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Combining AI Art and Blockchain for Decentralized Collaboration, Enhancing Provenance, Scarcity, and Authenticity

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Abstract

Background: AI art is a rapidly evolving field that challenges traditional notions of creativity and authorship. As AI art continues to develop, there are still significant gaps to address. This research aims to explore the intersection of AI art and blockchain, providing new approaches to collaborative creation, sharing, and valuation of AI-generated artworks.

Research objectives: This research aims to investigate the feasibility of on-chain storage for AI art parameters and evaluate the ability to regenerate the original image. It further explores the use of DLT to preserve and enhance the provenance of the creative process in AI-generated art, assessing its impact on the value and acceptance of blockchain-based technology. Additionally, it tries to evaluate the potential of blockchain-based technology in addressing challenges related to scarcity and authenticity in AI art, ensuring originality and traceability. Lastly, it evaluates the role of blockchain-based technology in fostering collaboration and community engagement in the field of AI art, examining its impact on collaborative AI art creation and the sense of community within the AI art field. Through the development of proof of concepts and surveys, this research presents the achievements and insights gained from exploring the practicality and potential of blockchain in the context of AI art.

Preliminary study: The preliminary study establishes the feasibility of storing AI art on-chain in a way that allows to regenerate the original image using Stable Diffusion. It lays the foundation for the main experiment by providing evidence that AI art can be successfully stored on the blockchain.

Main Experiment: The main experiment focuses on capturing and documenting subsequent contributions to AI-generated artworks on the Ethereum blockchain. Through the implementation of a decentralized platform, it showcases how blockchain-based technology enables provenance, scarcity, authenticity and collaborative AI art creation. The findings demonstrate the effectiveness of blockchain-based technology in addressing the challenges associated with AI art.

Survey: The survey provides insights into the perceptions of participants regarding AI art, blockchain, and the factors of provenance, scarcity, and authenticity. The majority of participants recognize the importance of these factors in determining the value of artwork and acknowledge the potential of blockchain technology to enhance them. These insights validate the significance of blockchain in the context of AI art.

Conclusion: This research contributes to the field of AI art and blockchain by showcasing the potential for decentralized collaboration, enhanced provenance, authenticity, and scarcity in the creation and valuation of AI-generated artworks. The findings highlight the potential of blockchain-based technology to transform the landscape of AI art and emphasize the need for further research, as this is only the beginning.

Contents

1 Introduction

AI art is the new, fascinating and innovative field that challenges traditional notions of creativity and authorship. We might be witnessing a new era of art where humans and machines collaborate to produce masterpieces. But with this innovation come challenges. How can we ensure the authenticity and provenance of AI art in a world where physical forms are absent and replication is effortless? Can decentralization revolutionize the way we perceive ownership, authorship and value in the AI art industry? And, what possibilities arise when we enable collaboration in AI art?

This thesis explores the potential of enhancing AI art through the use of blockchain-based technology. AI-generated art, being unique and lacking physical form, is particularly vulnerable to replication and tampering. Cetenic et al. emphasizes this in their paper, they state that AI art requires an alternative approaches to ownership transactions compared to traditional physical artworks [7]. The value of AI art might be dependent on its provenance and authenticity, which can only be guaranteed through secure and reliable methods of storage, preferably decentralized and fully on-chain.

In recent years, Decentralized Ledger Technology(DLT) and especially blockchain has, through smart-contracts, enabled artists to explore new ways of sharing and monetizing their work, while allowing collectors to acquire and prove ownership over digital art in novel ways. These specific smart-contracts are often referred to as NFTs (Non-fungible tokens) which is a standardization of a smart-contract. NFTs are defined as "a unit of data stored on a blockchain that certifies a digital asset to be unique and therefore not interchangeable while offering a unique digital certificate of ownership for the asset" [25] [14].

But challenges arise with decentralized art as smart-contracts are verifiable but the information it refers to might not always be. The most common method for storing digital artworks on the blockchain is to use centralized servers or decentralized storage solutions like IPFS. The smart-contract stores a link or hash reference pointing to the actual image and metadata.

This approach has several limitations, including potential loss of assets if the servers go offline or are hacked, reliance on third-party providers that may charge fees or censor content and interoperability issues among different platforms and standards.

These limitations underscore the necessity of developing new methods, ensuring AI arts authenticity, provenance and collaborative potential. This research aims to explore innovative approaches and propose a solution for secure and transparent storage and collaboration in AI art, leveraging blockchain technology to enable trust, attribution and collaboration.

The remainder of this thesis is structured as follows: The background will include information on DLT, as well as a review of related work. After which the research design will be outlined including the research questions, aims, and objectives. The preliminary study on storing AI art parameters on-chain will be discussed, followed by the main experiment focusing on AI art collaboration using blockchain-based technology. The survey study and results will examine the perceptions of AI art and blockchain, and the evaluation of the proof of concept. The thesis concludes with a discussion of the findings and limitations, as well as a final conclusion. The appendix will include source code of the smart-contracts implemented in the main experiment.

2 Background

This section provides a background overview of Distributed Ledger Technology (DLT) and its many applications. It also includes a review of related work in the field, highlighting the existing knowledge and gaps that this research aims to address.

2.1 Distributed Ledger Technology and its Applications

Distributed Ledger Technology (DLT) is a decentralized and distributed ledger that enables the secure and transparent recording of transactions across multiple participants. [35]. One of the most well-known implementations of DLT is Blockchain, which forms the basis of various applications in different domains. The first blockchain was introduced by Satoshi Nakamoto when he published his paper "Bitcoin: A Peer-to-Peer Electronic Cash System" in 2008 [26]. Since then, many other blockchain platforms have been developed, each with its own unique features and applications.

The most important key concepts are Transparency and Immutability. Immutability refers to the inability to alter or tamper with transactions once they are recorded on the chain. This provides a high level of data integrity and trust, making it suitable for applications where verifiability and authenticity are crucial [33]. Transparency refers to the ledger being publicly accessible, allowing participants to view and audit the transaction history. This transparency enhances accountability and can be particularly beneficial in areas such as art, where provenance and ownership are important [33].

Consensus mechanisms play a vital role in DLT. The consensus is utilized to preserve agreement among the nodes in the network. [19] By establishing consensus, DLT eliminates the need for a central authority, enabling decentralized and trustless transactions. Numerous consensus algorithms have been developed, well known are Proof of Work (POW), Proof of Stake (POS) and Byzantine Fault Tolerance (BFT).

In 2015 Ethereum emerged as a groundbreaking platform that extended the capabilities of Blockchain beyond currency. Ethereum was founded by Vitalik Buterin, who introduced the concept of smart-contracts, which are programmable contracts with predefined conditions [5]. This enabled developers to create decentralized applications (DApps) and execute complex logic in a verifiable and decentralized manner. Ethereum continues to evolve, one significant development is the recent transition from Proof of Work (PoW) to Proof of Stake (PoS) through the implementation of the Beacon Chain in 2022. The transition to the Beacon Chain represents a major milestone for Ethereum, as it reduced energy consumption by 99.98% and improved the scalability of the network[18].

This innovation paved the way for a revolution in DLT applications. Some examples are:

- Financial services: DLT enhanced the efficiency and transparency of financial transactions, such as payments, clearing and settlement. An example is Pyctor, a DLT-based platform that provides post-trade market infrastructure for digital assets. Pyctor's technology manages private keys by fragmenting and distributing them among blockchain nodes hosted by regulated institutions [15].
- Supply chain management: DLT provides a transparent and traceable ledger for tracking the movement of goods and products. This ensures authenticity, reduces fraud and enhances sus-

tainability by verifying the provenance of products. An example is IBM Food Trust. It provides real-time visibility into the movement of food products, which can help to improve food safety and traceability.

- Healthcare: DLT offers a secure and confidential method for storing and sharing patient medical records. Especially Zero-Knowledge Proofs will be a promising innovation as they can be used to verify the authenticity of healthcare claims and provide medical records without compromising the privacy of patients. [32]
- Government services: DLT has the potential to improve the efficiency and transparency of government services. Examples are the voting systems, taxation and land registration. Zero-Knowledge proofs are promising as well, ensuring integrity and removing the risk of fraud. Estonia, for example, uses a blockchain-based land registry and voting system. [31]
- Art and collectibles: NFTs have had lots of exposure over the last year. DLT can ensure the authenticity and uniqueness of digital and physical artworks, reducing the risk of fraud and counterfeiting.

Through examples given in financial services, supply chain management, healthcare, government services and art and collectibles, DLT has showcased its potential to enhance transparency, security and efficiency across various industries. The emerging field of AI art could greatly benefit from DLT by providing value as well as enable for collaboration in AI-generated content.

2.2 Related Work

The integration of blockchain technology with the creative industries has been growing in recent years. This section reviews related work to AI art and art collaboration, as well as DLT/blockchain and storage solutions.

