Aalto-yliopisto
Aalto-universitetet
Aalto University

Master's Programme in Sound in New Media

Moments Minted

Audio visual Textures as Non-fungible Tokens

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Master's Thesis
2023

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Master of Arts thesis abstract

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Title of thesis Moments Minted – Audio Visual Textures as Non-fungible Tokens

Department Department of Art and Media

Degree programme Sound in New Media

Year 2023 **Number of pages** 44 **Language** English

Abstract

This thesis explores my personal audiovisual artwork and the potential of non-fungible tokens for digital artists and creative individuals. The centerpiece of the thesis is a collection of four audiovisual videos, each embodied as a unique non-fungible token. The visual component of the videos is generated from custom-made TouchDesigner software patches, incorporating elements from my own photographs. The audio for the videos is derived from live recordings of improvised hardware performances, utilizing a range of samplers, synthesizers, and drum machines to bring my prepared sounds and themes to life. My artistic vision and philosophical approach to the audio component of my work has been shaped through my studies at Aalto University Media Lab and Sibelius Academy. In the written portion of the thesis, I delve into the influences, techniques, and processes that led to the creation of the final product and explain why they were integral to my artistic expression.

In addition to my artistic pursuits, I am passionate about discovering alternative methods for releasing, distributing and monetizing music and audiovisual projects. The current creative industries and distribution networks are highly centralized, algorithm-driven, and unsustainable. Despite the concerns and uncertainties surrounding non-fungible tokens (NFTs), I believe that the technology holds immense potential and is just beginning to unlock new industries, business models, and funding opportunities. The disruptive power of blockchain technology is offering exciting new prospects for startups, emerging technologies, and independent artists and creative individuals.

Keywords Blockchains, Digital Art, Cryptocurrencies, NFT, Audio Visual Art, Generative Art

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Master of Arts thesis abstract

Tekijä Hannu Ikola		
Työn nimi Moments Minted – Audio Visual Textures as Non-fungible Tokens		
Laitos Median laitos		
Pääaine Sound in New Media		
Year 2023	**Sivumäärä** 44	**Kieli** Englanti

Tiivistelmä

Tämä opinnäytetyö tutkii henkilökohtaista audiovisuaalista taidettani ja ei-korvattavien rahakkeiden potentiaalia digitaalisille taiteilijoille ja luoville yksilöille. Opinnäytetyön keskiössä on neljän audiovisussaalisen videon kokoelma, joista jokainen on ilmennyt ainutlaatuisena ei-korjautuvana merkkinä. Videoiden visuaalinen komponentti on luotu räätälöidyistä TouchDesigner-ohjelmistopäivityksistä, joihin on sisällytetty elementtejä omista valokuvistani. Videoiden ääni on peräisin improvisoitujen laitteistoesitysten live-tallenteista käyttämällä erilaisia samplereita, syntetisaattoreita ja rumpukoneita herättämään valmiit äänet ja teemat henkiin. Taiteellinen näkemykseni ja filosofinen lähestymistapani työni ääneen ja musiikkiin on muotoutunut opintojeni kautta Aalto-yliopiston Media Labillä ja Sibelius-Akatemiassa. Opinnäytetyön kirjallisessa osassa syvennyn vaikutteisiin, tekniikoihin ja prosesseihin, jotka johtivat lopputuotteen syntymiseen ja selitän, miksi ne olivat olennainen osa taiteellista ilmaisuani.

Taiteellisen tekemiseni lisäksi olen kiinnostunut tutkimaan vaihtoehtoisia menetelmiä musiikin ja audiovisuaalisten projektien julkaisuun, jakeluun ja kaupallistamiseen. Nykyiset luovat teollisuudenalat ja jakeluverkostot ovat erittäin keskitettyjä, algoritmilähtöisiä ja monella tavalla kestämättömiä. Uskon, että NFT-teknologialla on merkittävä potentiaali, joka tulee avaamaan uusia toimialoja, liiketoimintamalleja ja rahoitusmahdollisuuksia. Lohkoketjuteknologian luomat mullistukset tarjoavat kiinnostavia uusia näkymiä startup-yrityksille, kehittyville teknologioille sekä itsenäisille yrittäjille, taiteilijoille ja muille eri alojen toimijoille.

Avainsanat Lohkoketjut, Digitaalinen taide, Kryptovaluutat, NFT, Audiovisuaalinen taide, Generatiivinen taide

Contents

1. Project Idea

1.1. Preliminary

Prior to my studies, my visual expression was largely confined to photography, where I focused on capturing textures, macro-objects, colors, and abstract shapes. At the Media Lab, I became fascinated with the world of moving images and visual programming, and gradually integrated these elements into my work as a musician and later as an audio-visual artist. After trying various software and frameworks, I discovered TouchDesigner, which seamlessly fit into my workflow. I started utilizing it to create dynamic textures based on my photographic work.

My musical studies, resulted in a more minimal, colorful, and musical form. While I completed major studies in Sound in New Media, I also focused on minor studies in Performing with Electronic Devices at Sibelius Academy during my second year. As a counterbalance to my studies and work with computer-generated visual material, my sound and music creation increasingly moved away from digital software environments and evolved into live improvisations on electronic hardware devices, culminating in a nearly entirely hardware-based approach.

This thesis focuses on audio and music as NFTs, delving into the technology and culture of the leading blockchains, wallets, and marketplaces. I am documenting my journey as a recording and performing artist, exploring the process of producing, minting, and selling my music as NFTs on various blockchains. The goal of this thesis is to gain a deeper understanding of NFT technology and to determine if NFTs can offer a new and more equitable way for artists to showcase and monetize their work.

1.2. Motivation

As an individual who has managed an independent record label that specializes in releasing electronic music in vinyl format, I have personally encountered a variety of issues and concerns related to this particular aspect of the music industry. These problems have prompted me to consider the potential benefits of utilizing music NFTs as an alternative format for releasing and distributing music. One of the primary concerns I have encountered involves the environmental impact of physical distribution, particularly the consumption of oil-based products and the general culture of material object collection. The second issue that I have observed is the economic unsustainability of releasing music on vinyl, especially for smaller record labels. In fact, even for major labels, the trend has been towards an increase in new releases with smaller sales and pressing per release. As a result, if a release is limited to 300 copies or less, it is unlikely to be profitable for the label or

artists and may only cover the costs of production. Additionally, other issues include major record labels' priority in pressing queues, the quantity of unsold copies, unfair terms and conditions, unpaid royalties, and manipulated sales.

Given these challenges, I believe that exploring the use of music NFTs as a viable alternative to vinyl could offer several benefits to artists and labels. By eliminating the need for physical production and distribution, NFTs could reduce the environmental impact associated with traditional formats while also providing a more financially sustainable option for independent labels. Moreover, the use of blockchain technology can also help ensure transparency and fair distribution of royalties, which has been a long-standing issue within the music industry.

1.3. Project Idea

During the years 2021-2022, I have created generative video patches based on my personal photographs, as well as recorded several hours of improvised audio material. My aim with this project was to combine my individual visual and musical aesthetics, utilizing the techniques that I had learned during my studies in Aalto media lab, and to reflect my growth as an artist and individual during this time. As there is no clear method for releasing and selling audiovisual artworks as music files, I decided to mint them as NFTs. Through this project, I aim to learn by doing, exploring new possibilities for creating and deploying digital art, investigating NFTs as a technology, and gaining an understanding of the crypto art culture, its possibilities, pitfalls, and trends.

Furthermore, I am interested in alternative ways of viewing, understanding, and utilizing audio on digital platforms in various roles, including as an artist, a sound designer, a DJ, a producer, and a music listener. I am fascinated by the potential of new technologies such as artificial intelligence, Internet of Things, and web 3.0, and how blockchain technology can benefit each other. This project marks my first release of audio-visual content that combines video, audio, photography, and generative techniques in the same artwork.

1.3.1. Concept

The project, entitled "Aural Aquarelles," is a collection of unique audiovisual art pieces, each represented as a non-fungible token (NFT). The collection comprises four video files that blend generative visual textures based on photography with contemporary ambient and low-tempo music and soundscapes. Each NFT in the collection showcases an ever-changing and colorful visual landscape with slow and organic movements, paired with a rhythmic but slow tempo electronic soundtrack featuring harmonic synth layers and sampled

vocals. The generative visuals were created using TouchDesigner, resulting in organic, liquid-like movements with harmonious colors that resemble watercolors. The accompanying music was produced using Ableton and Max for Live devices. The overall style of the collection is ethereal and calming, designed to transport the viewer to a serene and meditative state.

Aural Aquarelles NFTs were designed with the intention of providing audiovisual ambiance, promoting focus and calmness, and inspiring viewers. Owners of the NFTs may use the artwork for personal or business projects, as decoration, on social media platforms, or as digital art collectors. The project also included a public exhibition, titled "Few Understand This," which was held in Helsinki's city center at the Central Library Oodi's interactive gallery space Kuutio. The exhibition showcased the art pieces and provided viewers with the opportunity to experience the calming and inspiring effects of the Aural Aquarelles collection.

1.3.2. Road map

I am starting the process by selecting the most pleasing generative patches I find suitable for the project. I try to keep the selection limited to certain techniques but also presenting the idea in rich and colorful way to make the collection coherent and curated. The same process will be made for audio. For the selected patches I do final minor fixes defining the color tones, cropping, surfaces, movement and codecs. For the audio I do final improvements including fine tuning sounds, adjusting tempo, making final mixing and mastering the tracks.

Setting up Open Sea page and account. This includes preparing images, links, descriptions and other additional info. When the initial patch of clips is finished, they are uploaded to collection page in Open Sea. This part also includes setting the metadata for the art works, such as titles, descriptions, tags and possible features.

The main mid-term goal in the project is a public exhibition where the first patch of NFTs is presented. This gives an opportunity to view and audit the material in public space with high quality video walls, video projectors, media players and speakers. It also offers an opportunity to gain possible feedback of gallery visitors.

As the pre-minting versions are available in Open Sea it is time for promoting the, contacting other artists, collectors and influencers and interacting with various NFT-related online communities. Updating the social media channels. I try to focus on limited channels only including Twitter, Instagram, Reddit and Soundcloud. Once finished, the works are uploaded to Open Sea. Deciding the date for the drop, defining a fair price point for NFTs. Social media campaign. After the drop my aim is following up the price, volume and others

activity monitors around the NFT collection and social media channels. Open Sea has built-in analytics feature that allows you to track your sales and revenue, so you can see how your NFTs are performing.
I am looking forward to also find interesting artists, projects, possible collaborators during the process and keeping in touch with friends, followers, collectors and buyers. Any feedback during and after the process is valuable and vital for following projects in NFT space.

1.3.3. Goals

NFTs have the potential to affect the way content creators distribute and monetize their digital creations. As an artist, I am interested in exploring this technology to better understand its potential and limitations. To do this, I am creating an NFT collection featuring a variety of digital artworks that combine audio and video elements. I am using my own photographs as visual textures in TouchDesigner and incorporating my own music and sound design. This project represents a new and exciting challenge for me as an artist, as it is my first major project involving moving images and music. I am looking forward to learning a lot during the process, and to creating artwork that evokes similar feelings and thoughts in viewers and listeners as it does in me. Additionally, I am excited to expand my musical and visual skills and learn more about NFTs and crypto art.

Philosophically and ethically, it is important for me to maintain exclusivity while releasing my work, protecting my intellectual property rights, and utilizing fair economic models. I strive to focus on community-driven initiatives and work in a sustainable manner. However, I find it challenging to adhere to these principles within traditional industry pipelines, particularly in today's highly centralized music industry. Therefore, I am eager to explore potential alternative for current industry leading platforms. The growing volumes of NFT projects and platforms focusing on digital art, are presenting positive examples. Despite the challenges associated with NFTs, cryptocurrencies, and blockchain technology, I believe they offer the best chance to disrupt highly centralized industries, such as music, art, media, and the internet, in the coming years.

