluster centers μ_k is a minimum (Kassambara, 2017).

The total within-cluster variation is defined as follows (Kassambara, 2017):

$$\sum_{k=1}^k W(C_k) = \sum_{k=1}^k \sum_{x_i \in C_k} (x_i - \mu_k)^2. \tag{2}$$

The total within-cluster sum of square measures the compactness (i.e. goodness) of the clustering and the desirability of keeping it as small as possible (Kassambara, 2017).

In the next chapter, a cluster analysis of NFTs will be carried out.

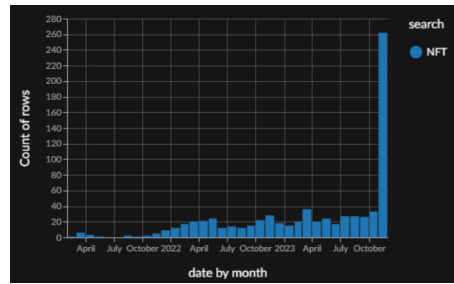


Figure 1. Frequency of queries from Internet users on the topic of NFTs (source: composed by the authors)

4. Research results and discussion

This study used the Graphext Tractor tool to collect data from popular platforms such as Google, Twitter, and Facebook Ads to perform NFT cluster analysis.

As mentioned in the methodology section, Graphext is utilized to create distinct clusters for each article. These clusters are then presented and analysed, employing a combination of the identified topics using SciMAT (a bibliometric tool used for analyzing and visualizing the structure of scientific research, allowing researchers to identify and explore major themes, trends, and relationships within a specific body of literature). Research areas related to NFTs were thus explored. A total of 752 publications from 2021 to 2024 were selected for further investigation.

After analysing the collected data, we can conclude that most of the requests were completed from November 2023 to January 2024 (see Figure 1).

Figure 2 shows the dashboard constructed with Graphext. So, analysing the research data, a total of 23 clusters emerged. The main domains of publications can be identified as follows: cryptosaurus.tech, decrypt.co, cointelegraph.com, forbes.com, nftnow.com, theverge.com, techcrubch.com, coindesk.com, reuters.com, news.artnet.com, etc.

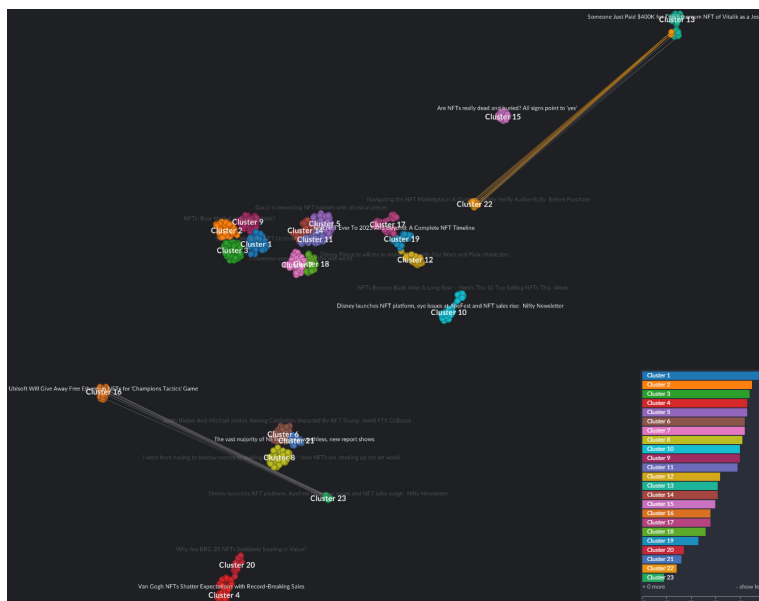


Figure 2. Graphext Dashboard (source: composed by the authors)

The cluster analysis reveals a diverse range of topics and themes within the domain of NFTs and cryptocurrency. Each cluster represents a distinct aspect of the NFT ecosystem, including market trends, technological developments, real-world applications, and industry news.

Cluster 1 – OpenSea NFT Marketplace Review – Forbes Advisor. This cluster appears to focus on a review or analysis of the OpenSea NFT marketplace, likely providing insights into its features, usability, or performance, possibly from a financial or investment perspective.

Cluster 2 – NFTs: Bear Market or Burst Bubble? This cluster explores the current market sentiment and speculation surrounding NFTs, discussing whether they are experiencing a downturn (bear market) or facing a potential bubble burst.

Cluster 3 – New Bitcoin protocol may shake up the NFT market. This cluster discusses the potential impact of a new Bitcoin protocol on the NFT market, suggesting that developments in the broader cryptocurrency ecosystem can influence the NFT space.