Malik et al. [22] discuss the potential benefits of using DLT in the creative industries, including the use of non-fungible tokens (NFTs) to identify unique artworks and record ownership on the blockchain. The authors also highlight how smart-contracts can be used to codify the rules of sale, usage and licensing of NFTs. The authors discuss how generative AI can create realistic images and how it is becoming a new way to create art and mint NFTs. This paper provides valuable insights into the intersection of blockchain technology and creative industries.

Cetinic et al. [7] further explores the impact of artificial intelligence on visual arts, including the emerging field of Blockchain Art. The authors explore how AI technologies can stimulate advances in digital art and art history and inspire new perspectives on the future of art. This is relevant as this thesis explores new grounds with the intersection of AI Art and DLT. They state that "The very nature of digital artworks requires different approaches to ownership transactions than in the case of traditional physical artworks"[7]. The discussion by Cetinic et al. provides context for understanding how blockchain-based technology can be used to create a secure and transparent platform for buying, selling and trading AI-generated artworks.

An interesting platform, but rather focused on the intersection of generative art and blockchain, is GEN.ART[1]. GEN.ART is a platform and community that enables artists to release art immutably on

[1]https://gen.art

the Ethereum blockchain. GEN.ART has been an inspiration for this study as it was found to save the code of generative artworks fully on-chain, meaning the underlying asset is on-chain as well. They do distribute AI art, but further investigation showed that they save the JPGs on IPFS(InterPlanetary File System)[2][2]. This means that the actual AI image is not on-chain, but rather a hash referring to the image on IPFS.

Yusa et al. [36] provide valuable insights into the potential benefits, drawbacks, ethical considerations, collaborative practices, technical challenges and social implications of AI-generated art. Their work explores the synergy of art and animation technology in multimedia performance art creation, highlighting the potential of technology to offer new modes of creative expression and engagement. The authors emphasize the importance of critical engagement and continued reflection on the use of AI in art, suggesting that future research should focus on developing ethical guidelines and even more relevant "exploring collaborative practices".

The paper by McConaghy et al. [24] titled "Visibility and Digital Art: Blockchain as an Ownership Layer on the Internet" investigates how blockchain-based technology can serve as an ownership layer for digital art, including the potential inclusion of AI-generated art. The paper explores the use of blockchain to provide greater visibility and authentication for digital artwork. This is particularly relevant as it mentions that DLT can be used to store and distribute digital art, which encompasses AI art, as on-chain non-fungible tokens (NFTs).

It is essential to address the security concerns surrounding the rapidly growing NFT market and its implications for AI-generated art integration. The most common method for storing digital artworks on the blockchain is to use centralized servers or decentralized storage solutions like IPFS, which poses several problems.

This is confirmed in a paper by Balduf, Florian and Scheuermann [1], it mentions that the storage of digital art in the context of non-fungible tokens poses several challenges and issues for the long-term availability and integrity of the content. The paper revealed that many popular NFTs rely on centralized platforms or allow changes to the metadata and assets that are referenced by the tokens. The paper also pointed out that the standard interface for NFTs on Ethereum does not provide any guidelines or recommendations on how or where to store the content and only suggests that the metadata should include a name, a description and an image. Similar concerns can be found in multiple news articles over the years. [20] [17] [9] [10] [12]

Das et al. [11] further highlights this in the paper "Understanding Security Issues in the NFT Ecosystem," which provides valuable insights into the security risks associated with NFTs. The authors analyze the components of the NFT ecosystem and identify associated threats, addressing security, privacy and usability issues.

Most importantly, the authors note that off-chain records are susceptible to tampering, censorship and prone to disappear if the NFT marketplaces database goes down. They found that only a fraction of the referenced content was stored on IPFS and that a large portion of data stored on other systems was already inaccessible. They state that 3.91% of the assets (images) and 9.04% of metadata records hosted on IPFS have disappeared in their dataset between June and December 2021. However, a majority of asset URLs (88.71%) as well as metadata URLs (80.69%) are hosted on non-IPFS

[2] https://docs.ipfs.tech/concepts/further-reading/academic-papers

domains. Looking at all the lost NFTs, they have generated a staggering amount of $160,761,805 USD in revenue from 118,294 transactions. To conclude, Das et al. stated that "Persistence is a pressing issue in the NFT space".

The discussed papers show how DLT can create a secure and transparent platform, not only for buying, selling and trading AI-generated artworks, but also for fostering critical engagement and collaborative practices in the field of AI art. It highlights the role of blockchain as an ownership layer for digital art, including AI-generated art, enabling greater visibility and authentication. Furthermore, the section addresses the security concerns associated with the NFT ecosystem, particularly in relation to off-chain records and the persistence of data. By embedding provenance in the creative process, blockchain-based technology offers a promising pathway for establishing trust and enhancing collaboration in AI art.

3 Research Design

This section outlines the research aims, objectives and questions that guide the exploration of the intersection between Distributed Ledger Technology (DLT) and AI-generated art.

3.1 Research Questions

The research questions shape the exploration of the intersection between Distributed Ledger Technology and AI art. They provide a framework for investigating specific goals within the field. The following research questions have been identified:

Research Question 1: Is it feasible to store AI art parameters on-chain and regenerate the original image?

This question aims to investigate the practicality of on-chain storage for AI art parameters and the ability to regenerate the original image. The successful regeneration of the original image demonstrates the potential to eliminate reliance on centralized servers or IPFS.

Research Question 2: How can DLT be used to preserve and enhance the provenance of the creative process in AI-generated art?

This question seeks to explore how blockchain-based technology can be used to capture and document the creative process of AI-generated artworks. By building a proof of concept and conducting a survey to understand how provenance information of the creative process can contribute to the value, authenticity and collaborative aspects of AI-generated art.

Research Question 3: What is the potential of DLT in addressing challenges related to scarcity and authenticity in AI-generated art?

This question aims to assess how blockchain can enhance the scarcity and authenticity of AI art by developing a proof of concept. This includes conducting a survey to assess the beliefs of participants in the use of blockchain in ensuring the uniqueness, originality and traceability of AI art.

Research Question 4: Can DLT foster collaboration and community engagement in the field of AI art?

This question aims to evaluate the effectiveness of DLT in fostering collaboration and community engagement among artists and art enthusiasts on AI-generated art. This is done by building a proof of concept that allows for collaborative AI art creation/contribution and conducting a survey to gather feedback from participants. The question seeks to assess the impact of DLT on shared decision-making, creativity enhancement and the sense of community in the AI art field, which is relevant because it addresses the emerging need for innovative frameworks and tools that foster collaboration and collective creation as mentioned Yusa et al. [36].

The goal is to provide valuable insights into the transformative potential of blockchain-based technology in the context of AI-generated art, offering new perspectives and opportunities for artists, enthusiasts and the broader art community.

3.2 Research Aims and Objectives

The research aims and objectives are derived from the research questions outlined in 3.1. Each research aim aligns with one or more research questions and provides a focused direction for investigation. By achieving the objectives associated with each aim, this research seeks to shed light on the potential of DLT in the context of AI art.

Research Aim 1: Investigate the feasibility of On-Chain Storage for AI Art parameters

Research Objective 1.1: Develop a proof of concept to explore the practicality of storing AI art parameters on-chain.
Research Objective 1.2: Evaluate the ability to regenerate the original image from on-chain stored parameters.

Research Aim 2: Explore the use of DLT for preserving and enhancing Provenance in AI Art

Research Objective 2.1: Develop a proof of concept that uses blockchain-based technology to capture and document the creative process of AI-generated artworks.
Research Objective 2.2: Conduct a survey to assess the contribution of including provenance information to the value and assess their acceptance and/or awareness towards blockchain-based technology enhancing provenance in AI art.

Research Aim 3: Assess the potential of blockchain-based technology in addressing Scarcity and Authenticity challenges in AI Art

> **Research Objective 3.1:** Develop a proof of concept using blockchain-based technology to ensure originality and traceability in AI art.
> **Research Objective 3.2:** Conduct a survey to assess the perceptions and beliefs of participants regarding the potential of blockchain to enhance scarcity and authenticity of AI art.

Research Aim 4: Evaluate the role of DLT in fostering collaboration and community engagement in AI Art

> **Research Objective 4.1:** Develop a proof of concept to enable collaborative AI art creation and contribution using DLT.
> **Research Objective 4.2:** Conduct a survey to assess the impact of DLT on enabling AI art collaboration, creativity enhancement and the sense of community in the AI art field.

3.3 Methodology

This section outlines the methodology used to address the research aims and objectives derived from the research questions outlined in 3.1. The research methodology involves the following steps:

3.3.1 Data Collection

Multiple data collection methods will be used to gather insights and address the research questions.