1.4. Project Examples

In 2021, the non-fungible token (NFT) market experienced a significant surge in popularity, as various celebrities and well-known influencers ventured into the market, leading to a widespread increase in demand for NFTs amongst the wider audience. Notable examples of popular music and EDM artists who participated in NFT auctions during this period include DJ producer 3Lau, Grimes, Steve Aoki, Whitney Houston, Aphex Twin, and Richie Hawtin. However, it should be noted that these kinds of sales are exceptional, as average income and viewings for a single artist in centralized music services such as Beatport and Spotify remain low. It is important to highlight that collections’ success can vary greatly depending on timing, uniqueness,

and the strength of the artist's and project's following and promotion. Therefore, the artists and projects serve as examples, and their success should not be considered as a representative outcome of the NFT market. In this context, the following project examples are presented based on the author's personal interest and relevance to their approach and aesthetics.

1.4.1 Project Example 1

Illmind is a highly regarded hip-hop producer who has been active in the music scene since the late 1990s. He has collaborated with many notable artists, including Drake, J. Cole, Beyonce, and Kendrick Lamar. In early 2021, he entered the NFT space with the release of an NFT sample pack called "Alorium". The sample pack features ten unreleased melody compositions using a variety of analog synthesizers from the 70s and 80s, such as Arp Odyssey, Mini Moog, Fender Rhodes, Farifsa Polychrome and Casio FZ-1. Each composition in the pack comes with audio stems, in stereo WAV 16bit 44.1 kHz file formatting for DAW-friendly use. The tracks are free for commercial purposes, with a royalty-free guarantee and contract included in the file. The audio recordings were also mastered with a 1/4" Reel to Reel Tape LYREC PTR-1, also known as the "Frida" so the whole audio chain is made with classic but already rather rare and expensive equipments to underline the speciality and exclusiveness. The Alorium NFT sample pack was released on the NFT marketplace called Mintable, and it has garnered significant attention from both music producers and NFT enthusiasts.

1.4.2. Project Example 2

Joonas Toivonen aka Toiminto, is a producer of electronic music and digital art who has been active since the late 1990s. He began in the tracker music scene and had since created music, visual art, live performances, and installations. Joonas has been mostly drawn to glitch art, misbehaving vector graphics, broken 3D, and generative and AI-assisted/generated art. For the past 20 years, Joonas has been promoting and organizing related events in Finland through SWÄG, a nonprofit art, music, and tech organization. He usually works with code and software such as TouchDesigner, Blender, Tidalcycles, Three.js, p5.js, and others.

The Augmented Sequence project is building upon his previous work on audiovisual installations and electronic music performances. The project involves generating complex and chaotic snapshots of a larger form, presenting still images with a sense of rapid motion. The snapshots are created through the repetitive sequencing of parametrized mathematical functions, rotations, and placement of objects, all based on primitive shapes. One unique aspect of the Augmented Sequence project is that the parameters for sequence attributes, shapes, lighting, materials, and colors are all driven by the hash of the minting transaction. This results in unique and surprising visual outputs that cannot be replicated. The project is a demonstration of the potential of NFTs as a tool for creating generative and unpredictable art.

2. Non-Fungible Tokens

Non-fungible tokens (NFTs) are digital tokens inside a blockchain representing an ownership of an item, digital or physical. The ownership can be transmitted, sold, bought or rented digitally from peer to peer without additional middlemen or centralized entities. Technically NFT is a signature referring to certain tokenized object and it is created during a process of minting a token. The ownership of an NFT, as digital signature associated with certain object, can be stored and distributed inside a blockchain, which is a decentralized digital ledger that includes the complete transaction history and is fundamentally decentralized, immutable and transparent. "*Fungible tokens all have the same value and are interchangeable with one another, whereas nonfungible tokens represent something that is unique*." (Lantz, 2020). In contrast, currencies such as euro, dollar and bitcoin are fungible and they can be divided to smaller units, and they are interchangeable and equivalent with other euros, dollars or bitcoins. NFT creators and owners can define a price for the token as they like.

2.1. NFT Features

Non-fungible tokens (NFTs) possess unique and certain features that make them distinct from other digital assets. One of the key features of NFTs is their versatility, as they can represent almost anything in the virtual or physical world. This makes them applicable to a broad range of industries, including art, music, gaming, sports, and real estate. NFTs can also be customized to include various juridical, economical, ethical, and communal terms, reservations, and conditions, giving NFT owners control over the use and distribution of their assets. Another significant feature of NFTs is their ability to create scarcity and exclusivity in the digital space through the use of smart contracts. Smart contracts can automate various processes such as resale, renting, borrowing, and updating of the original object. This allows NFT owners to benefit from ongoing revenue streams based on the resale of their work, as smart contracts can be used to implement automated royalties. Controlling the supply can potentially increase demand and value for digital assets. Overall, NFTs can transform the way we think about ownership, value, and exchange in the digital world. NFTs offer increased security, immutability, and transparency, making them an attractive option for various use cases.

2.2. NFT Use Cases

The utilization of non-fungible tokens (NFTs) has been mainly focused on digital property, including images, videos, audios, 3D models, code, text, and applications. NFTs can be used to connect to users' digital identities, such as avatars, virtual fashion, music, memes, game assets, or other virtual collectibles. In

addition to their virtual collectibles aspect, NFTs can provide practical use cases, such as representing domain names like Ethereum Name Service (ENS), or rights to vote, register, or access closed meetings and events, such as concerts and galleries. NFTs also have the potential to represent investment assets, such as stocks, bonds, shares of treasuries, or any tokenized objects like buildings and land. By representing ownership and value in both virtual and physical worlds, NFTs offer a novel method for individuals and businesses to monetize and trade digital assets.

As NFTs gain broader acceptance and understanding, their mainstream adoption is rapidly increasing. New trends in NFTs are constantly evolving and can change suddenly. Despite market fluctuations, NFT marketplaces and decentralized applications that involve sports, art, music, metaverse, gaming, and DeFi (decentralized finance) projects have remained popular. As the market continues to mature, greater diversity of NFTs can be expected, including virtual real estate, interactivity, GameFi, updated content, and investment or collaboration opportunities. For instance, musicians have been exploring NFTs to release limited-edition tracks, music videos, merchandise, and sample packs or stems of their tracks. While digital art has been popular in NFT marketplaces, other industries are likely to emerge as leading participants in the coming years.

NFTs are one of the key elements in web 3.0. By using blockchain technology, ownership of digital assets can be tracked securely and transparently, allowing for high-speed transfers and automated verifications executed by smart contracts. NFT's can represent any data such as friends and followers, cookies and browsing history. This creates possibilities for new revenue streams for not only creators but also consumers as they can monetize their ownership by renting, selling, and trading assets in the global digital market space. In the current web 2.0 model, centralized entities own the platforms and all its data. According to Sandvine GIPR January 2022 report, across traffic categories, 56.96% of traffic was attributable to the top-6 brands Google, Netflix, Facebook, Apple, Amazon, and Microsoft – a 33% increase in total traffic from 2019's 43.10% (www.sandvine.com). Sitra's Mega Trend Report 2023 highlights converging perspectives regarding the upcoming digital revolution, encapsulating three key shifts: *"...of gatekeepers the crumbling of power, common interfaces becoming more common and the balancing of power structures. Web 3.0, distributed internet, challenge the power of the technology giants."* (Sitra 2023).

The full potential of NFTs is still being discovered as new use cases continue to evolve with the advancement of technology, users' needs and the market. This allows for a more flexible and adaptable approach to NFTs and their potential use cases. The integration of NFTs with blockchain technology and smart contracts provides a secure and transparent way to manage digital assets and their ownership, making it a powerful tool for individuals and various industries.

2.3. Concerns and risks

The increasing adoption of non-fungible tokens (NFTs) has led to significant benefits for monetizing and trading digital assets, but also raises inherent risks and concerns. One of the key issues surrounding NFTs is regulatory challenges, as they often fall outside the scope of traditional legal frameworks. Additionally, discussions around NFTs, blockchains, and cryptocurrencies are highly polarized, and misconceptions abound, making understanding and keeping up with rapid technological changes challenging.

Energy consumption has been a significant concern for NFTs, especially due to Ethereum's previous use of the Proof-of-Work (PoW) consensus mechanism. However, the adoption of Proof-of-Stake (PoS) technology has significantly increased energy efficiency. As of September 2022, the CCRI Industry Report revealed that the implementation of the Merge protocol has reduced Ethereum's electricity consumption and carbon emissions by over 99% (CCRI Industry Report, 2022). Furthermore, NFTs can be minted on even more energy-efficient ways such as including carbon offsetting initiatives in smart contracts. Such progress is likely critical for wider adoption and increasing investments, as well as engaging institutions.

Another known issue with NFTs is that the regulatory framework for NFTs remains unclear in many jurisdictions. The regulatory treatment of NFTs depends on their legal classification and the underlying assets' characteristics. In some jurisdictions, NFTs are treated as intangible property, while in others, they may be considered securities, commodities, or collectibles. The regulatory treatment of NFTs can have significant implications for the NFT industry's growth and development, affecting areas such as taxation, investor protection, and anti-money laundering measures. As NFTs continue to grow in popularity, it is expected that regulatory clarity will become more critical in the coming years. The lack of regulatory clarity is a significant challenge for NFTs' wider adoption and acceptance.

Third common issue related to NFTs is the question of property rights. Since NFTs represent ownership or proof of authenticity of a digital asset, they raise questions about the ownership and transferability of digital assets. Although the ownership of physical assets is typically governed by property law, digital assets' ownership is still a complex issue. NFTs create a digital ownership ecosystem where property rights can be established and enforced through smart contracts. However, the enforceability of such contracts may depend on the legal recognition of NFTs as property. The legal status of NFTs as property is still in its early stages of development, and it remains to be seen how property rights in NFTs will be regulated and enforced in different jurisdictions.

2.4. NFT Markets

As a relatively new technology, NFT market have evolved rapidly. While a global market, the highest user volume is from Europe, North America, and Asia. NFT markets are still considered a marginal industry, and price fluctuations and volatility can be remarkably high. The overall NFT market price action follows the global crypto industry market cap, which is led by Bitcoin that more often reacts to global market indexes, especially to Nasdaq technology index (www.bloomberg.com/news/articles/2022-04-11/bitcoin-s-correlation-with-big-tech-increases-to-record-chart) The latest NFT market peak was following the latest Bitcoin all-time-high value in November 2021, at which time there was a tremendous amount of demand from both buyers and sellers. This was partly driven by the hype and rising interest in digital art, collectibles, and other unique digital assets. However, it is important to note the similar fluctuations in traditional investing markets globally, especially with technology stocks. Many individual stocks fell 50-60% including Meta (formerly known as Facebook), Netflix, and Nvidia. Currently, the NFT market is largely unregulated, which can make it risky for investors and consumers. Despite the high volumes on certain times, projects and marketplaces, NFTs in general are not very liquid assets. Some NFTs have sold for remarkably high prices, making them an attractive option for artists, musicians and content creators.