Cluster 4 – Van Gogh NFTs Shatter Expectations with Record-Breaking Sales. This cluster highlights the success and significant sales of NFTs related to Van Gogh artworks, indicating a trend of high-value transactions in the NFT art market.

Cluster 5 – Despite crypto crash, NFT enthusiasts keep the party going. This cluster focuses on the resilience of NFT enthusiasts amid broader cryptocurrency market fluctuations, suggesting that interest in NFTs remains strong despite market volatility.

Cluster 6 – NFT Video Startup Glass to Crypto Bear Market. This cluster likely discusses the challenges or impacts faced by a specific NFT video startup in the context of a cryptocurrency bear market, indicating the broader economic environment's influence on NFT-related businesses.

Cluster 7 – 5 common uses of NFTs in the real world. This cluster explores practical applications of NFTs beyond the digital art realm, highlighting various real-world use cases and potential benefits of NFT technology.

Cluster 8 – Most NFT collections no longer have any value: Report. This cluster presents findings or analysis suggesting that the majority of NFT collections have depreciated in value, indicating a shift in market dynamics or investor sentiment.

Cluster 9 – How to Store NFTs. This cluster likely provides guidance or instructions on securely storing NFTs, addressing concerns related to NFT ownership, storage solutions, and best practices for digital asset management.

Cluster 10 – has two subheadings: Disney launches NFT platform, eye issues at ApeFest and NFT sales rise: Nifty Newsletter; NFTs Bounce Back After A Long Bear – Here's The 10 Top Selling NFTs This Week. This cluster covers a diverse range of topics, including Disney's entry into the NFT space, recent developments in NFT sales trends, and updates from events like ApeFest.

Cluster 11 – ANA Group launch NFT marketplace. This cluster likely focuses on the launch of a new NFT marketplace by the ANA Group, indicating an expansion of the NFT ecosystem by major companies or organizations.

Cluster 12 – Disney Pinnacle will try to revive NFTs with Star Wars and Pixar characters. This cluster discusses Disney's attempt to rejuvenate the NFT market by leveraging popular intellectual properties such as Star Wars and Pixar characters, suggesting potential mainstream adoption of NFTs.

Cluster 13 – Someone Just Paid \$400K for This Ethereum NFT of Vitalik as a Jester. This cluster highlights a notable NFT transaction where an Ethereum NFT depicting Vitalik Buterin, the co-founder of Ethereum, as a jester was sold for a significant amount, indicating the value and demand for unique digital assets.

Cluster 14 – The Rise of NFTs: Transforming the Art World – LCX. This cluster explores the transformative impact of NFTs on the art world, suggesting that NFT technology is reshaping traditional art markets and creating new opportunities for artists and collectors.

Cluster 15 – Are NFTs really dead and buried? All sings point to “yes”. This cluster presents a provocative viewpoint questioning the viability of NFTs, indicating skepticism or pessimism regarding the future of NFT markets.

Cluster 16 – Ubisoft Will Give Away Free Ethereum NFTs for “Champions Tactics” Game. This cluster discusses Ubisoft's initiative to distribute free Ethereum-based NFTs as part of their “Champions Tactics” game, signaling the integration of NFTs into mainstream gaming.

Cluster 17 – has two subheadings: Disney launches NFT platform, eye issues at ApeFest and NFT sales rise: Nifty Newsletter; Creator of Mutant Ape Ripoff NFT pleads guilty to \$3M fraud scheme. This cluster covers a range of topics including Disney's entry into the NFT space, issues at ApeFest, and legal matters related to NFT fraud, reflecting the diversity of news and events within the NFT ecosystem.

Cluster 18 – The Latest NFT Trend: Taking Out Loans on Rolexes. This cluster discusses a novel trend where individuals are using NFTs as collateral to obtain loans, highlighting innovative applications of NFT technology beyond digital assets.

Cluster 19 – Whatever happened to NFTs? This cluster poses a question regarding the current status or trajectory of NFTs, suggesting uncertainty or curiosity about the evolution of NFT markets.

Cluster 20 – has two subheadings: Why Are BRC-20 NFTs Suddenly Soaring in Value? Starbucks' NFT enforcement; IP office extinction warning; Barbie's DEI mission: takeaways from 2023 INTA Leadership... This cluster covers diverse topics including the sudden rise in value of BRC-20 NFTs, Starbucks' enforcement of NFTs, warnings from intellectual property offices, and Barbie's diversity, equity, and inclusion (DEI) initiatives,

indicating the intersection of NFTs with various industries and societal issues.

Cluster 21 – The vast majority of NFTs are now worthless, new report shows. This cluster presents findings from a report suggesting that a significant portion of NFTs have lost value, highlighting challenges and risks associated with NFT investments.