1. **Preliminary Study:** The preliminary study together with the background research gives insights of the current state of AI art and blockchain technology and includes implementing the proof of concept to validate the feasibility of storing AI art as NFTs on the Ethereum blockchain.
2. **Main Experiment:** The main experiment collects data through the implementation of the proof of concept, specifically for on-chain storage of AI art parameters, image regeneration, and collaborative AI art creation. During the evaluation of the proof of concept, user feedback and survey responses are gathered from participants who interact with it to provide their perspectives and experiences.
3. **Survey:** The survey is conducted to get a greater understanding of the perspectives of art students and artists on the proposed system. Data such as demographics, level of familiarity with certain topics and their perspectives on art, blockchain, NFTs and AI generated art, are collected.

3.3.2 Data Analysis

Data analysis will be used to extract meaningful insights and address the research objectives. The analysis will primarily consist of descriptive statistics to summarize and interpret the survey data.

The data collected from both quantitative and qualitative sources will be analyzed separately. Most of the quantitative data is related to the view of participants on AI art, NFTs, Blockchain and provenance, scarcity and authenticity. Were as the qualitative analysis will focus on the analysis of open-ended question to gain deeper insights into participants opinions regarding the proof of concept and collaborative AI art.

3.3.3 Evaluation and Validation

The developed proof of concept and survey will undergo an evaluation and validation process to assess their effectiveness in achieving the research objectives. The survey will be validated by other researchers. The proof of concept will be evaluated through user feedback and the survey. Participants will be asked to provide their opinions on their experience using the systems, specifically focusing on the collaborative mode and its benefits. The evaluation will gather insights on the usability, intuitiveness and effectiveness of facilitating collaboration and community engagement.

4 Preliminary study: On-Chain AI Art Parameter Storage

This section outlines the objectives of the preliminary study and provides a technical implementation overview. The section also discusses the benefits, challenges, and accomplishments of the objectives.

4.1 Concept Overview and Objectives

The primary goal of the preliminary study is to explore the feasibility of storing AI art on-chain as Non-Fungible Tokens (NFTs) on the Ethereum blockchain. This goal is addressed by building a proof of concept to prove its feasibility.

During exploration of the preliminary study, gen.art[3] was explored. Gen.art is one of the first platforms to store their generative artworks code fully on-chain, but their AI art is stored through IPFS. This discrepancy raised the question of why not? Because it hasn't been done before. This preliminary study explores the possibility of saving AI art on-chain.

The study explored Stable Diffusion by Stability AI, an open-source model that encompasses both image and natural language processing capabilities. By examining the underlying parameters of Stable Diffusion, such as latent vectors, model parameters and prompts, it was hypothesized that it may be possible to store the necessary information on-chain to regenerate the original AI-generated image.

The preliminary study can be divided into steps that aim to answer the first research question and the research objectives (1.1 and 1.2), derived from the section 3.2, These are defined as follows:

1. Investigate the feasibility of storing AI-generated images entirely on-chain.
2. Identify the essential parameters required for reconstructing the original image using Stable Diffusion.
3. Develop a technical implementation that utilizes a smart-contract on the Ethereum blockchain to store the relevant parameters.
4. Demonstrate the ability to regenerate the AI-generated image using the on-chain data stored in the smart-contract.
5. Assess the benefits and challenges associated with on-chain art storage, particularly in terms of decentralization, security and the size limitations imposed by the Ethereum blockchain.

[3]https://gen.art/gallery

4.2 Technical Implementation

The technical implementation of the proof of concept involves two main components: the setup of the Stable Diffusion environment and the integration with the Ethereum blockchain.

4.2.1 Stable Diffusion

The Stable Diffusion environment was set up using Google Colab. This environment allows for image generation using the Stable Diffusion 2.1 model as mentioned by Rombach et al. [30]. The interface is based on an open-source GUI and altered with Gradio, see figure 1. For this exploratory proof of concept, the parameters were capped at prompt, guidance scale, steps, width, height, seed and attentionSlicing. Each of these parameters plays a role in the generation process:

- **Prompt**: The prompt serves as a textual input that guides the generation process. It can be a short sentence or a few keywords that describe the desired image. The prompt provides high-level instructions for the model, this reflects on the overall theme of the generated image.
- **Guidance Scale**: The guidance scale parameter determines the strength of the prompts influence on the generated image. A higher value for the guidance scale makes the generated image more "faithful" to the prompt, while a lower value allows for more creative interpretation by the model.
- **Number of Diffusion Steps**: The number of diffusion steps controls the level of detail and complexity in the generated image. A higher number of diffusion steps typically results in more detailed images, but it also increases the computational time required for generation.
- **Image Width and Height**: The image width and height parameters define the size of the generated image. This not only influences the resolution but also the aspect ratio of the image.
- **Seed**: The seed parameter plays a crucial role in the deterministic nature of the Stable Diffusion model. The seed is a random number that acts as a starting point for the generation process. Controlling the seed can generate reproducible images.

  The same seed, generator(that is, a deterministic one) and other parameters, will produce the same image [21], allowing for reproducibility. This deterministic behavior is essential for storing and regenerating AI-generated images on the blockchain.
- **Attention Slicing**: Attention slicing is an option that determines how the model allocates its attention across the image. By adjusting the attention slicing parameter, different regions of the image can be emphasized or de-emphasized during the generation process.

The deterministic properties of the model is a key aspect of storing and preserving AI-generated images as NFTs on the blockchain, as it allows for reproducibility of the generated artwork. While the model's sampler, in this case a Diffusion Probabilistic Model, is not necessarily deterministic, using a specific seed reproducibility can be ensured as it produces the same initial noise signal [21].

It is important to note that the model offers a wide range of additional parameters and customization options that can further refine the image generation process.

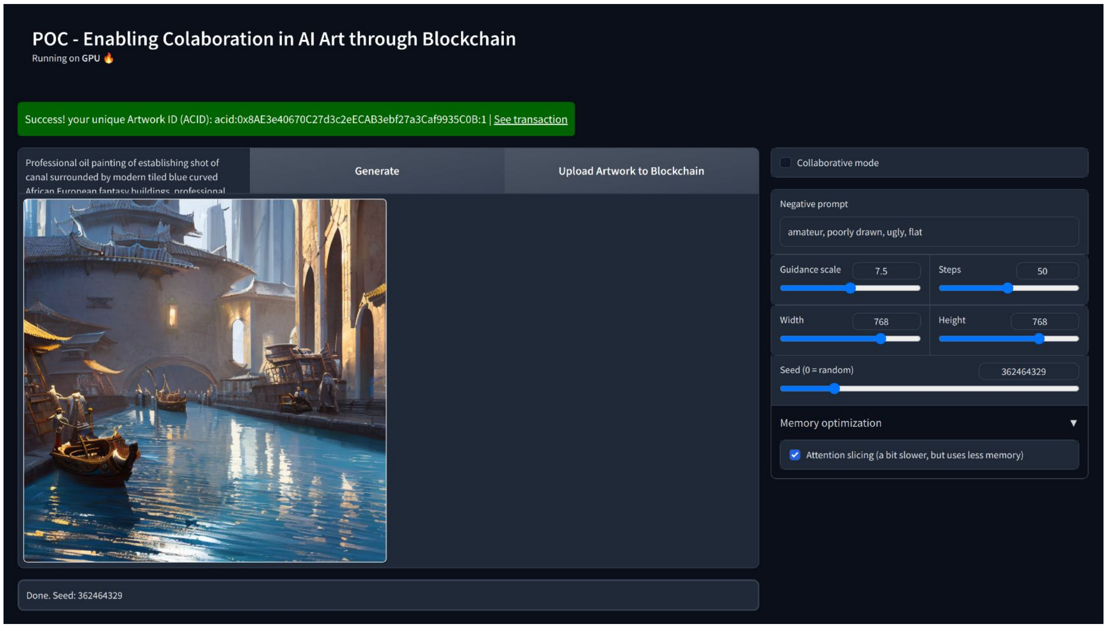


Figure 1: Interface of the proof of concept. See more artworks: Jessedegans.com/ArtCollab

4.2.2 Ethereum Blockchain

Ethereum is a decentralized blockchain platform that enables the creation and execution of smart-contracts, which are programmable contracts with predefined conditions [5]. It serves as the foundation for many decentralized applications (dApps) and has gained significant popularity over the last years. One of the key features of Ethereum is it support for executing code on their EVMs (Ethereum Virtual Machines). Smart-contracts are written mostly in Solidity, Ethereums general purpose programming language or Vyper. Solidity was chosen for this proof of concept due to its accessibility. A form of smart-contracts are digital tokens such as the non-fungible token (NFT). More about Ethereum can be read in the background subsection 2.1.