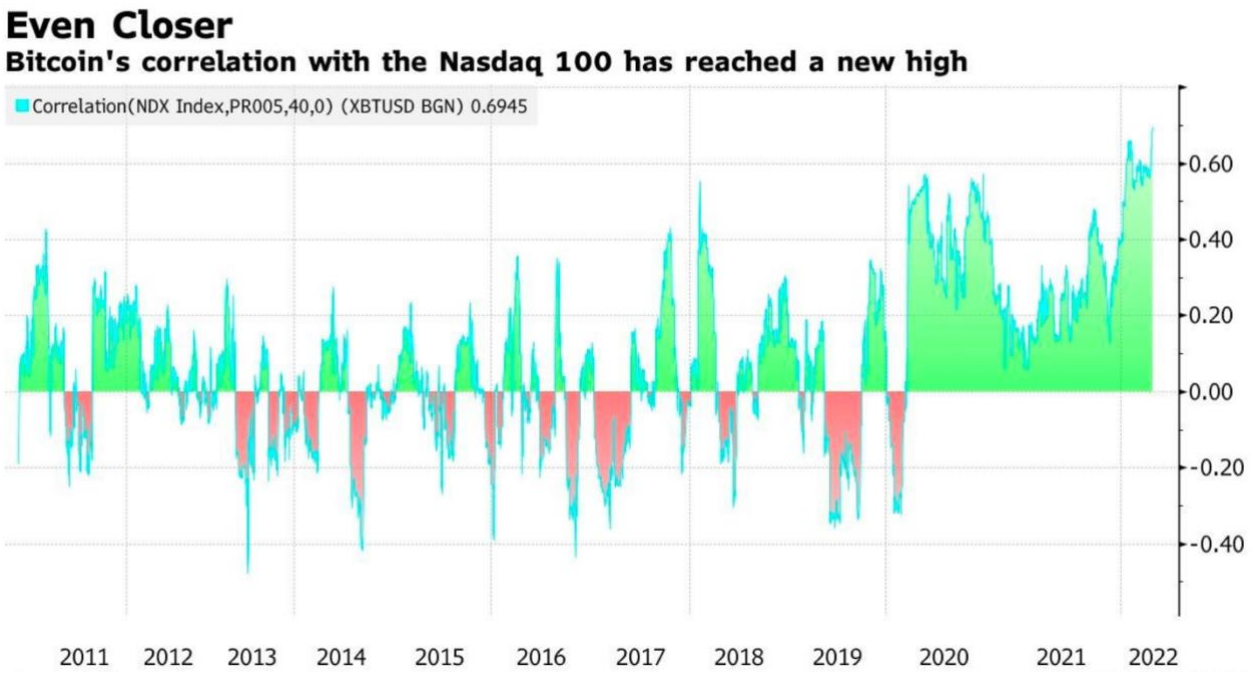

Figure 1. Bitcoin correlation to Nasdaq 100 technology index. Bloomberg.

2.5. NFTs and Digital Art

Digital art has been a leading market in NFT marketplaces, but it is still in its early stages. Artists have been braising and experimenting with the new technology selling and monetizing their works with completely new income models. This has created a new revenue stream for digital artists and has also led to an increase in the number of digital artworks being created. With the use of NFTs, potentially anyone can create and sell

digital art, giving artists more opportunities to monetize their work. Additionally, NFTs provide a way for artists to prove ownership of their work, which can help combat copyright infringement. NFTs can also offer more democratic and decentralized market space. Current music industry as an example is highly centralized as Spotify, Apple Music, Amazon Music, Tencent Music and YouTube are dominating 80% of global music streams (www.midiaresearch.com/blog/music-subscriber-market-shares-q2-2021) There is some technical skills and knowledge needed for creators and users to be able to operate in crypto space. For collectors, NFTs provide a new way to acquire and own digital art but it also raises ethical questions about the potential for fraud and misrepresentation. Additionally, the increasing value of digital art raises questions about the role of art as an investment rather than a cultural artifact.

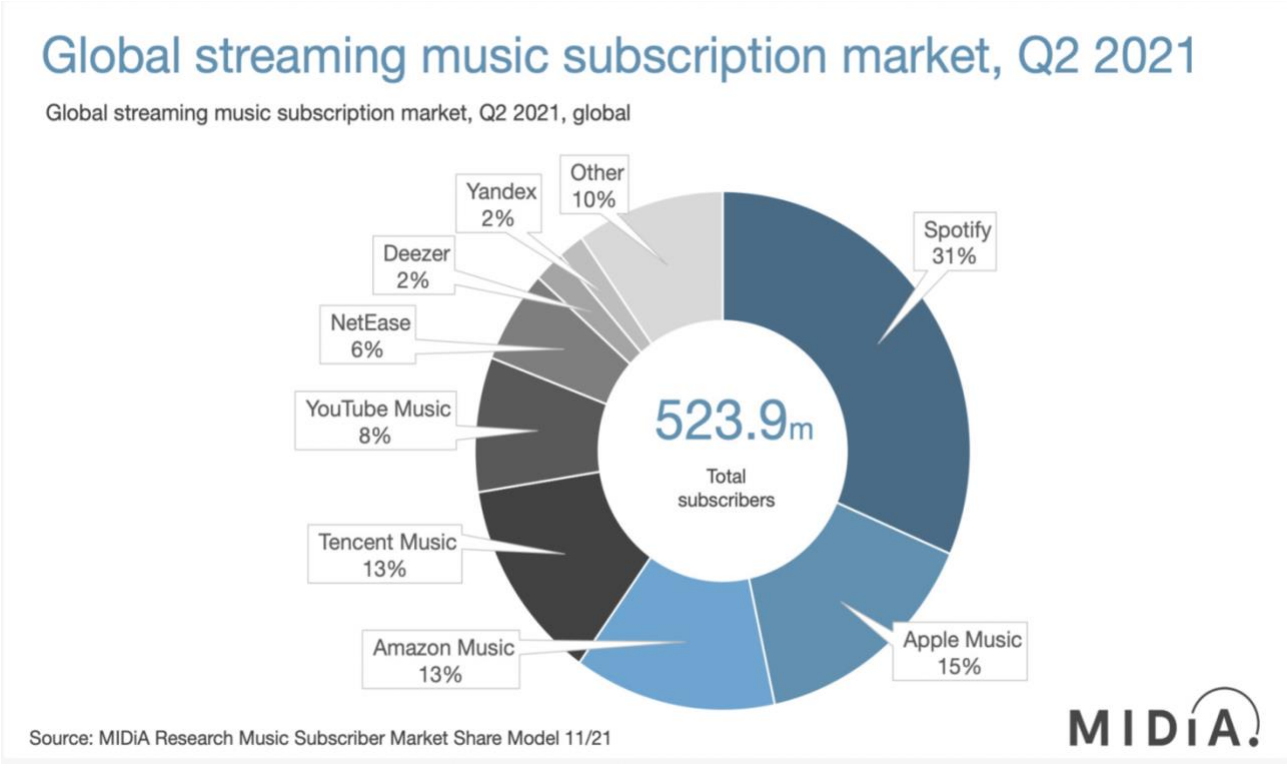

Figure 2. Global streaming music subscription market, Q2 2021. Midia Research.

3. NFT technology

This section is focusing on NFTs technical specifications, features and functionally. As NFTs are built on top of blockchain platforms it is important to understand the key elements of blockchains, blocks, cryptocurrencies, cryptography, smart contracts and the commonly used consensus algorithms. It is also important to understand the role of Ethereum as it is the leading platform for smart contracts and NFTs and second biggest crypto currency. Bitcoin, the leading blockchain network and cryptocurrency is also key element of the crypto space dominating more than 40% of the whole global cryptocurrency market cap.

3.1. Blockchains

A blockchain is a digital ledger of transactions maintained by a network of computers. These transactions can represent any type of digital exchange of value, such as money, assets, or information. The key feature of a blockchain is decentralization, meaning that it is not controlled by any single entity, such as a government or financial institution. Each block in a blockchain contains a record of multiple transactions which is defined by block time and block size in blockchain architecture. These blocks are linked together in a chronological chain, hence the name "blockchain". Once a block is added to the chain, the information it contains is permanent, immutable and unchangeable. This creates a secure and transparent record of all transactions on the blockchain. One of the most well-known applications of blockchain technology is Bitcoin which is a form of a decentralized digital currency. However, blockchains can also be used for other applications such as supply chain management, voting systems, and digital identity verification. One of the key features of a blockchain is that it is secured by cryptography, which ensures that it is tamper-proof and resistant to hacking. The data on a blockchain is stored on multiple computers in the network, which makes it difficult for any single point of failure to occur. This decentralization also makes blockchains very resistant to censorship, as there is no single point of control that can be targeted.

3.1.1. Blocks

In a blockchain, a block is a collection of transactions that are grouped together and added to the chain at a specific time. Each block contains several important pieces of information such as transactions from senders' wallet address to receivers' wallet, block size, block time, hash and nonce. The data that is recorded in a block is typically a list of transactions that have occurred on the network. These transactions can be financial transactions, such as the transfer of cryptocurrency, or other types of data, such as digital assets or other information. The block size is the amount of data that can be stored in a block. The block size limits the number of transactions that can be included in a block. In Bitcoin, for example, the block size is limited to 1MB, which means that only a certain number of transactions can be added to each block. The block time is the amount of time it takes for a new block to be added to the blockchain. In Bitcoin, for example, the block time is approximately 10 minutes which means a new block is added to the blockchain approximately every 10 minutes and all the transactions that have occurred in that time period are recorded. A block also contains a unique code called a hash, which is generated using a cryptographic function. This hash links the current block to the previous block in the chain, creating a secure and unbreakable link between the blocks. In proof-of-work based blockchain like Bitcoin, a block also contains a nonce, which is a number that is used to solve a mathematical problem. Miners compete to find the solution to this problem, which is used to generate the block's hash.

3.1.2. Cryptography

Cryptography is the practice of securing communication and information using mathematical algorithms. It plays a crucial role in the security of blockchains and other digital systems. The Turing test is a measure of a machine's ability to exhibit intelligent behavior that is indistinguishable from a human. In the context of cryptography, it is used to test the strength of an encryption algorithm by attempting to break it. If the encryption is strong, it should be virtually impossible for an attacker to break the code and read the encrypted message, even if they have access to advanced technology like a Turing machine. Public key cryptography is a method of encrypting and decrypting messages using a pair of keys. One key is a public key, which can be shared with anyone, and the other is a private key, which is kept secret. When a message is encrypted with a public key, it can only be decrypted with the corresponding private key. This allows for secure communication, as anyone can send an encrypted message, but only the holder of the private key can read it. *"There is a mathematical relationship between the public and the private key that allows the private key to be used to generate signatures on messages. This signature can be validated against the public key without revealing a private key"* (Antonopoulos, 2017). A public key and private key are two large numbers that are used together to encrypt and decrypt messages. Public key is shared with others, while the private key is kept secret. Public key is used to encrypt the message and private key is used to decrypt the message. Public key can also be used to verify the authenticity of the sender by checking the digital signature.

3.1.3. Consensus algorithms

In decentralized blockchain with hundreds and thousands of users, conventions creating a consensus between users using the blockchain is needed. "*Consensus is a way of reaching agreement between various participants who have shared values and goals, and it is an important component of how blockchain networks succeed*" (Lantz, 2020). For this purpose, there are different kinds of algorithms defining the rules for mutual understanding and trust on how the users maintain the transactions and create new tokens. Bitcoin blockchain is managed by Proof-of-Work (PoW) consensus algorithm. "*Proof-of-Work means nodes are maintaining the network generating a hash by solving complex calculation tasks"* (Neel, 2019). This process is called mining and miners are rewarded with tokens. In PoW, mining is mostly made with specialized hardware called ASICs. These computers require a lot of processing power to run which consumes a lot of energy. This demanding process is meant for protecting the network from attacks as anyone trying to attack the network needs to use an extreme amount of energy and capital to control at least 51% of the hash power. Ethereum switched from PoW to proof-of-stake (PoS) algorithm during the process of launching Ethereum 2.0. Proof-of-Stake is currently the most common consensus algorithm in cryptocurrencies. In PoS, miners are rewarded by staking the token instead of calculating complex mathematical tasks. In theory, it could be easier to control 51% of the hash power with PoS as a single entity with enough capital could simply buy most tokens. It also makes it possible for early stakeholders to hold most of the tokens and create consensus together. This is a problem for smaller coins as they are not actually decentralized as most tokens are owned

by project creators, early adapters and venture capitalists.