Cluster 22 – has two subheadings: Navigating the NFT Marketplace: A Guide to Safely Verify Authenticity Before Purchase; What are NFT DApps, and how to create and launch one? This cluster provides guidance on navigating the NFT marketplace, including tips for verifying authenticity and creating NFT decentralized applications (DApps), indicating a focus on education and practical advice for NFT enthusiasts.

Cluster 23 – Trading volume for NFTs hits four-month high. This cluster reports on a significant increase in trading volume for NFTs, suggesting heightened activity and interest in NFT markets.

The cluster analysis has revealed a wide spectrum of themes and discussions within the NFT space, indicating a vibrant and dynamic market. By delineating the NFT market into 23 distinct clusters, analysis uncovered the depth and diversity of topics, ranging from market trends and technological developments to practical applications and regulatory challenges. This comprehensive segmentation not only demonstrates the multifaceted nature of the NFT ecosystem but also highlights its rapid evolution and the burgeoning interest across various domains.

Notably, clusters related to market dynamics, such as “OpenSea NFT Marketplace Review” and “NFTs: Bear Market or Burst Bubble?”, reflect the current sentiment and speculative aspects surrounding NFT investments. These clusters suggest a keen investor interest in understanding market fluctuations, investment potentials, and the underlying value of NFTs amidst a backdrop of market volatility.

Furthermore, the emergence of clusters focused on real-world applications of NFTs, like “5 common uses of NFTs in the real world”, underscores the expanding utility of NFTs beyond digital collectibles. It points towards a growing recognition of NFTs’ potential to innovate traditional sectors, including art, music, gaming, and real estate, thereby reshaping the concept of ownership and value in the digital era.

By examining the clusters collectively, we can gain a comprehensive understanding of the multifaceted nature of the NFT landscape, encompassing both opportunities and challenges faced by stakeholders. This analysis underscores the dynamic and evolving nature of the NFT market, characterized by innovation, speculation, and ongoing discourse surrounding its future trajectory.

5. Conclusions

In this research paper, a detailed cluster analysis of publications in the field of NFT was carried out. By examining articles from various sources analysis revealed a

rich tapestry of themes, discussions, and developments within the NFT space. The resulting clusters shed light on diverse topics such as market trends, technological innovations, real-world applications, investor sentiment, and industry news. Notably, clusters highlighted the resilience of NFT enthusiasts amid market fluctuations, the emergence of new protocols impacting the NFT market, significant sales of NFT artworks, and the exploration of NFT use cases beyond digital art.

Several key findings emerged from our analysis, including the ongoing debate surrounding the sustainability of NFT markets, the influence of broader cryptocurrency trends on the NFT space, the diversity of real-world applications for NFT technology, and the challenges faced by NFT collections in maintaining value over time.

Moreover, the research identified notable events and developments shaping the NFT landscape, such as Disney’s entry into the NFT market, the launch of new NFT marketplaces, high-profile NFT sales, and advancements in NFT storage and authentication technologies.

Overall, cluster analysis provides valuable insights into the multidimensional nature of the NFT ecosystem, highlighting both the opportunities and challenges inherent in this rapidly evolving industry. By understanding the nuances and dynamics of the NFT market, stakeholders can make informed decisions, develop strategic initiatives, and contribute to the ongoing evolution of NFT technology.

As the NFT space continues to evolve and mature, further research and analysis will be necessary to track developments, assess trends, and anticipate future directions.

References

- Alizadeh, S., Setayesh, A., Mohamadpour, A., & Bahrak, B. (2023). A network analysis of the non-fungible token (NFT) market: Structural characteristics, evolution, and interactions. *Applied Network Science*, 8(1).
<https://doi.org/10.1007/s41109-023-00565-4>
- Babel, M., Gramlich, V., Körner, M. F., Sedlmeir, J., Strüker, J., & Zwede, T. (2022). Enabling end-to-end digital carbon emission tracing with shielded NFTs. *Energy Informatics*, 5.
<https://doi.org/10.1186/s42162-022-00199-3>
- Bao, T., Ma, M., & Wen, Y. (2023). Herding in the non-fungible token (NFT) market. *Journal of Behavioral and Experimental Finance*, 39, Article 100837.
<https://doi.org/10.1016/j.jbef.2023.100837>
- Faqir-Rhazoui, Y., Arroyo, J., & Hassan, S. (2021). A comparative analysis of the platforms for decentralized autonomous organizations in the Ethereum blockchain. *Journal of Internet Services and Applications*, 12(1), Article 9.
<https://doi.org/10.1186/s13174-021-00139-6>
- Flick, D. C. (2022). A critical professional ethical analysis of Non-Fungible Tokens (NFTs). *Journal of Responsible Technology*, 12, Article 100054.
<https://doi.org/10.1016/j.jrt.2022.100054>
- GRAPHEXT INC. (2024). *Data analytics for visual thinkers*. Graphext.