4.2.2.1 Token Standards

Token standards are interfaces / technical guidelines on how specific assets on chain behave, it helps to ensure that smart-contracts remain composable. Token standards are proposed through Ethereum Improvement Proposals (EIPs). In the context of non-fungible tokens, the ERC721 and ERC1155 standards are most common. Note that at the moment of writing ERC-4910 is proposed which is a new standard focusing on Royalty Bearing NFTs [16]

4.2.2.1.1 ERC721 Standard

The ERC721 standard is specifically designed for non-fungible tokens, which represent unique and indivisible assets on the Ethereum blockchain. It was proposed in 2017 by William Entriken et Al. they stated that “A standard interface allows wallet/broker/auction applications to work with any NFT on Ethereum. We provide for simple ERC-721 smart-contracts as well as contracts that track an arbitrarily large number of NFTs.” [13]. They stated that the fungible token standard ERC-20 was not sufficient as “NFTs are distinguishable, and you must track the ownership of each one separately.”.

The ERC721 standard proposal introduced the term "NFT" as a widely applicable term for the concept of non-fungible tokens. They state that they surveyed different terms such as "distinguishable asset" but eventually choose the term NFT.

The core structure of ERC721 is that each token has a distinct identifier. This makes it ideal for representing and trading unique artworks, collectibles and other one-of-a-kind assets. The ERC721 standard defines the basic functions and interfaces for creating, transferring and managing non-fungible tokens.

4.2.2.1.2 ERC1155 Standard

The ERC1155 standard introduces a more flexible token model. It was proposed in 2018 by Radomski and his team from Enjin [29]. The reason for introducing the standard is that ERC721 refers to a contract where every NFT must be the same type of asset. Where ERC1155 allows for the creation of both fungible and non-fungible tokens. It enables the issuance of multiple types of assets within a single smart-contract, making it more efficient and cost-effective compared to deploying separate contracts for each asset type. Similar to the ERC721 standard, the ERC1155 standard supports functions for creating, transferring, but managing both non-fungible and fungible tokens.

On top of that, ERC1155 offers unique functions such as Atomic Batch Operations that enables for multiple token transfers in a single transaction. This feature ensures that all transfers within a batch are executed together or fail together, maintaining consistency and reducing the risk of incomplete transactions [29]. It also supports token ID flexibility as it uses a combination of the contract address and token ID, similar to the approach in the main experiments proof of concept.

4.2.3 Smart-contract Implementation

The smart-contract is developed based on the ERC721 token standard. To extend the ERC721 functionality, a custom contract named OCAV1 (On Chain Art V1) is deployed.

The choice of the ERC721 token standard for the exploratory proof of concept was made after careful consideration of the project requirements and objectives.

- ERC721 tokens are specifically designed for representing unique non-fungible assets only, making them well-suited for the storage and preservation of AI-generated images as individual pieces of art.
- The ERC721 is way more popular and widely adopted than the ERC1155 token standard. This is confirmed by Tan et Al. in their paper "Measurements, Analyses and Findings on the Ethereum ERC721 and ERC1155 Non-fungible Token Ecosystem". They state that at their time of writing " only 3,682,417 ERC1155 NFTs are created comparing to the 71,143,539 ERC721 NFTs" [34]
- The ERC721 standard offers a simpler and more straightforward implementation compared to ERC1155 which was beneficial for the initial proof of concept.

The core data structure in the contract is the OCAData object, which represents an individual NFT. It contains the essential parameters required to regenerate the AI-generated image, including the text prompt, guidance scale, number of steps, width, height, seed and the address of the creator.

The OCAData object is stored as a token. Each token is uniquely identified by its token ID. Currently, the token ID is set to be equal to the seed used for generating the image. However, future implementations will address the need for establishing uniqueness to avoid conflicts.

The contract provides methods for minting new tokens, querying token information and transferring tokens between addresses. It includes functions for retrieving the parameters associated with a specific token ID, which enables for the reconstruction of the AI-generated image.

The Sepolia Ethereum Testnet is used for testing the deployment and functionality of the smart-contract. During the testing phase, the first token with ID 67956308 was published on the Sepolia Testnet, serving as an initial proof of concept.

The successful integration of the Stable Diffusion environment with the Ethereum blockchain demonstrates the potential of on-chain AI art NFTs. Blockchain-based technologies can be used to offer valuable features such as provenance and ownership transparency, which extends into verifying authenticity. It is important to note that achieving scarcity in AI art does not solely rely on blockchain-based technologies and while the precise impact on the overall value of AI generated artworks is yet to be determined, the integration of blockchain-based technology provides a framework that has the potential to enhance the value and integrity of AI art.

4.3 Benefits, Challenges and Objective Accomplishments

The implementation of on-chain art storage through the use of smart-contracts has several benefits and challenges. This section discusses how the defined objectives have been addressed and explore the potential benefits and challenges encountered during the proof of concept.

4.3.1 Objective 1.1 and 1.2

By successfully storing AI-generated images as NFTs on the blockchain, the feasibility of on-chain art storage has been demonstrated. This showcases the possibility for preserving AI art in a decentralized manner.

Through the retrieval of parameters from the blockchain and their utilization in the Stable Diffusion environment, the original AI-generated image can be accurately reconstructed. This finding is important as it paves the way for further research into how DLT can enhance AI art.

4.3.2 Challenges

While on-chain art storage offers numerous benefits, there are also challenges to consider. One significant challenge is the scalability of the Ethereum smart-contract and the Ethereum blockchain itself. As the number of AI-generated artworks increase, the storage and processing requirements on the Ethereum blockchain may become more demanding. A more modular design that further splits it down to multiple contracts is needed.

The International Standard Content Code (ISCC), which encodes metadata and data similarity, was explored in an earlier thesis exploration related to biometrics. However, the implementation of ISCC was deemed beyond the scope of this particular proof of concept. It might solve the challenge where people steal each other's AI art by simply submitting the same parameters to chain and selling that artwork.

Another challenge is the potential for high transaction fees, as this can greatly influence the affordability of on-chain storage for artists and users. Optimization of the smart-contract is needed, and the exploration of layer-two scaling solutions can help address these challenges. pp Other potential smart-contract optimizations are:

- Minimize unnecessary computations: Remove redundant calculations or computations that do not affect the contract's logic or functionality
- Reduce storage operations: Minimize write operations to contract storage, as these can consume significant gas.
- using Function modifiers: function modifiers eliminate duplicated code and improve contract readability and maintainability.
- Upgradability and Modularity: Design contract with upgradability and modularity in mind. Separating functionality into separate contracts can make upgrades and optimizations easier in the future.

5 Main Experiment: AI Art Collaboration Using Blockchain

The main experiment focuses on enabling AI art collaboration through blockchain-based technology. This section discusses the proof of concept, the concept overview, objectives and the analysis of moxie's autonomous art. A survey is conducted to validate the proof of concepts and further address the research questions.

5.1 Overview and Objectives

The proof of concepts primarily focuses on AI art collaboration. It aims to explore the practicality and effectiveness of using blockchain to enable collaboration, preserving provenance, ensuring authenticity, enhancing scarcity and promoting community engagement in AI art.

Artists will be able to submit new AI artwork to chain, as well as contribute to existing AI artworks by building upon each other's work in a decentralized way.

The objectives of this concept align with the previously mentioned research aims and objectives 2 through 4 as the research objectives 2.1, 3.1 and 4.1, defined in 3.2 directly involve building the proof of concept to implement the following:

- Use blockchain-based technology to capture and document the creative process of AI-generated artworks, thereby preserving provenance.
- Use blockchain-based technology to ensure originality and traceability in AI art, addressing challenges related to scarcity and authenticity.
- Use blockchain-based technology to enable collaborative AI art creation and contribution.

This structure provides a clear outline of the main experiment and its components connecting the objectives, the analysis of related work (Moxie's autonomous art), the proof of concept and the survey study.

The following sections will focus on the implementation and evaluation of the proof of concept and the analysis of Moxie's Autonomous Art as a source of inspiration for potential implementations of the proof of concept.

5.2 Analysis of Moxie's Autonomous Art

Moxie Marlinspike, the CEO of Signal, explored web3 to better understand it. Moxie explains in his blog that to better understand the world of web3 he created what is called Autonomous Art, a dApp (decentralized App) that enables artists/users to create and mint NFTs in collaboration through visual contribution [23]. Every contribution to the NFT costs an incremental "minting fee" on top of the transaction fees. This minting fee is shared among the contributors as a way of earning for the contributions.

The contract(s) will be analyzed to map different ways on how provenance can be tracked in the NFT space. Moxie uses the standard templating from hardhat and OpenZeppelin which are both open-source initiatives that develop contract standards. The contract *CollectiveCanvas.sol* will be mainly explored, which is located at 0x3a56AB63c7ef4f07fe353bEb132e0Fd5AD270Ca0 with token tracker: AutonomousArt (AART).

5.2.1 Image-related functions

The contract stores the image itself as well as the metadata 100% on chain. The metadata contains the creator, a timestamp, the funding and how much value withdrawn.