3.2. Cryptocurrencies

Cryptocurrencies are digital or virtual currencies that use cryptography for security. They are ideally decentralized although only few mature, time tested and widely adopted currencies like Bitcoin can truly achieve this. Cryptocurrencies operate on a blockchain network, which is a digital ledger of transactions that is maintained by a network of computers on the internet. Bitcoin is the first and most well-known cryptocurrency and since its creation, thousands of other cryptocurrencies have emerged. These currencies can be used to purchase goods and services and can also be traded on various online platforms even though most of them are not designed to operate as digital cash or FIAT-currencies. Transactions with cryptocurrencies are recorded on a public ledger, which allows for increased transparency and security, but also allows for complete or pseudo anonymity. Although the cryptocurrencies in general are often referred as a currency, they are, in fact, also tokens used as a "*Security Tokens*" or "*Utility Tokens*" (Lantz & Cawrey, 2020). Security Tokens can be referred to stocks. They work as a fund-raising instrument for a company or a startup business but enables them to operate and gain investments without an IPO (Initial Public Offering). IPOs are highly regulated and thus an expensive and slow process only possible for certain level of businesses. The same function works for utility tokens but in addition, utility tokens can also be used inside a service or a project. Utility tokens can be used, for example, inside a game or a streaming service for buying and selling digital items, advertising, rewards or gaining access to a limited content.

3.2.1 Digital Tokens

Token is an essential tool for interacting in a digital world between users, service providers and other operators. As an example, token can be personal verification link sent to user by service provider to verify that the user owns something they agreed, a particular email address. By clicking the verification link the token is sent back and both parties have an agreement that the user has a permission to use the service when signed up. Tokens can represent anything such as credits in online games, personal bonuses in online store or activity points in social platforms. These kinds of tokens have usually only limited value and they cannot be usually resold or used outside of the system. They are usually created and deployed by service providers which also maintain user accounts, their credit balances and other user data. This is called centralized system where majority of the benefits belongs to service provider as a centralized entity even if the significant amount of value is created by the users.

3.2.2. Bitcoin

Bitcoin is by far the most well spread, time tested, decentralized and trusted digital currency. It is the most valuable cryptocurrency project dominating around 40% of the whole global crypto space market cap alone. Bitcoin uses decentralized technology and encryption for secure and uncensored payments and storing value. It operates independently of a central bank or government by using network of computers including nodes and miners. Transactions with Bitcoin are recorded on a public ledger called the blockchain, which allows for transparency and security. Bitcoin can be bought and sold on various online exchanges and can also be used to purchase goods and services from businesses that accept it. One of the key features of Bitcoin is that it uses complex mathematical algorithm, SHA-256, to secure transactions and control the creation of new bitcoins. This process is called mining, and it requires powerful computers to solve complex mathematical equations. Miners are rewarded with new bitcoins for their efforts. Bitcoin also has a finite supply, with a maximum of 21 million bitcoins that can be in circulation. This scarcity is intended to ensure that the value of the currency does not depreciate over time such as FIAT currencies. It was first introduced in 2009 by an unknown person or group using the pseudonym Satoshi Nakamoto.

3.2.3. Ethereum

"Ethereum is a decentralized and open source blockchain platform that supports tokens, smart contracts, and decentralized applications, known as Dapps. In contrast to Bitcoin, which is often referred to as "Digital Gold" as a store of value, Ethereum is referred to as "Digital Oil" due to its role as fuel for a multitude of other cryptocurrencies and projects operating on the Ethereum blockchain. The native token of Ethereum is Ether (ETH), which serves a variety of purposes on the blockchain, including payment for transactions. According to the Ethereum Developer documents, *"...Ether is required to validate and propose blocks on the Mainnet. It is also used as a primary form of collateral in the DeFi lending markets, as a unit of account in NFT marketplaces, as payment for performing services or selling real-world goods, and more*" (Ethereum.org). ETH functions as a utility token, as developers and users within the Ethereum blockchain require ETH payments for network usage, referred to as a gas fee, which is paid when executing immutable events such as minting, buying, selling, transferring tokens, or executing smart contract events within the Ethereum Mainnet.

3.2.4. Ethereum Tokens

Ethereum tokens are digital assets built on top of the Ethereum blockchain. There are several standards for Ethereum tokens and the most common token types are ERC-20, ERC-721 or ERC-1155. ERC-20 (Ethereum Request for Comments 20) is *"The ERC-20 introduces a standard for Fungible Tokens, in other words, they have a property that makes each Token be exactly the same (in type and value) as another Token"*

(https://ethereum.org/en/developers/docs/standards/tokens/erc-20/). It is a token standard for independent crypto projects that implements an API for tokens within smart contracts in Ethereum blockchain. These tokens can represent a variety of assets, such as digital currency, loyalty points, assets in a game, or even shares in a company. As an example of ERC-20 tokens projects like oracle protocol Chain Link (LINK), lending platform Aave (AAVE) and decentralized exchange Uniswap (UNI) which are individual projects with their own cryptocurrency tokens operating on Ethereum blockchain. As NFT's are representing individual items with different values they use their own standards. ERC-721 was Ethereum's first NFT token version used in CryptoKitties. Later, Ethereum released ERC-1155 Multi Mode Standard that *"...allows for more efficient trades and bundling of transactions – thus saving costs. This token standard allows for creating both utility tokens (such as $BNB or $BAT) and Non-Fungible Tokens like Crypto Punks." (Ethereum Developer….*

3.3. Smart Contracts

Smart contracts are self-executing programs that automatically enforce the terms of a contract when certain conditions are met. They are implemented on blockchain technology, allowing for transparent and tamper-proof execution of contractual obligations. Smart contracts have the potential to revolutionize a wide range of industries, from finance and insurance to real estate and supply chain management.

One of the key benefits of smart contracts is their ability to automate complex processes, reducing the need for intermediaries and increasing efficiency. By eliminating the need for third-party intermediaries, smart contracts also reduce transaction costs and increase transparency. Moreover, smart contracts can be programmed to automatically trigger payments, releases of goods, and other actions when predetermined conditions are met, reducing the need for manual intervention and ensuring contractual obligations are met in a timely manner. Smart contracts have a wide range of applications, from simple transactions such as payments and transfers to complex processes such as insurance claims and supply chain management. In the finance industry, smart contracts can be used for automated loan processing and digital identity verification. In real estate, smart contracts can be used to automate property transfers and title deeds. In supply chain management, smart contracts can be used to track and verify the authenticity and movement of goods, reducing the risk of fraud and errors.

Despite the numerous benefits of smart contracts, there are also several challenges that need to be addressed. One of the key challenges is the lack of standardization and interoperability across different blockchain platforms. This makes it difficult for smart contracts written on one blockchain platform to interact with smart contracts on another platform. Additionally, the security and privacy of smart contracts need to be ensured, as any bugs or vulnerabilities in the code could result in significant losses. As the technology

continues to develop, it is expected that smart contracts will become increasingly prevalent and more sophisticated. The potential benefits of smart contracts are significant, and they have the potential to streamline a wide range of industries and reduce inefficiencies. Nonetheless, there are still significant challenges to be addressed, and further research is needed to fully realize the potential of this promising technology.

4. NFT blockchains

This section presents and compares some of the most common blockchains for NFT technology and digital art communities. Most of these blockchains are known as Layer 1 (L1) chains, which form the core infrastructure or foundation of a blockchain network and enable the creation of a complete ecosystem. However, Polygon stands out as a leading Layer 2 (L2) solution that aims to increase the scalability of other blockchains by working as an additional layer, or side chain, on top of them. The rise of L1 blockchains for NFTs, smart contracts, and dApps was largely driven by Ethereum's scalability challenges, slow transaction times, and high gas fees. In 2021, according to Coinmetrics' Ethereum gas report: *"...DeFi usage and high competition for block space has led to full blocks and congestion, which has driven up gas prices."*

4.1. Ethereum NFTs

Ethereum is a decentralized blockchain platform that enables the development and execution of smart contracts and decentralized applications (dApps). It was created in 2013 by Vitalik Buterin and launched in 2015. It used a proof-of-work (PoW) consensus mechanism but in the process of updating Ethereum to 2.0 version, the consensus mechanism was changed to proof-of-stake (PoS). One of the key features of Ethereum is its Turing-complete programming language Solidity, which allows for the development of complex and sophisticated smart contracts and dApps. This has led to the creation of a wide range of use cases, including decentralized finance (DeFi), gaming, and prediction markets, among others. Another important aspect of Ethereum is its ability to facilitate the issuance and trade of custom digital assets, such as tokens, which can represent a wide range of assets and rights. This has led to the creation of a wide range of token standards, such as ERC-20, ERC-721 and ERC-1155 (multitoken standard), which have been widely adopted by developers and users. Ethereum also has a growing ecosystem of tools and services that support the development and deployment of dApps, such as development frameworks, wallets, and decentralized exchanges, making it the most mature and widely used blockchain platform after Bitcoin.

4.2. BNB

Binance is Hong Kong based centralized exchange (CEX) for cryptocurrencies founded by Changpeng Zhao (CZ) in 2017. Binance is the global market leader in crypto exchanges. Binance Coin (BNB) is the native cryptocurrency of the Binance ecosystem which is used for transaction fees. Binance ecosystem includes liquidity pools, staking services, decentralized swapping service (Pancake swap), NFTs, NFT marketplace, crypto wallet (Trust wallet), dollar-pegged stable coin (BUSD) and numerous other services and products. Binance is known for high trading volumes, wide selection of trading pairs and small trading fees. As the volume, fees and amount of are important factors for creators, sellers and buyers, Binance ecosystem is highly potential and pealing platform for NFT-artists. Essentially BNB is originally highly based Ethereum's design and architecture.

4.3. Solana

Solana is a cutting-edge layer one blockchain known for its fast, secure, and scalable platform. It was designed to support decentralized applications (dApps) and decentralized finance (DeFi) projects that require high transaction speeds and low fees. Solana has also gained popularity as an NFT platform, attracting top technology companies such as Meta (formerly known as Facebook) to build on its blockchain. However, in 2022, Solana suffered from several network outages and negative publicity due to its close ties with FTX cryptocurrency exchange CEO Sam Bankman-Fried. According to CNBC "Collapsed Crypto Exchange FTX Owes Top 50 Creditors $3 Billion: Filing." CNBC, 21 Nov. 2022, www.cnbc.com/2022/11/21/collapsed-crypto-exchange-ftx-owes-top-50-creditors-3-billion-filing.html. In 2023, some well-known NFT projects have since migrated to other chains. Solana uses Rust as its programming language.

4.4. Cardano

Cardano is a decentralized blockchain platform that is built on a proof-of-stake (PoS) consensus mechanism and is focused on providing a more secure and sustainable ecosystem for the development and execution of smart contracts and decentralized applications (dApps). The project was created in 2015 by the IOHK (Input Output Hong Kong) and it was launched in 2017. Cardano is decentralized governance system, which allows for the decentralized management and upgrading of the network. This is achieved through a process called "formal verification," which uses mathematical proofs to ensure the correctness of smart contract code. Cardano also has a multi-layer architecture, which allows for the separation of the settlement and computation layers, providing flexibility and scalability to the network, this allows for the development of more complex and sophisticated dApps. Cardano has rather slow and scientific approach to developing their ecosystem including peer-reviewing. Cardano uses Haskell programming language in its development.