- Han, J., Kamber, M., & Pei, J. (2011). *Data mining: Concepts and techniques* (3rd ed.). Elsevier.
- Karjus, A., Canet Solà, M., Ohm, T., Ahnert, S. E., & Schich, M. (2023). Compression ensembles quantify aesthetic complexity and the evolution of visual art. *EPJ Data Science*, 12(1), Article 21. <https://doi.org/10.1140/epjds/s13688-023-00397-3>
- Kassambara, A. (2017). *Multivariate analysis I. Practical guide to cluster analysis in R. Unsupervised machine learning* (1st ed.). STHDA. <http://www.sthda.com>
- Kong, D.-R., & Lin, T.-C. (2021). *Alternative investments in the Fintech Era: The risk and return of non-fungible Token (NFT)*. <https://doi.org/10.2139/ssrn.3914085>
- Longshak, J. E. (2022). *The emergence of Web3 and metaverse technologies: Implications for Library and Information* (pp. 84–113). IGI Global. <https://doi.org/10.4018/978-1-6684-5964-5.ch007>
- Mazur, M. (2021). Non-Fungible Tokens (NFT). The analysis of risk and return. SSRN. <https://doi.org/10.2139/ssrn.3953535>
- Meyns, S. C. A. (2022). *Happy, risky assets: Uncertainty and (mis)trust in non-fungible token (NFT) conversations on Twitter* (Degree project). Linnæus University.
- Mikalajūnas, E. (2022). NFT doktrinis-teisinis apibrėžimas ir jo problematika, sietina su Europos Sąjungos kriptoteisinių santykių reguliavimo modeliui. *Jurisprudencija*, 29(1), 122–134. <https://doi.org/10.13165/JUR-22-29-1-06>
- NonFungible. (2022). *NFT Market Q1*. <https://nonfungible.com/reports/2022/en/q1-quarterly-nft-market-report>
- Phumphuang, P., & Jareevongpiboon, W. (2023). Predicting GameFi's daily market direction using support vector machine. In *Proceedings of JCSSE 2023 – 20th International Joint Conference on Computer Science and Software Engineering*, 476–481. IEEE Xplore. <https://doi.org/10.1109/JCSSE58229.2023.10201987>
- Proelss, J., Sévigny, S., & Schweizer, D. (2023). GameFi: The perfect symbiosis of blockchain, tokens, DeFi, and NFTs? *International Review of Financial Analysis*, 90, Article 102916. <https://doi.org/10.1016/j.irfa.2023.102916>
- Renduchintala, T., Alfauri, H., Yang, Z., Pietro, R. Di, & Jain, R. (2022). A survey of blockchain applications in the FinTech sector. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(4), Article 185. <https://doi.org/10.3390/joitmc8040185>
- Sestino, A., Guido, G., & Peluso, A. M. (2022). *Non-Fungible Tokens (NFTs) examining the impact on consumers and marketing strategies*. Springer. <https://doi.org/10.1007/978-3-031-07203-1>
- Tang, G., Tian, R., & Wu, B. (2022). An overview of clustering methods in the financial world. In *Proceedings of the 2022 7th International Conference on Financial Innovation and Economic Development (ICFIELD 2022)*. Atlantis Press. <https://doi.org/10.2991/aebmr.k.220307.084>
- Trček, D. (2022). Cultural heritage preservation by using blockchain technologies. *Heritage Science*, 10(1), Article 6. <https://doi.org/10.1186/s40494-021-00643-9>
- Urom, C., Ndubuisi, G., & Guesmi, K. (2022). Dynamic dependence and predictability between volume and return of Non-Fungible Tokens (NFTs): The roles of market factors and geopolitical risks. *Finance Research Letters*, 50, Article 103188. <https://doi.org/10.1016/j.frl.2022.103188>
- Wilson, K. B., Karg, A., & Ghaderi, H. (2022). Prospecting non-fungible tokens in the digital economy: Stakeholders and ecosystem, risk and opportunity. *Business Horizons*, 65(5), 657–670. <https://doi.org/10.1016/j.bushor.2021.10.007>
- Xia, Y., Li, J., & Fu, Y. (2022). Are non-fungible tokens (NFTs) different asset classes? Evidence from quantile connectedness approach. *Finance Research Letters*, 49, Article 103156. <https://doi.org/10.1016/j.frl.2022.103156>
- Zaucha, T., & Agur, C. (2023). Playbor, gamble-play, and the financialization of digital games. *New Media and Society*. <https://doi.org/10.1177/14614448231190907>
- Zion Market Research. (2023). *Non-Fungible Token (NFT) market*. <https://www.zionmarketresearch.com/report/non-fungible-token-nft-market>