The image is rather interesting as it constantly changes. This is why Moxie used SVG standards to save the image on chain. Each contribution is stored separately in an array called $\_layers$. This array records the historical state of the artwork. Each of these layers have their own unique NFT token ID, linked to the contributor as he/she owns that specific NFT token which can be seen as proof of contribution. The $\_encodeSvgAtTokenId$ function reconstructs the historical state based on a given token ID by applying each layer on top of each other, where each layer is one or multiple elements that are added to the resulting SVG. This SVG is then converted to base64 and prepended with the string $data : image/svg + xml; base64$, for browser compatibility, by the $\_encodeSvgUriAtTokenId$ function.

5.2.2 Value Distribution Mechanism

Part of the contract is its unique value distribution. Token holders are able to earn a share of the minting fees, providing a potential source of passive income.

The contract uses the $balanceOfToken$ function to calculate the earnings for the holders of the NFT. To calculate the balance, this function iterates through all minting events and calculates the share owned by the token holder.

Let $tokenId$ be the ID of the token whose balance is being calculated and let $withdrawnValue$ be the total amount that the token holder has already withdrawn, which is stored in the $\_tokenMetadata$ mapping. The balance is computed as:

$$balance = \left(\sum_{i=tokenId}^{|\_layers|} \frac{\_tokenMetadata[i].funded}{i+1} \right) - withdrawnValue$$

This formula sums up the share owned by the token holder across all subsequent mintings. Starting from the $tokenId$ up to the current length of the $_layers$ array. The value of the share is calculated by dividing the amount funded for the minting event by one plus the index of the minting event. The withdrawn value is then subtracted from the total value to obtain the withdrawable balance.

The NFT token holders can call the $withdraw$ function to transfer their earnings to their wallet.

5.2.3 Analysis and findings

The NFT contract implemented by Moxie Marlinspike's Autonomous Art represents a single image that constantly evolves with each subsequent contribution. Which is something totally different from what is seen in regular NFT contracts that mostly consist of collections of similar images, such as CryptoPunks or Bored Ape Yacht Club.

Each contribution is treated as a separate non-fungible token (NFT) with its own unique identifier. Each NFT is a specific contribution to the overall artwork. Not only allowing for collaboration, but also encouraging it with the value distribution mechanism.

Although the value distribution mechanism and monetization approach are outside the scope of the proof of concept, they provide interesting insights into alternative models for generating revenue and rewarding contributors to AI art. Exploring such models in future research or projects would be interesting to further explore the potential of these systems.

It is interesting that the concept of NFTs has been mainly associated with digital images in the collective consciousness due to the hype surrounding NFT art (while the non-fungible token may not have that association). This contract demonstrates that NFTs can represent more than just images. Since in this case, it represents a contribution. By analyzing Moxie's Autonomous Art, valuable insights were found. These findings help the design and development of the proof of concept.

5.3 Considerations for the proof of Concept

The implementation of the proof of concept required careful considerations. One important decision was whether to use a single contract to manage all the images and their contributions, or to create a new contract for each AI image.

Using a single contract has several advantages, such as reduced deployment time and lower gas fees. Multiple images can be stored within a single contract, minimizing the costs of deploying the contract and adding contributions. But the contract may become too large and disorganized as the number of images and contributions grows. Since a smart-contract is limited in size by the block limit, this approach could potentially lead to performance issues and increased code complexity. Which is far from ideal for the proof of concept stage. The idea of having a single point of failure, a single contract, is also not favorable.

Deploying a new smart-contract for each AI image provides improved security and better separation of concerns. Each contract would be responsible for managing a single AI image and its contributions/derivations, resulting in better transparency. But this approach increases the cost of deployment and management, as new artwork contracts are more expensive in gas fees.

For this proof of concept, the decision was made to use multiple smart-contracts. This keeps the contributions and derivations inside the contract of the original work. As previously mentioned, using a single contract offers advantages such as reduced deployment time and lower gas fees, but it also means increased complexity and security risks. Deploying a new contract for each AI image leads to better security and separation of concerns, and at this stage that weights more than cutting transaction fees. The Artwork-Contribution Identifier (ACID) registry is implemented as it not only serves as a gateway and information hub but also takes on the responsibility of deploying the contracts. This integration reduces the complexity of the proof of concept and minimizes the system's gas fee costs.

5.4 Technical Implementation of the Proof of Concept

This section provides detailed insights into its specific components, mechanisms and interactions. The subsections that follow will explore the smart-contract structure, including the Artwork Contract and the Artwork-Contribution Identifier Registry, as well as provide an overview of the smart-contract design and functionality.

5.4.1 System overview

The system proposed here ensures the secure, decentralized storage of artworks and their provenances. Each artwork is represented by a smart-contract that contains information about the artwork itself and any derivations or contributions made to it. Contributions are recorded as unique tokens (NFTs) within the original artwork contract.

The Artwork-Contribution Identifier (ACID) registry functions as a gateway/information hub and artwork contract deployer. This registry allows for the registration and lookup of artwork contracts and their associated ACIDs. It also keeps track and updates the artwork's meta information, such as artist, title and description.

In essence, both the original AI artwork and every contribution made to it are unique NFTs with their own value and ownership. But deploying a new contract for a new AI image is far more expensive in terms of transaction fees. This incentivizes collaboration and derivations from existing works, as it is cheaper for artists to build upon and enhance previously created artworks.

The system's architecture consists of artwork contracts, the ACID registry and the client. Together they establish a decentralized framework for managing AI art and preserving its provenance. The following subsections will delve into the specifics of each component such as their structure, functionality and interactions within the system.

5.4.2 Client

The client component of the proposed system is built on top of Stable Diffusion using version 2.1, which is fine-tuned from Stable Diffusion 2 (768-v-ema.ckpt) [30]. The Diffuser package is used to obtain the pretrained model with a DPM scheduler, which serves as the foundation for the text-to-image generation.

The client's interface is based on an open-source GUI. To make the proof of concept feasible, the functionalities of the GUI have been stripped down to focus on the text-to-image generation feature. This allows users to generate AI-generated artwork based on the provided text input. The proof of concept has been scaled down to prioritize the functionality.

Added to the client is the integration with the Ethereum blockchain. Transactions are issued directly from the user's wallet on the Sepolia testnet. After an image is generated, users can push the artwork to the Ethereum blockchain with a simple click of a button. For the proof of concept, it was more practical to use a dedicated wallet instead of integrating with MetaMask or other similar services. This approach simplifies the demo of the proof of concept for the survey participants.

Another significant feature of the client is the collaborative mode. This mode enables users to choose from a gallery of images that are already on the blockchain and load them into the editor. Users

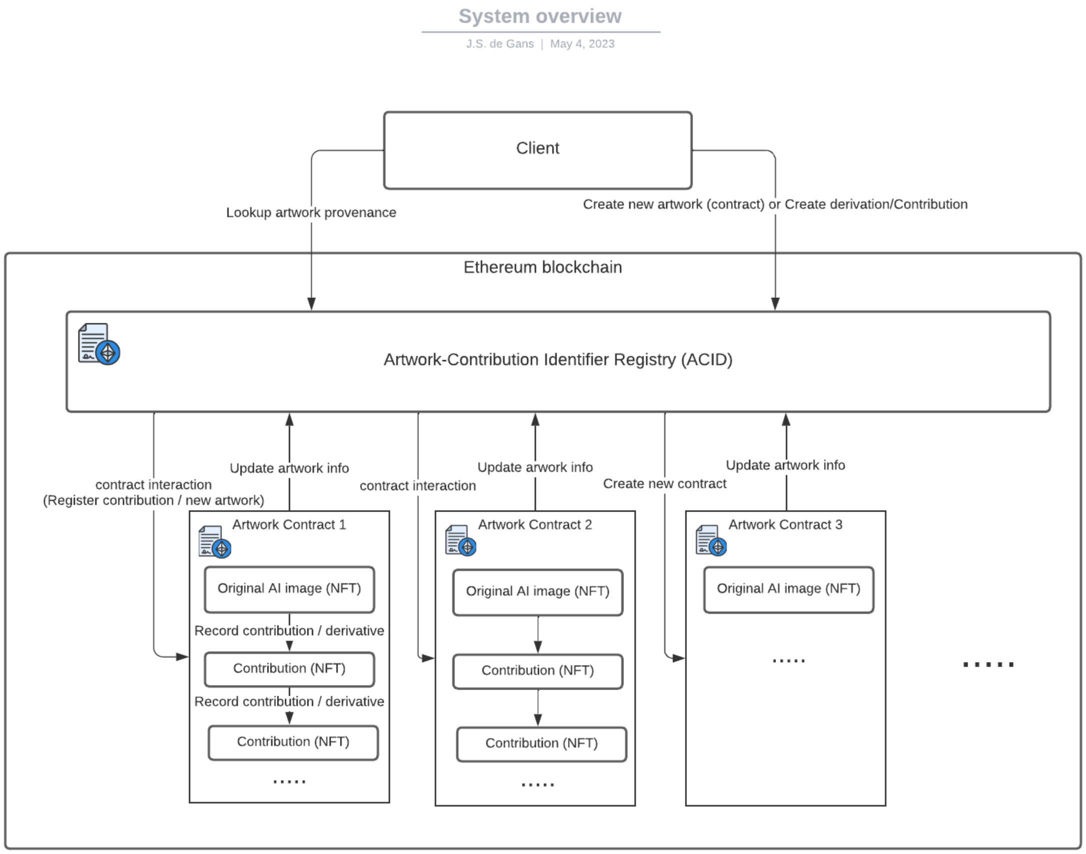


Figure 2: System overview

can then add their own creative touch and modify the artwork using the editor. Users can then add their contributions to the chain. The client will then call the method addContribution on the right artwork contract. This method pushes the modified parameters as a contribution(NFT). The two smart-contract ABIs (Application Binary Interfaces) are loaded to enable the client to have an overview of the methods on the contracts. The ABI both defines the different functions and their specifies inputs.