4.5. Tezos

Tezos is a decentralized blockchain network that utilizes a unique governance model and a formal verification process for smart contract development. It was created in 2014 by Arthur and Kathleen Breitman and launched in 2018 through an initial coin offering (ICO). One of the key aspects of Tezos is its use of a unique consensus algorithm called "liquid proof-of-stake" (LPoS). This allows for a more energy-efficient way of achieving consensus on the network and allows for a greater degree of decentralization by allowing all holders of the native cryptocurrency, XTZ, to participate in the validation of transactions and earn rewards for doing so. Tezos has gained significant popularity among digital artists and especially generative patches made with javascript based libraries which can run on browsers.

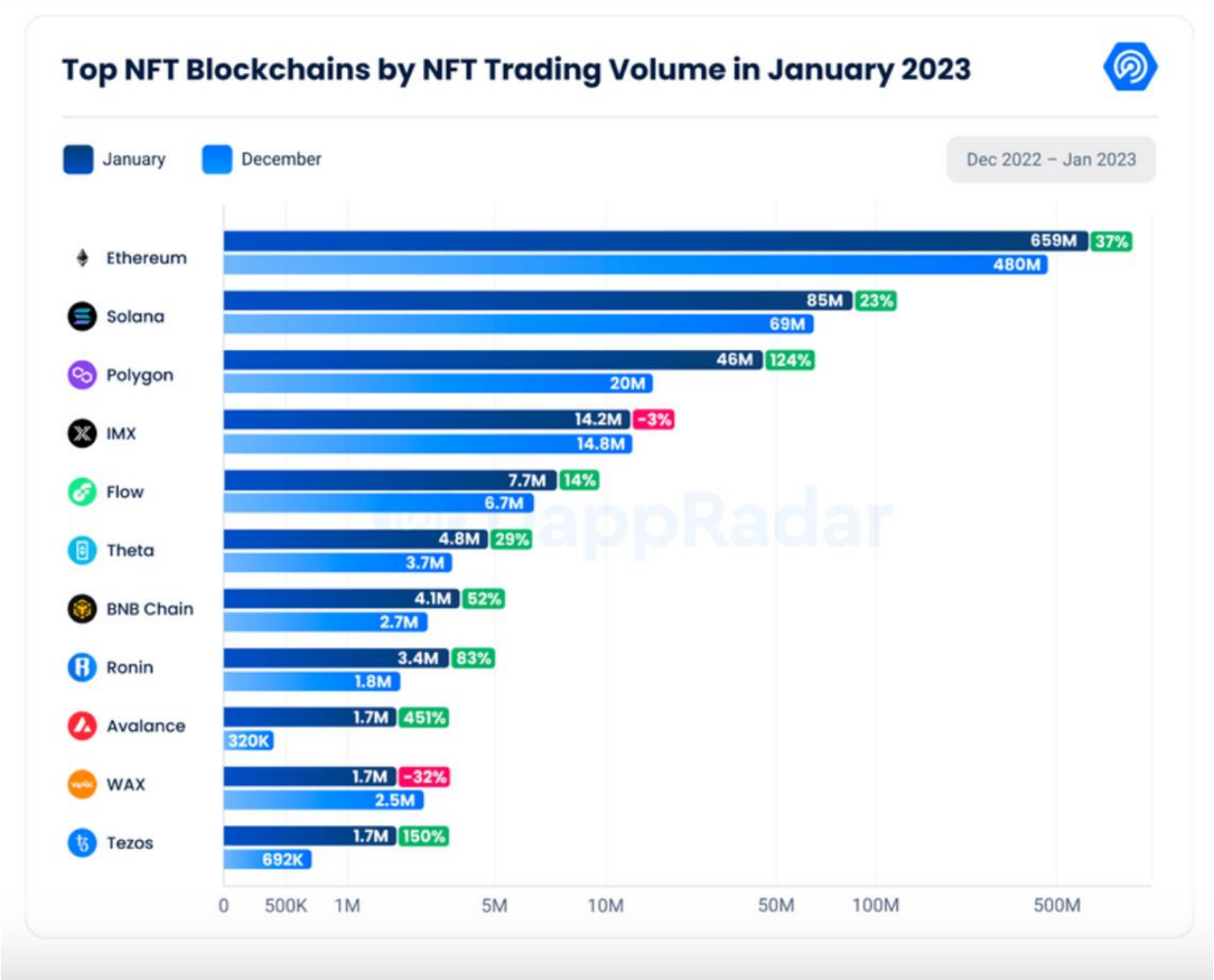

Figure 3. Top NFT Blockchains by NFT Trading Volume in January 2023. Dappradar.

Blockchain	Native Token	Max Supply	Market Cap	Consensus Algorithm	NFT Marketplaces	Transaction Times	Average Gas Fees
Ethereum	ETH	N/A	$150B	PoS	OpenSea, Rarible, SuperRare, Blur	15-60 sec	$10-50
BNB	BNB	171,175,000	$80B	PoS	Binance NFT, Treasureland	1-3 sec	$1-10
Solana	SOL	440,000,000	$15B	PoS	Magic Eden, Serum, Mirror	<1 sec	<$1
Cardano	ADA	45,000,000,000	$20B	PoS	JPG Store, flipr, CNFT.io, SpaceBudz	15-20 sec	<$1
Tezos	XTZ	10,000,000	$200M	PoS	Hic et Nunc, objkt.com, fxhash	N/A	N/A
Polkadot	DOT	1,000,000,000	$40B	PoS	N/A	<3 sec	$0.1-$1
Immutable X	IMX	100,000,000	$100M	PoS	Nifty Gateway, OpenSea	<3 sec	<$1
Polygon	MATIC	10,000,000,000	$20B	PoS	Quickswap, Aavegotchi, Jump.trade,	<2 sec	<$1
Avalanche	AVAX	720,000,000	$1.5B	PoS	Joepegs	<2 sec	<$1

Figure 4. Blockchain comparison chart.

5. Pre-Minting preparations

In order to mint anything as an NFT into a blockchain there are few necessary preparations needed.
At minimum, user needs to have a crypto wallet for connecting to a marketplace and to pay gas fees for registering transaction to the blockchain. The fees are usually paid in cryptocurrencies so user should get a small amount of certain cryptocurrency to be able to make permanent changes to blockchain such as minting something.

5.1. Cryptocurrency Exchanges

The easiest way to acquire cryptocurrency is by exchanging it for an equivalent amount of FIAT currency. Cryptocurrencies are highly volatile assets, meaning their value can fluctuate significantly. Cryptocurrency exchanges are widely available and many of them accept deposits via VISA card payments, SEPA transfers through third-party banks, and cryptocurrency transactions for all their listed cryptocurrencies. VISA payments are processed immediately, while SEPA transfers typically take a few hours excluding the first transfer that may take one or more bank days. Popular exchanges include Binance, Crypto.com, Coinbase, Kraken, and KuCoin. Additionally, some investment services, such as Robinhood and E-toro, also offer cryptocurrency trading. All the exchanges mentioned here are centralized exchanges, or CEX, owned and operated by private entities. They are subject to strict regulations and must comply with Know-Your-Customer (KYC) policies and report suspicious activity and customer information to local authorities as required.

5.2. Decentralized Exchanges

One of the fundamental concepts and philosophies behind cryptocurrencies is the development of decentralized finance. As there seem to be high demand for decentralized alternatives for traditional banking services, almost all the services and more are available including payments, lending, savings, investments, insurance, and exchanges. Decentralized exchanges, or DEXs, are platforms for peer-to-peer markets. They provide liquidity pools where users can contribute their cryptocurrency holdings as liquidity for various cryptocurrency pairs in exchange for a share of the exchange fees. Unlike centralized exchanges, where currencies must be deposited to make trades, in decentralized exchanges, currencies are kept in the user's own digital wallet. Trades are executed through smart contracts, where the trade is carried out only if all the conditions are met. DEXs generally have higher trade fees and rewards than centralized exchanges, and they are more private and less regulated. Some of the most popular DEXs include dYdX, Uniswap, Curve Finance, and Pancake Swap.

5.3. Wallets

Wallet is an encrypted key to a certain address in a blockchain. Wallet can be, for example, either a simple line of code on a paper (paper wallet), a software on an external electronic device such as USB-drive (hard wallet or a cold wallet if it is offline) or an application on a computer, mobile device or a software such as internet browser. Currently the most popular wallet by the number of user accounts is Meta Mask. Meta Mask is an external plugin or app, which can be added to an internet browser or on a mobile device. The process is relatively anonymous as registration, signing up and other processes of providing users personal details such as date of birth, credit card numbers or street addresses are not provided. As user is already linked to certain wallet address, only the wallet can be connected to the third-party services. For example, when users are entering into marketplace, online game, metaverse or social media platform, instead of registration, they simply connect their browser's wallet to the service. Wallet offers similar authenticator role in modern web 3.0 environment, and more as currently e-mail does in current web 2.0 services.

5.4. Storing the files and artwork

As blockchains are designed to store small bits of data per block they are currently not suitable for storing large files such as audio and video. As NFT is only a signature referred to certain tokenized object which is created in the minting process and stored in a blockchain, they do not include the original object. This creates a problem of storing the original assets NFTs are associated to. Marketplaces usually offer storage space for NFTs, but they are often limited to certain file sizes. As an example, current limit in Open Sea is 100 mb per NFT. For larger and uncompressed media files there is usually a compressed version available on the marketplaces, but the original files are stored elsewhere. Common options are cloud services and private FTPs, webpages and servers. It is not unusual that users who own a certain NFT does not have the original files or even access to them anymore but only signature referring they are the current owners of the asset.

One mentionable, trusted and popular option is Interplanetary File System, shortly IPFS, which is a peer-to-peer file sharing protocol that aims to make the web more decentralized and open. It is designed to make the web also faster by allowing users to access files directly from other users' devices instead a central server. All data is made encrypted and tamper-proof and it is designed to make the web more open by allowing anyone to access and share files without the need for centralized control. IPFS works by breaking files into small data packages and distributing them across a network of devices. When a user wants to access a file, they can request it from any device that has a copy of the file. Similar to bit-torrent, this allows for faster download speeds, since the user can download the file from multiple devices at the same time.

5.5. Marketplaces

NFTs can be sold or sent directly from person to person inside a blockchain, but so far most of the trades are made in dedicated marketplaces. Measured by daily trading volumes, most popular marketplaces in October 2021 were Open Sea, Axie Infinity, Crypto Punks, Pancake Swap and Super Rare (Dappradar). All of them are operating mainly or completely on Ethereum blockchain. Notable exception is Pancake Swap, which uses Binance Smart Chain but is still remarkably based on Ethereums' standards and structure. As NFTs are rapidly becoming more popular, many cryptocurrency platforms have implemented NFTs in their blockchains. Moreover, marketplaces are adding new blockchain networks into their services. Almost all Layer 1 blockchains forming similar ecosystem that Ethereum have NFT adoption including Cardano, BNB, Solana, Polkadot and Avalanche. A similar trend can be seen on cryptocurrency exchanges like Binance, Coinbase, KuCoin and Kraken. As Bitcoins' Taproot upgrade made smart contracts on Bitcoin more affordable (Sun), it is reasonable to expect that there will be NFTs projects and marketplaces built on the bitcoin blockchain.

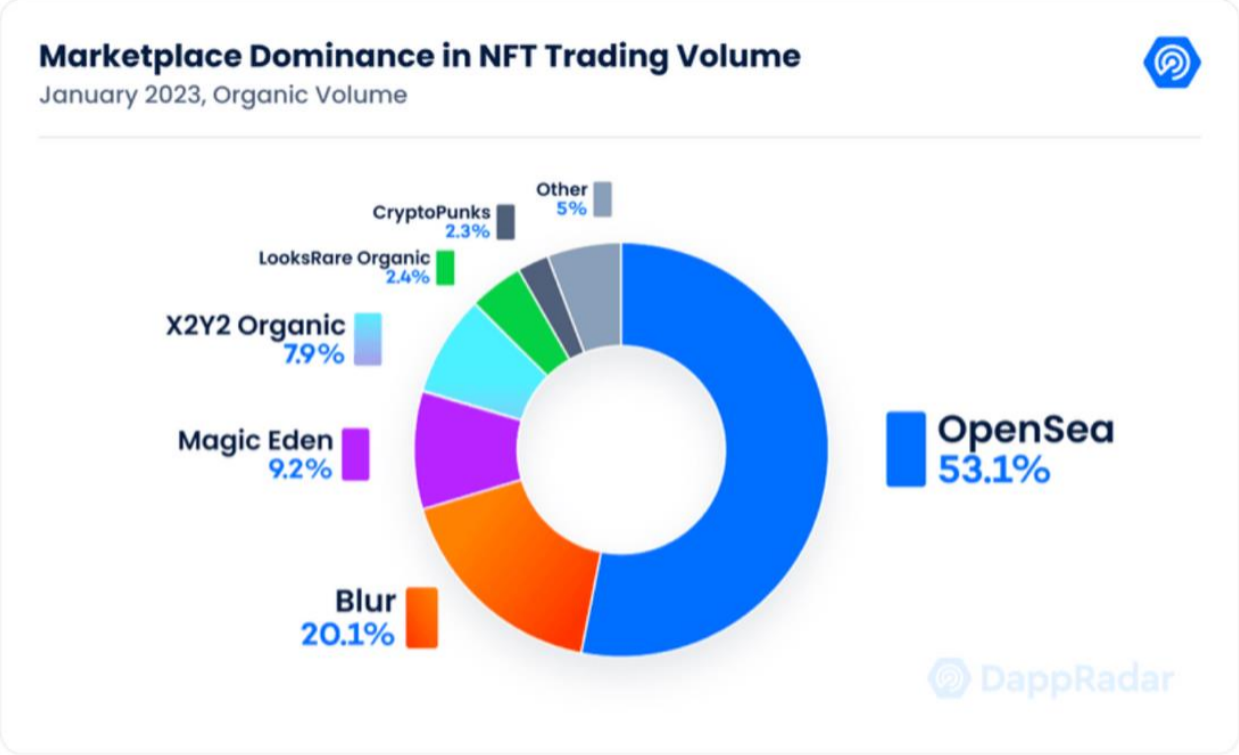

Figure 5. Marketplace Dominance in NFT Trading Volume. Dappradar.

5.6. Pricing NFTs

As NFTs are still relatively new technology and sales on marketplaces are mostly dealt with cryptocurrencies, there is a lot of fluctuation and a wide range of prices for different types of NFTs. Uniqueness and rarity are essential factors next to limited auction times and limited editions. For established entities such as a well-known artist with high reputation, hype and followers may drive the price up radically. As it might be difficult for unknown artists to get their works sold, providing them to curated platforms such as Art Blocks can significantly affect viewings, volumes and prices. Also, trading fees and trading volume of a marketplace and overall user volume in a blockchain affects the pricing as number of potential buyers, sellers and traders increase. If a single NFT is part of a larger collection, the overall trading volume of the collection can affect the pricing.

5.7. Marketing

Currently most of the marketing is happening in crypto related online communities such as Twitter, Telegram, Discord and Instagram. Before the actual sales listing, unlocking the content and the actual minting, there is usually a marketing period for the forthcoming release, or “drop” as they are often called. Strong online presence is vital. Having a website, multiple social media accounts, and a newsletter are common tools to promote NFT drops. Offering artwork for curated and established marketplaces can remarkably improve artist's visibility in NFT communities. Reaching influencers can also have a positive impact for sales volume. Artwork can be promoted by sending a free sample as an airdrop which is common among crypto enthusiasts.

5.8. Airdrops

An NFT airdrop is a distribution of non-fungible tokens to a group of individuals for free. It is similar to a traditional airdrop in the cryptocurrency world, where tokens are distributed to holders of a specific cryptocurrency. NFT airdrops are typically used as a marketing strategy to increase awareness and adoption of a particular NFT project or platform. The individuals who receive airdropped NFTs can then use or trade them. Airdrops can be done in different ways based on various criteria. Random distribution is where the NFTs are randomly distributed to a group of individuals. Distribution is Claim-based when NFTs are distributed to ones who actively claim them, for example following specific instructions or completing certain tasks. Loyalty-based distribution is more related to fans and supporters who have shown loyalty to a particular project or platform. Social media-based distribution is targeting individuals who engage with a project or platform on social media, such as by retweeting or sharing a post. Airdrops can be directly linked

to certain wallet fulfilling the criteria receiving an airdrop automatically. Airdrops are usually limited for certain limited period.

6. Project and Process

6.1. Visuals

In 2012, I embarked on my initial foray into digital visual art through street photography, right in the heart of Berlin. Exploring numerous abandoned sites adorned with vibrant graffiti and street art, I began capturing spontaneous moments of walls, windows, and staircases drenched in artistic expression. The abundance of captivating combinations of materials, colors, shapes, and lighting fascinated me. Soon, I discovered these photographs served a purpose beyond their inherent appeal; they became valuable assets for various projects affiliated with my electronic music label, Etherwerks. These ventures encompassed social media promotions, event flyers, podcasts, and even vinyl record artworks. During my time at Aalto media lab, I further cultivated my visual acumen by enrolling in courses with a strong emphasis on visuals. The utilization of these images as source material proved profoundly inspiring, empowering, and endlessly intriguing to me.

6.1.1. Premises and Aesthetics

In my creative works, be it videos, images, or audio, I find myself consistently drawn to textures and patterns that evoke unique atmospheres and abstract sensations. To accomplish this, I often rely on photographs I've personally captured, aiming to infuse them with a distinct mood by highlighting intricate details such as shapes, color combinations, lighting, and shadows. One subject of interest for me is the urban environment adorned with graffiti, where I find great delight in the captivating color palettes, abstract shapes and intriguing cropping opportunities. Some of these images possess a harmonious interplay of colors, organic shapes, and reflective light, giving them a dynamic quality that goes beyond what can be achieved through still colors or predetermined palettes alone.

Within these photographs, I am fascinated by the organic essence they convey, along with the element of chance and the multiple layers of history and artistic expression they encapsulate. Each picture captures a convergence of various artists' perspectives, resulting in a rich tapestry of visual elements. I strive to translate this organic and layered feel into my art, both visually and sonically. Just as my soundscapes rely on overall textures and sensations to evoke emotions, my visual style echoes this approach.

When working with images and videos, I consciously avoid directing the viewer's attention to any single focal point. Instead, I invite the eyes to meander freely across the texture, seeking out intriguing and captivating figures, color combinations, and cropping choices. I aim to create an experience where the viewer's gaze is encouraged to explore beyond the immediate surface, allowing the eyes to wander and drift amidst the canvas. It is through this process that I hope to captivate the audience and encourage a deeper engagement with the artwork.

6.1.2 Visual Production and Techniques

In my videos, I am captivated by a textural aesthetic, often utilizing photographs I have taken as a basis for the visual content. I aim to create an abstract theme with an atmospheric quality, utilizing a shallow depth of field that invites the viewer to wander around the image and take in the various details, shapes, color combinations, and play of light and shadow. My focus is on shooting macro shots of graffiti-covered urban surfaces and materials, seeking out visually pleasing and interesting color combinations, and cropping the images to enhance their impact. At times, I aim to create images with harmonious color tones, natural shapes, and reflections of light, lending an organic quality to the final product.

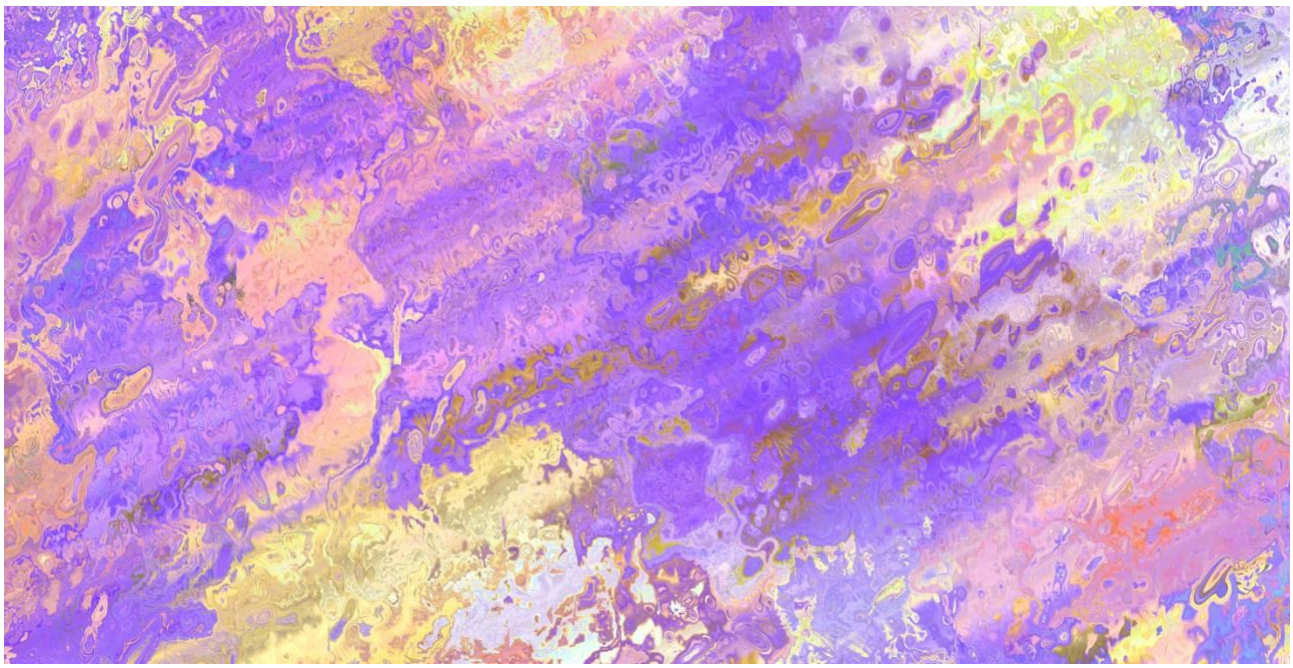

Figure 6. Aural Aquarelle #3. Ikola.

To achieve the textural effects in my videos, I primarily use Texture-Operators (TOPs) in TouchDesigner. I start with two to three photos, importing them into the project with the Movie File In operator. I then mix the images with noise, such as Simplex or Perlin, and control the movement by moving the noise along the z-axis, giving the illusion of depth. The movement of the pixels in the target image is further manipulated using the Displace operator and different color channels, such as red, green, blue, and alpha, to drive the movement. To refine the movement, I may apply slight blurring or soft feedback, and use various blend

modes from the Composite operator to combine the most effective textures. The final color tones are refined using the Levels operator, adjusting contrast, brightness, blackness, and gamma values. In instances where I am not satisfied with the result, I may incorporate additional still colors with the Constant operator or gradients with the Ramp operator.

Figure 7. Aural Aquarelle #2. Ikola.