The client is hosted on Google Colab. Which provides a free and accessible hosting platform enabling users to interact with the system. The web3 library for Python handles the signing and building of transactions. This library enables interaction with the Ethereum network by providing functions for transaction management, signature generation and communication with the smart-contracts.

5.4.3 Smart-contract overview

The system has two main smart-contracts, the artwork contract and the ACID registry contract. The artwork contract is responsible for managing the creation and storage of the artworks. The ACID contract provides a unique way of identifying artworks and contributions by giving it a unique identifier.

For a detailed class diagram on the decentralized components structure, see figure 3.

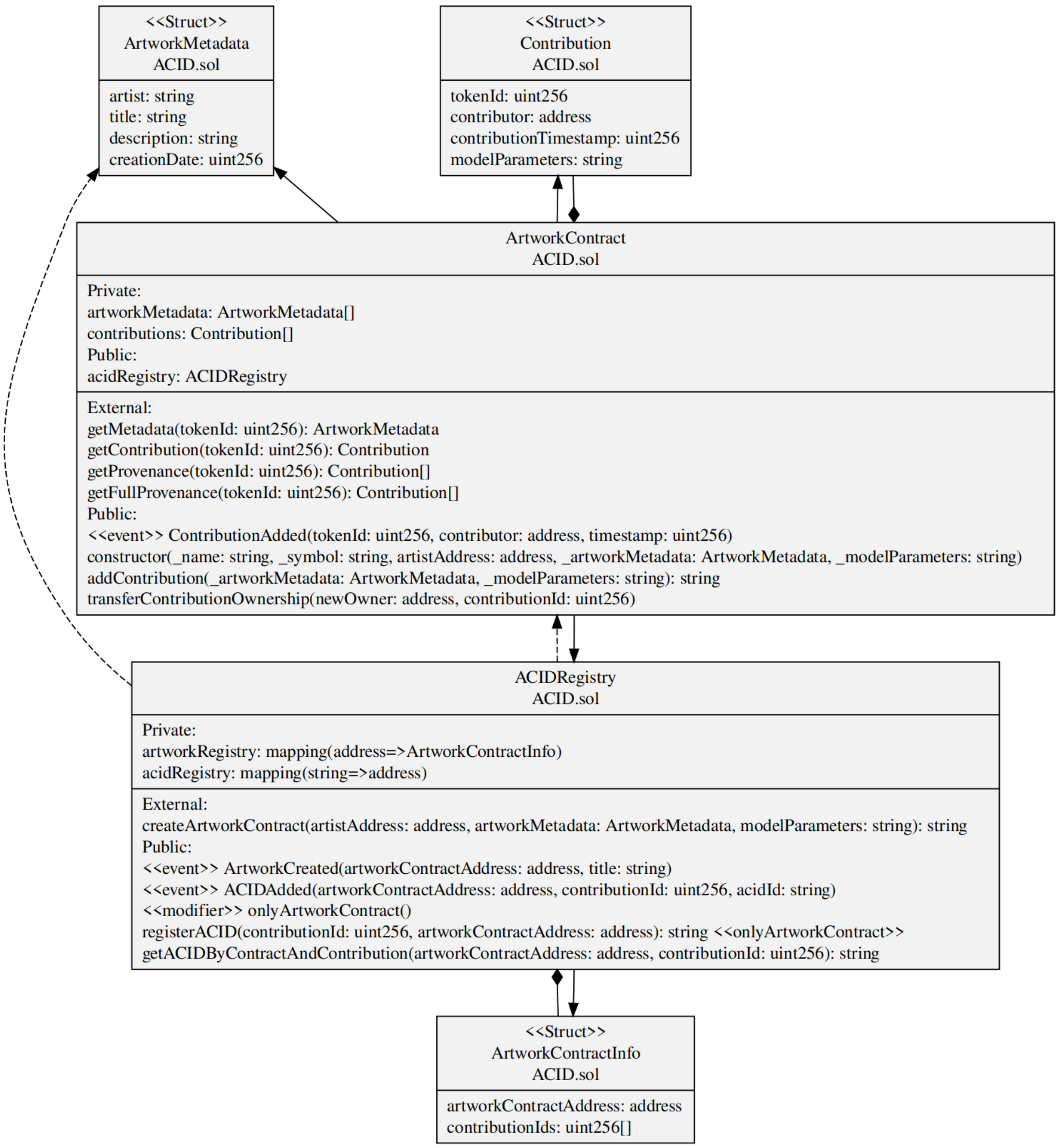


Figure 3: Class diagram showing the smart-contracts datastructures and functions

5.4.4 Smart-contract structure: Artwork Contract

The artwork contract is the heart of the proposed system. Each original artwork is represented by its own instance of the smart-contract that contains information about the artwork itself and any contributions made to it.

The constructor of the artwork takes a name and symbol as defined by the ERC721 contract standard. To initialize the artwork it also needs an artist address, initial artwork metadata and model parameters, these consist of the following:

- **Artwork metadata**: artist, title, description, creation date.
- **Stable Diffusion model parameters**: prompt, negative prompt, guidance, steps, width,

height and seed. It should also include generator version(i.e. stabilityai/v2-1_768-ema-pruned.ckpt)

- **ACID registry address**: The address of the Artwork-Contribution Identifier registry contract. This is needed to issue ACIDs for new contributions, which needs to be registered on the acid contract address

5.4.4.1 Data structures

The following data structures are used to represent an Artwork Contract:

- **Artwork Metadata array**: an array consisting of structs containing artist, title, description, creation date etc. of the original artwork as well as the contributions.
- **Contributions Array**: An array of structs that contains information about contributions made to the artwork, including the NFT token ID, contributor's address, the contribution timestamp and the Stable Diffusion model parameters. Here, index 0 would be the original artwork.
- **ACID Registry address**. To validate information requests from the ACID registry.

5.4.4.2 Functions

The following functions will be used in the artwork contract

- **Constructor** As discussed above, the constructor initializes all the metadata for the artwork, adds the genesis contribution and sets the ACID registry address.
- **getMetadata**: This function returns the metadata of the artwork, including the artist, title, description, creation date and other relevant information. Input: TokenID (contributionID)
- **getProvenance**: This function returns an array of structs that contains information about the contributions made to the artwork, including the contributor's address and the contribution timestamp. Input: TokenID (contributionID)
- **getFullProvenance**: This function returns the same information as the one above but with the full Stable Diffusion model parameters. Input: TokenID (contributionID)
- **addContribution**: This function adds a new contribution to the artwork and mints a new NFT for it. Input: Stable Diffusion model parameters, Metadata for the contribution.
- **GetContribution**: this function returns contribution for a specific token ID. Including the Stable Diffusion model parameters. Input: TokenID (contributionID)
- **transferContributionOwnership**: This function transfers ownership of one of the contributions. Only the current owner of that contribution can call this function.

5.4.4.3 Ownership

Ownership of the artwork as a whole would be determined by the collective ownership of the contribution NFTs. The contract ownership is tied to the ACID registry that created the contract, but individual contributions made to the artwork and the artwork creation as a whole are all represented by NFTs that are individually owned by their creators.

5.4.4.4 Standards and interfaces

The artwork contract uses multiple standards and interface. All the standards are provided by OpenZeppelin. OpenZeppelin provides interfaces and standards to build, automate, and operate decentralized applications. They are a big player in the Ethereum ecosystem. This contract uses ERC721, Ownable and Safemath libraries provided by OpenZeppelin.

The ERC721 token standard is the base for most NFT smart-contracts as it defines an interface of functions that need to be implemented as well as implemented functions for creating, safely transferring and managing tokens. Interoperability with marketplaces and platforms such as token explorers are ensured by implementing this interface. More about ERC721 can be found in section 4.2.2.1.1

Ownable library provides basic access control mechanisms. It provides functions that can be used to make sure that a function can only be called by the owner (using the OnlyOwner modifier) of the contract or the owner of a certain token.