6.2. Sound and Music

Sound has always been a natural means of self-expression for me through musical elements. I strive for a rich and living sound, characterized by simplicity and contrast, rather than complexity. I prefer raw and moody sounds, even if individual sounds may be heavily processed or polished. I think that a dominance of a single elements, such as certain type of phaser or reverb in the overall mix can create a fresh, intriguing, and captivating listening experience. I personally enjoy raw and unpolished sounds as they are relatively rare to hear in our daily surroundings. Tonal artifacts such as gentle noise, movement, errors, and emptiness are also crucial elements in my work. I think these kinds of elements used side by side with lush, clear, warm and musical tones can create an interesting contrast to overall soundscape and music.

Musically influences from styles such as grime, techno, ambient, and jazz are strongly present. Even if they may not be immediately recognizable to the listener, they all have had strong influence for me during certain times of my production. As a sound artist, I try to incorporate my background in electronic music, but sometimes find the material too musical, despite the minimal output. I think finding a delicate balance between music and sound art in my works is something that encourages and inspires me as an artist, producer and musician.

6.2.1. Preliminaries

Over the course of the years 2020 to 2022, I began to concentrate on creating music almost exclusively with external hardware devices. My studio setups are constantly changing but they are usually built up in a similar way including a mixer as a center piece with samplers, sequencers, synthesizers, drum machines, and effect devices. During this period, many of these devices accumulated sequences, sounds, themes, chords, rhythms, and patterns storing multiple layers of single elements trough out several years. As I was also producing visual textures using TouchDesigner, I noticed similarities between the moving images and sounds and started to experiment with incorporating musical elements into my texture work. As both projects had progressed independently for a considerable time, I eventually merged them together.

6.2.2. Audio Aesthetics

The musical pieces produced during the years 2020-2022 are characterized by a distinctive aesthetic that reflects my personal history and influences. The style is a fusion of subgenres from ambient, hip-hop, reggae, and techno music, taking inspiration from the spontaneous, stripped-down instrumental hip-hop tracks and the broken rhythms of breakbeat and early jungle music. Later I was particularly influenced by UK Grime music, which I found obstinate, heated, and distant. The music incorporates elements of danger and deep soulfulness, reminiscent of RnB, Lo-fi House, Vaporwave and African Electronic music such as Gqom.

The production process involves the use of hardware devices such as samplers, synthesizers, drum machines, and effect devices, which add unique advantages and limitations to the workflow. I tried to seek to balance between contrasts and to create a fusion of warmth and coldness, rawness and polish, and ferocity and gentleness in the musical pieces. The use of samples, modular synthesizers, and mixer boards adds depth and uniqueness to the sound, while striving to maintain the balance between elements of beauty and danger.

6.2.3. Audio Techniques

The music and sounds of this thesis artwork are creations of improvised and live played parts with musical hardware only. My workflow is based on preliminary preparations, where I create, test, edit and mix blanks that include rhythms, sounds, sequences, melodies, harmonies and processed samples. As functional, coherent and aesthetically pleasant combinations are found, I store them in the memory of the devices of my hardware set up. I use Elektron Octratrack as a master sequencer, through which I can control the patterns, sounds and parameters of other devices with MIDI and MIDI CC -commands. Some of the devices are synchronized to Octratrack's master tempo, but some elements are playing off sync.

One method I used a lot during the process was a creative use of convolution reverb. I like to use convolution reverb as a sample trigger in effect send channels using vocal samples in convolution plugins instead of impulse responses. This results an ethereal, hollow and cold sound that is easy to place in the background of the mix. It also sometimes creates an interesting and rich harmonies when several elements of the track are played throughout the same vocal phrase. I also use automation, gate and LFOs to make the output of the convolution more controlled and varying.

6.2.4. Audio Production

In my musical setup, the mixer plays a crucial role. I use a Venice Midas 320 analog mixer as the central device, to which all the other hardware devices such as samplers, synthesizers, drum machines and effect devices are connected in individual channel tracks. The mixer has six send outputs, which I use for distortion, delay, modulation, reverb, harmonizer, and shimmer through external effect pedals. These effects are then routed back to the mixer for their own channels, creating feedback loops and adding noise. With the mixer, I can manipulate the noise and turn it into a musical and harmonious sound, even reaching the level of oscillation and feeding it back to the pedals for further processing. This way of working blends the Dub-style instrument use of mixers and effects with a distorted rhythmic soundscape reminiscent of techno and electro, creating an electrifying and dense timeless sound. The mixer also functions as a multi-circuit equalizer, compressor and summing, giving me even more control over the final sound.

6.2.5. Musical Structure

I perceive these soundtracks not as songs, tracks, or compositions, but rather as musical pieces that are constructed through a combination of sounds, moods, melodies, harmonies, rhythms, and sequences. However, these combinations are subject to variability, depending on the day, time, and mood. In particular, the tempo, sounds, tones, harmony, and degree of processing can differ from one session to another. I also incorporate elements of my own process into the devices I use for additional processing and reuse of ideas and elements, resulting in the creation of layers, interactivity, and curated coincidences. This approach keeps the work interesting and surprising for me, offering both a player and musician experience. From this perspective, the release should not be considered as a finished product or final version of the work, but rather as a snapshot of the process at a certain level of coherence. After the clips were selected, I employed equalization, compression, and gentle limiting techniques to master the tracks.

6.3. Audio and Visuals Combined

During the creative process, I experimented with various techniques to make the visuals audio-reactive, such as beat detection, dividing bandwidth, and mapping peaks with various parameters in TouchDesigner. However, I was unsatisfied with the results as they appeared too obvious and formulaic. As a result, I decided to exclude all audio reactivity. When I played the clips for friends and colleagues, they frequently inquired about the connection between audio and video, as it seemed subtle. Through these discussions, I came to the realization that the human brain tends to seek out connections between movement and sound, even if none exists. This insight became a central aesthetic principle in the project, guiding the combination of audio and moving images.

7. NFT Exhibition

The NFT project of the thesis also includes an audiovisual exhibition that I held at the central library Oodi on January 9-15, 2023. The exhibition titled as “Few Understand This” is an immersive NFT exhibition where generatively evolving visuals and vibrant textures merge with experimental soundscapes and electronic music inspired by subcultures. The exhibition's theme revolves purely around self-expression, while also reflecting our rapidly changing and difficult-to-grasp world.

Figure 8. “Few Understand This” -exhibition poster. Ikola.

7.1. Artwork

The exhibition featured a collection of four unique videos rendered from generative patches made with TouchDesigner. The collection is titled as Aural Aquarelles. The patches were generated from macro photographs a have taken during the years. The overall style of the videos is organic and colorful, and the composition is texture-like without any central objects. Each video is paired with composed music consisting of ambiences and harmonies made with synthesizers and short sequences composed, recorded and produced with hardware devices. The length of the videos ranged from 2:45 minutes to 3:30 minutes.

7.2. Preparation

The space served as an immersive space on the second floor called Kuutio. It has two video walls and six ceiling-mounted speakers and powerful desktop PC for running the media on the walls. As a media playback software, I used a VJ program called Resolume Arena 7. With Resolume, I was able to define the precise alignment to place the image in the windowpanes of the video wall, as well as make the automatic fades and transition to the next video and audio clip automatically. Due to the large size of the files, I decided to share the same video content on both display surfaces. I ended up making the videos in 3600 x 1200 resolution, with an aspect ratio of 3:1 and a pixel count of 4,320,000. Due to the high resolution, optimal quality and 60 fps framerate, the files were very large. The approximately three-minute video took about 70 gigabytes when rendered with the HAP Q codec in TouchDesigner.

7.3. Installation

The material of the video walls is glass, and the image is projected onto them with video projectors from back side outside the gallery space. There are normally seven projectors, but one of the projectors was out of use, so there were two projectors on one wall and four on the other. The combined resolution of the display surface of the space was 15087 x 1200 with the current calibration. I did three separate layers in Resolume with four columns each. Each column has a different video and audio clips and the layers one and two was playing separate walls as layer three played the audio files. Videos rendered with 3600 x 1200 resolution covered exactly four windowpanes on both walls making the installation symmetrical and harmonious. Rest of the walls were covered with black theatre fabrics. The exhibition space was left minimalistic as there were only four chairs left on the floor and a stand for exhibition information with info text, cover photo and QR-code leading visitors to my NFT-collection page in Open Sea marketplace.

Figure 9. Few Understand This -exhibition in Cenral Library Oodi, Media space Kuutio. Ikola.

7.4. Findings

The exhibition and installation as a whole provided an immensely positive and empowering experience. However, there were certain technical aspects that required improvement. One such issue was the presence of minor flickering in the videos, which stemmed from a combination of finding the optimal settings for rendering and codecs, as well as the original parameter values for specific noise channels, colors, and movements. Additionally, the setup process for the installation proved to be highly time-consuming. Drawing from my prior experience as an employee at Oodi, I was already aware of certain technical challenges, including light leakage, limited sound systems, and less-than-ergonomic working facilities. Furthermore, there were some complications with Resolume Arena, as the software did not perfectly synchronize audio and video clips, resulting in a slight audio delay with each clip change, leading to an increasing gap between audio and video.

NFT exhibitions are still relatively uncommon in Finland, which led to uncertainty regarding the level of familiarity and comprehension among the exhibition visitors regarding NFTs and the exhibition's underlying concept.

The process of marketing the exhibition, as well as my own artistic works in general, has proven to be

challenging for me. Additionally, I believe that NFT communities primarily exist online and are fragmented into their own respective groups, making it difficult to target and attract local communities for one-time events. While global platforms such as Twitter, Telegram, and Discord are active hubs for crypto and NFT enthusiasts, I believe that Facebook and Instagram still maintain an active presence within local art and music communities.

Another crucial realization was the significance of thorough documentation, which demands substantial resources that can often be underestimated. In the future, I should allocate better time budgets and dedicate more time after the exhibition opening to meticulously document the intricate details.

8. Summary

8.1. Reflections

The project as whole was extensive, demanding and broad. There was not a lot of issues with single technical details, but rather broad entities, concepts, processing and utilizing that required deep effort, time and persistence. One of the challenges was how rapidly things might change cryptospace and NFTs. During the final work, from the first sketches to the final version, Bitcoin, the leading asset in crypto markets, broke twice its previous price peak and collapsed to half of its ATH (all time high) value. The rest of the crypto market followed, as usual. The NFT market looked particularly active and lively at the end of 2021, following sinking to almost nothing in the Google Trends search results at the beginning of 2022. The third significant phase was the bankruptcy wave of crypto exchanges that started in 2022, which also shook the entire market.

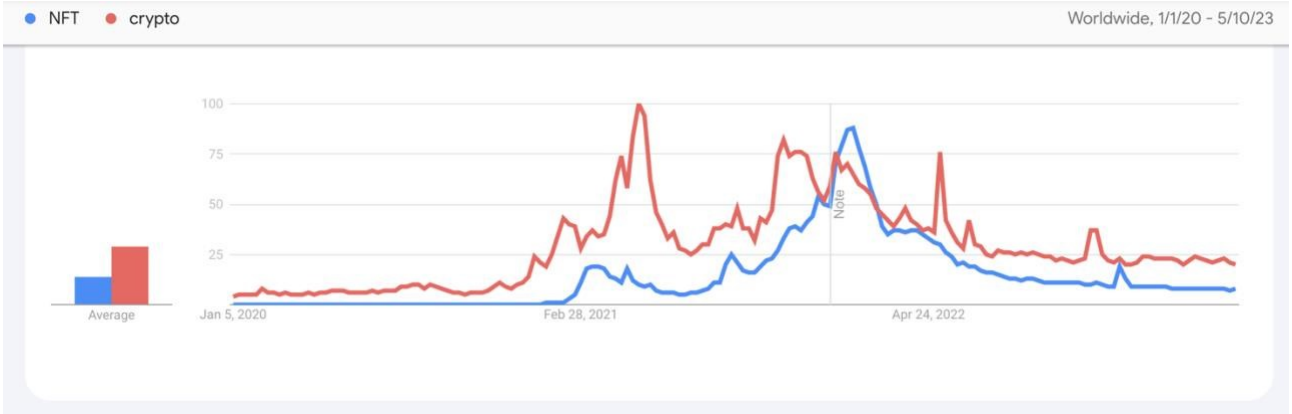

Figure 10. Google Trends: NFT vs. Crypto. Google.