SafeMath is another important library. Solidity's arithmetic operations wrap on overflow. This can result in bugs since in most high level languages, overflows would result in an error. According to OpenZeppelin's documentation: "SafeMath restores this intuition by reverting the transaction when an operation overflows."[27]. Using SafeMath has become standard practice for Ethereum smart-contracts.

5.4.5 Smart-contract structure: ACID Registry Contract

The ACID Registry Contract is responsible for managing Artwork-Contribution Identifiers (ACIDs) for each artwork and each contribution. It is designed to enable each artwork and contribution to have a unique, decentralized and permanent identifier that can be used to reference it across the network.

5.4.5.1 Data structures

The following data structures are used in the ACID registry contract:

- **Artwork Contract Info mapping**: This keeps track of all the artwork contracts, including the artwork contract addresses and an array of contribution IDs.
- **Artwork Registry mapping**: a mapping between the address of an artwork contract and its metadata stored in the artwork array.
- **ACID Registry Mapping**: a mapping between a unique ACID ID and the address of an artwork contract with a specific contribution ID.

5.4.5.2 Functions

The ACID registry contract has the following functions:

- **createArtworkContract**: This function deploys a new Artwork contract with the specified parameters.
- **registerACID**: This function is called by an Artwork contract to add a new ACID to the registry and link it to a specific contribution on that contract. It makes use of a custom modifier called

"onlyArtworkContract" which makes sure that only artwork contracts that are deployed by the acid can call this function. This function uses the strings utility library to convert the contract address to a readable string, so it can be used in the ACID creation.

- **getACIDByContractAndContribution**: This function retrieves the ACID associated with the specified Artwork contract address and contribution ID. This can be used to retrieve the ACID for the genesis contribution (0) as well as verifying the existence of the contribution and artwork contract.

5.4.6 Contract interactions

There are two types of interactions between the smart-contracts, intra-contract and inter-contract interactions. The intra-contract interactions are the interactions within a contract. For example, in the ACID registry contract inside the $registerACID()$ function it calls the $getACIDByContractAndContribution()$ function to verify that the ACID does not exist yet.

The inter-contract interactions are interactions between different contracts. An example is when a new contribution is added to the artwork contract. It will then call the $registerACID()$ function to issue an ACID for the NFT. Inter-contract interactions are a fundamental feature because it allows for a more modular setup of the on chain code. The contract interactions are illustrated by two examples. Adding a new artwork and adding a new contribution.

Example one: When an artist wants to add a new artwork to the platform, they first generate an AI artwork using a client(i.e. Stable Diffusion). The artist then uses the interface to push this new artwork and all its metadata to the ACID. The ACID contract deploys the new artwork contract and adds the genesis contribution. The ACID Registry then issues a ACID and returns this to the artist. This illustrated in figure 4

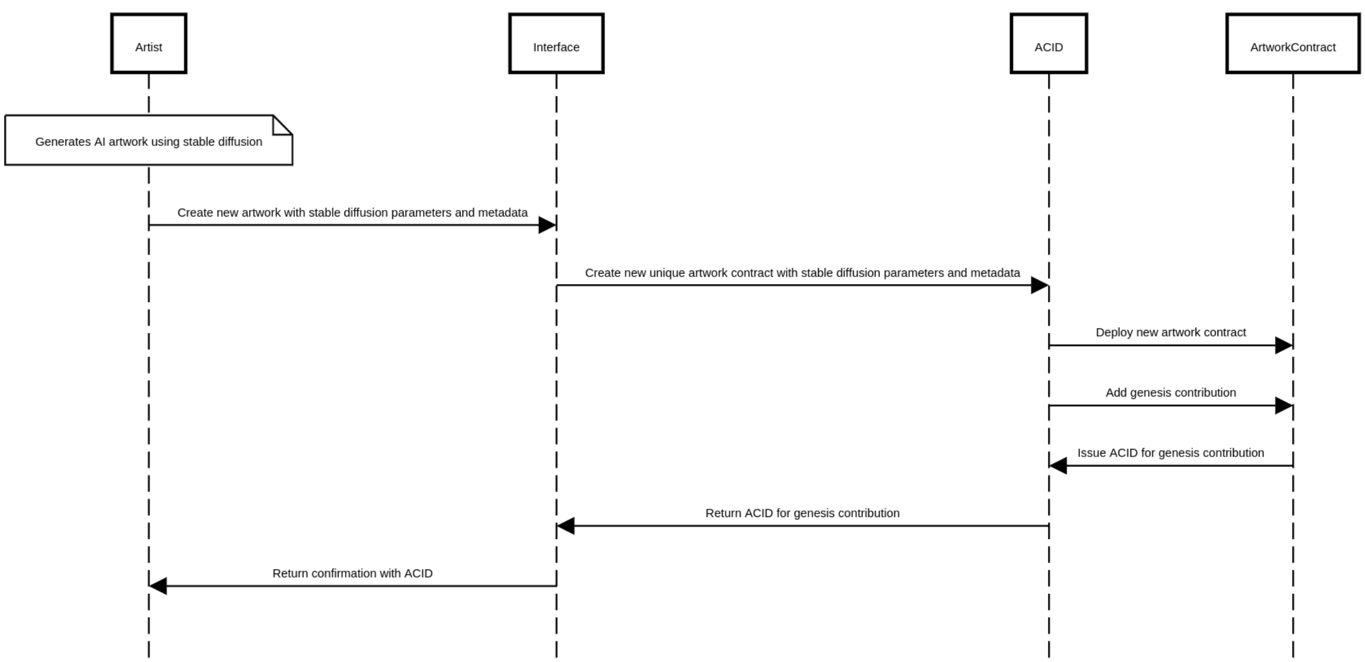


Figure 4: Process of creating a new artwork

Example two: When an artist wants to add a new contribution to an artwork, they must first retrieve the artwork from the chain using either the ACID or the contract address and the contribution of which they want to collaborate on. The artist then alters the artwork and pushes it as a new contribution to the artwork contract. The artwork contract will then issue a new ACID and return this to the artist. This is illustrated in figure 5.

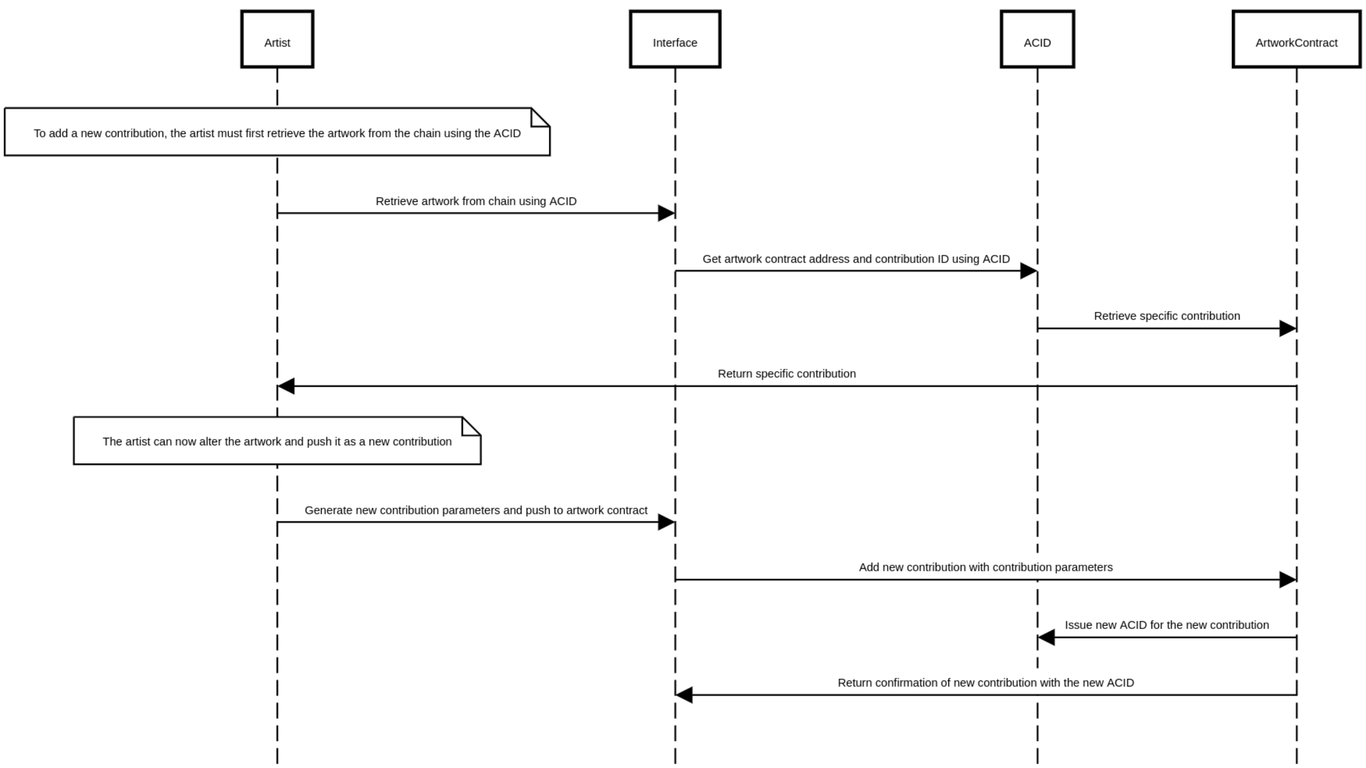


Figure 5: Process of adding a contribution

The examples demonstrate how these smart-contracts can interact with each other in a decentralized way. This modular setup not only allows for easy addition of more artworks and contributions, but also enhances security by the principle of separations of concerns. This way the system becomes more robust and reliable.