As an artist it was interesting to follow the special features related to NFT art and to consider these in my

productions. In NFT, art works are often released as collections containing multiple individual works, often in high numbers. As the art works in the collection are often single pieces, these extremely limited editions are likely to sell out quickly without a change for all the potential collectors and fans to participate in the auction. As number of art works in collection rise, also deviation between popularity and price increases and possibly spread more evenly between the art works. In some NFTs, the collection itself can be seen as the archetype of the artwork with different unique variations each individual work embodies in its own way. In my opinion, this is an interesting and welcome alternative especially in music sector that could disrupt the status of LP and EPs that have been possibly too established in music for decades.

8.2. Findings

In terms of the final work, the most important findings were the following: NFTs may significantly change the practices of how artists sell and market their work. NFTs may also change many other prevailing practices, including music, sports, internet, social media, gaming, finance, marketing, internet and many other industries. Expectations regarding NFTs are high, but at the same time there are many significant risks associated with them. These risks are related to copyright, consumer protection, fraud, money laundering, speculative investments, market manipulation and volatile conditions in the crypto market. Concerns about the burden on the environment related to technology are also still current, although there has also been significant development in the field in this regard. In general, the discussion related to NFT, and the crypto market is characterized by a lack of information, misconceptions, polarization of the discussion and stubborn assumptions about things that can be based to a significant extent on outdated information. Operating in the NFT market also requires some technical know-how and understanding of blockchains, activity in social media and Internet communities, timeliness, evaluation of various marketplaces and networks, and own activity. The use of curated platforms and established cooperation parties can significantly contribute to the growth of NFTs. It is worth noting, that NFTs are bringing exclusiveness, rarity and scarcity in digital world.

One notable observation pertained to the substantial amount of criticism encountered within the academic community regarding the topic under consideration. The primary focus of this criticism revolved around Ethereum's energy consumption resulting from its continued utilization of the Proof-of-Work (PoW) consensus algorithm, the ethical concerns associated with NFT art encompassing issues like fraud, hype, and instances of "rug pulls," as well as criminal activities like money laundering. Some of the criticisms were valid, particularly in relation to energy consumption, albeit it was indicated that this concern would be mitigated with Ethereum's transition to the Proof-of-Stake (PoS) consensus algorithm. While there have been reports of money laundering, reliable empirical data on this phenomenon remains limited. Given the relative youth and ongoing development of the culture surrounding these emerging technologies, it is crucial to

recognize and address the social issues associated with them. Notably, new technologies and their accompanying cultural spheres, such as social media and online gaming, possess inherent risks and addictive qualities that warrant particular attention, especially concerning younger individuals.

Through this process, I began to perceive my own creative work as a more personal endeavor, where the emphasis lies not so much on the final artworks themselves, but rather on the act of creation, the process, and the documentation and exploration thereof. New technologies, such as blockchain and artificial intelligence, as well as a more democratic approach to producing high-quality content, have saturated the realm of available content. Consequently, in my opinion, the individual significance of each artwork is no longer as substantial as it may have been in the past. Of course, every piece can hold great personal value to its creator, the viewer, and the owner. However, I found this notion to be liberating for myself, as it helped me focus more on the processes that reinforce my own creative output and the original strengths that are intrinsic elements behind my sound and aesthetic.

8.3. Results

As for the final work, the finished part of the NFT collection has been the biggest artistic entity I have worked on. Visual content, sound and music, post-processing, exhibition preparations, installation, maintenance and monitoring, adoption and monitoring of the NFT market and practices, as well as the written part of the final work and familiarization with the source materials were a very comprehensive project that lasted more than a year. This entity has given a lot of experience, learning, knowledge and skill related to these areas. Conceptualizing such an entity does not end there, but develops along with projects, technology and communities. In any case, this work has significantly shaped both my own artistic work and my own thinking as an artist, musician and content producer, student and person.

Financially or in terms of visibility, it's still too early to make bigger conclusions. As far as I am concerned, working with NFTs is only at the beginning, and therefore the expectations are not high. However, I consider the opportunities and potential power of change offered by technology to be promising, interesting and significant compared to the current alternatives. It's important to keep in mind that success can be challenging to measure in the NFT world. The prices of content-questionable works can rise to hundreds of thousands, and correspondingly, you can find a lot of skillful, insightful and eloquent works on the marketplaces, for which visibility, sales or interest do not necessarily appear at all. On the other hand, even a less significant work by a purely interesting artist might be an interesting, significant and valuable artifact.

8.4. Developing

I plan to finish the NFT collection and publish it when the works and the collection are in that condition. There are certainly many different approaches and techniques to the form, duration, adaptability, mobility, storage and transfer of the works, which I will try to find out and utilize in the future. I have a couple of preliminary collection ideas in mind that I could start working on after this collection is finished. Combining different techniques, experimenting with new styles, shapes and shades also interest me. Following NFTs, cryptocurrencies and digital art will certainly continue to be important, as new phenomena and trends are constantly emerging. For now, I consider Ethereum the most potential platform for my own NFT projects, but that may change in the future. For example, in relation to music, so far there has not been a single strong service, community or blockchain that would have established itself more widely, but this area is also presumably developing.

9. Afterthoughts

From the very beginning of my thesis journey and throughout the entire process of writing and creating, a persistent question has guided my exploration: Are we witnessing a cultural shift that challenges our perception of how we engage with art in the digital realm? As the digital era unfolds, a remarkable paradigm is emerging, where mass production and uniqueness coexist, reshaping our understanding of value and creative expression. The rapid development of Artificial Intelligence, Internet of Things, Decentralized Social Media platforms, the democratization of creation, and reimagined notions of ownership all contribute to these evolving questions and trends.

9.1. Rethinking Rarity

In the past, my perspective on the artistic process followed a linear trajectory, where the primary objective, shared by myself and many others, was the creation of exceptional content while continually striving for improvement. This mindset led me to prioritize the pursuit of a commonly accepted notion of "greatness" and focus on the end results of my creative endeavors. I observed a similar approach among my fellow artists and musicians, who dedicated significant efforts to refining their technical skills and employing post-production techniques to ensure that their unique art aligned with the standardized forms dictated by centralized platforms, global communities, and algorithm-driven social media.

However, I gradually found myself losing interest in the creation of finalized versions, full-length tracks, and adhering to the traditional production, distribution, and release pipeline. Instead, I became increasingly inspired by the process of creating musical assets, elements, and themes. I found joy in playing and mixing

these elements during improvised sessions, exploring hardware-only setups, and embracing the real-time, human-centered nature of creation, including its limitations, accidents, and emotional nuances. It was during this exploration that I began to perceive a strong connection between generative processes and my own curated elements, which I viewed as predefined "rules" encompassing sound sets, sequences, rhythms, patterns, and chords, with myself as the primary algorithm. Amidst the prevailing conformity, I also became captivated by modern artists who utilized these very platforms to share their working methods and creative processes. It was through these glimpses behind the scenes that I discovered something truly remarkable—a quality that was both unique and rare, holding immense value.

This realization prompted a profound reevaluation of the concept of rarity, transcending the mere notions of scarcity or limited quantity. Rarity assumed a deeper significance, reflecting the artist's individuality, their distinct approach, humanity, personality, and their willingness to unveil their creative journey. This documentation of the process encompassed techniques, technology, ideas, aesthetics, and more. In an era dominated by mass production and the replication of digital content, it became evident that what truly stood out were the authentic and personal narratives interwoven within the artistic process. The digital age has introduced a new understanding of rarity, challenging the prevailing emphasis on technical perfection and conformity. It celebrates the idiosyncrasies, imperfections, and intimate details of the creative journey, recognizing their value and embracing the beauty found within them.

9.2. Mass Production of the Unique

As an artist, my perspective on terms such as rarity, uniqueness, exclusiveness, and personal valuation has undergone a profound shift. I find myself deeply intrigued by the transition from replication to variation, which has revolutionized the traditional model of creating identical copies. With the advancements in generative algorithms, artificial intelligence, and programming, we now have the remarkable ability to generate a multitude of unique and individualized digital works in a relatively fast and efficient manner. This transformative process expands the concept of uniqueness beyond singular objects, unveiling an infinite realm of variations, each possessing its own distinctive qualities. As I embark on my creative journey, I find myself focusing on several key elements that shape my artistic process.

One of these elements involves exploring generative processes as an artist. I am filled with a growing curiosity to play and experiment with the vast potential of generative techniques, employing algorithms and computational methods to craft art that possesses the ability to evolve, mutate, or adapt over time. For instance, I find myself combining analog hardware devices with digital generative tools, utilizing MIDI, MIDI CC, analog to digital/digital to analog conversion, and control voltages. This fascinating realm of generative art blurs the conventional boundaries that separate the artist's original intent from the creative influence of algorithms, paving the way for innovative forms of collaborative expression. Within this

context, artists embark on a delicate balancing act, seeking to exert control over the generative process while also embracing the element of serendipity. By doing so, we open the door to unexpected and emergent properties, infusing our generative works with a sense of dynamism and unpredictability.

Another significant aspect that has captured my attention is the redefinition of rarity within the realm of digital art. This transformative shift challenges our conventional understanding of rarity, moving beyond a mere focus on scarcity based on limited quantities. Instead, a new paradigm emerges—one that emphasizes rarity based on the intrinsic qualities, combinations, and variations present within each digital item. Collectors and audiences are captivated by the allure of owning a singular piece from a series of variations, elevating the perceived value of these one-of-a-kind creations. This redefined concept of rarity celebrates the uniqueness and individuality inherent in each digital artwork, transcending traditional notions of scarcity and inviting a fresh appreciation for the diverse possibilities that arise from mass-produced uniqueness.

The democratization of creation is yet another fascinating phenomenon that has deeply impacted my artistic pursuits. This transformative shift is driven by the accessibility of digital tools, open-source software, and vibrant online communities. It empowers a wider spectrum of artists and creators, breaking down barriers and allowing for broader participation. Personally, I have found great value in leveraging AI to incorporate elements beyond my expertise, such as integrating 3D-elements with audiovisual textures, or exploring musical on-demand services that offer diverse sample libraries with exotic tones and timbres as a starting point for creating new sounds. The mass production of unique works challenges the long-held notions of elitism and exclusivity within the art world, fostering a more inclusive creative landscape. This shift towards democratization amplifies creativity and paves the way for a more democratic and egalitarian artistic ecosystem.

Furthermore, the reimagining of ownership and authenticity has emerged as a compelling narrative within the digital realm. This narrative is shaped by the integration of blockchain technology and Non-Fungible Tokens (NFTs), providing a transparent and verifiable mechanism for asserting ownership and establishing the authenticity of digital items. As artists and collectors embrace the concept of digitally scarce tokens, we utilize them to represent and track unique digital creations, ensuring provenance and safeguarding the rights of artists. This integration of blockchain, digital art, and the mass production of unique items shed new light to the perception of value, ownership, and the role of the physical in our increasingly digital environment.

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