5.5 Conclusion

The proof of concept successfully explored the practicality and effectiveness of using distributed ledger technology (DLT) to enable collaboration, preserve provenance, ensure authenticity, enhance scarcity and promote community engagement in AI art. As defined in the concept overview.

The analysis of Moxie Marlinspike's Autonomous Art provided valuable insights into the way they layered contributions on top of each other, where each contribution was its own unique NFT. It also gave great insights into an alternative mode to value distribution and earning through NFTs.

The proof of concept showcases the potential of AI art collaboration. This implementation paves the way for further research and development regarding collaborative practices in AI art. See figure 6 for the interface of the collaborative mode. The proof of concept is the perfect base to demonstrate the survey participants how AI art works, how fair collaboration may take place, how the artworks and its derivations are tracked, and shows potential for monetization.

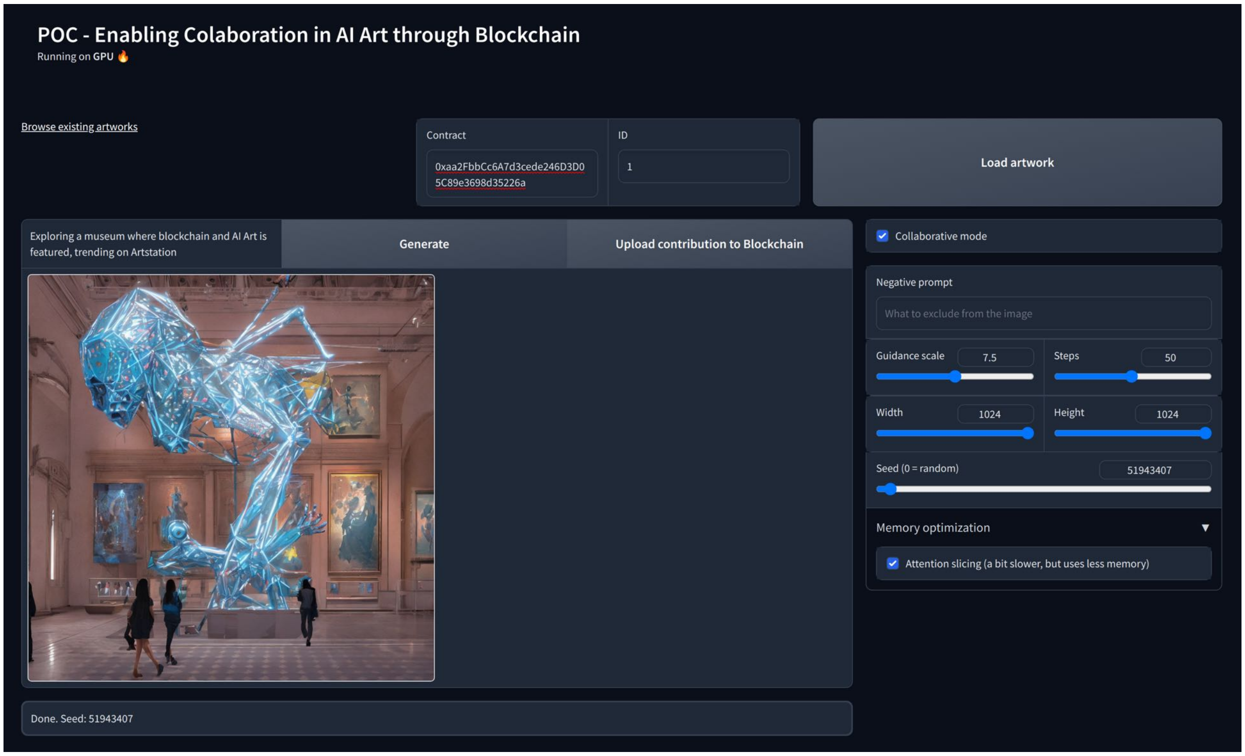


Figure 6: Interface of the proof of concept with collaborative mode enabled. Participants can browse artworks to collaborate on via: Jessedegans.com/ArtCollab

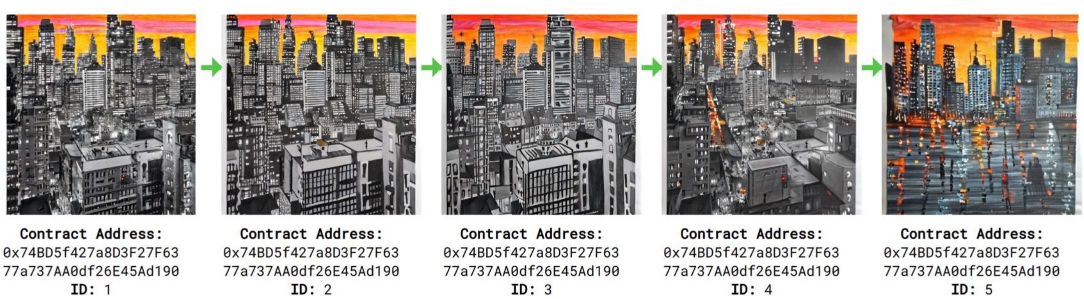


Figure 7: Jessedegans.com/ArtCollab visually shows the provenance of the creative process to participants.

6 Survey Study

The survey study aimed to gather insights and feedback on the proof of concept as well as directly addressing objective 2.2, 3.2, 4.2 and answering the overall research aim in 3.2 which focuses on exploring the use of DLT for enhancing provenance, addressing scarcity and authenticity challenges and evaluating DLTs role in fostering collaboration and community engagement in AI art.

The survey consists of a live demo of the main experiment's proof of concept and the survey related to AI art, blockchain, NFTs and evaluation of the proof of concept. Participants are first asked to make their own unique artwork. They can choose to upload the artwork to the blockchain. In the second task, participants will choose to load an artwork from the library of different artworks that are already on chain. The participant is then asked to alter this artwork, essentially contributing / collaborating on it. The artworks overview website demonstrates the connection of the different artworks and contributions, essentially showing provenance in a visual way. This interactive process served as a hand on experience that allows participants to directly explore the functionality and potential of AI art to help them in thinking about this new form of art.

The survey includes a combination of both closed-ended as open-ended questions. The following sections provide an overview of the methodology, participants and the survey design.

6.1 Methodology

The survey employed a mixed-methods approach, combining both quantitative and qualitative data collection. With 23 questions being quantitative and 2 qualitative. Using both types of data allows for a more holistic examination of the participant's responses.

6.1.1 Quantitative data collection

Participants were asked to give a rating to questions on a numerical scale or select from predefined options. Most questions were quantitative (23) which provided numerical data that can be analyzed statistically by identifying patterns trends and relationships in variables.

This was particularly useful for gathering information on participants demographics, level of familiarity with certain concepts, and their rating of various aspects related to art, blockchain, NFTs, and AI-generated art. Which gives a clear overview of the participant's overall perspectives and attitudes.

6.1.2 Qualitative data collection

Qualitative data collection allowed participants to provide detailed and descriptive responses. Two questions were designed to gather qualitative data. The questions were designed in a way that participants can express their thoughts, experiences and insights in their own words. Quotes from this can be used to further demonstrate the participant's view.

6.2 Participants

The participants of the survey were individuals who either work professionally in the field of art or are involved in higher art education. It involved a total of 19 participants contacted via various sources and contacts at art schools and professionals involved in different communities. Notably, the participant pool includes individuals of high stature, including renowned photographers.

By targeting this group, the survey study sought to capture the perspectives of people that have a deeper understanding of art through professional experiences or via art school. These participants not only have practical knowledge, but usually also are thought to apply philosophical reasoning to art and possible new forms of it.

Most of the student participants were recruited from higher education art schools in the Netherlands, such as ArtEZ and the Royal Academy of Art in The Hague. These schools are known to teach students to have a deeper understanding of art and to explore the philosophical meaning of their works.

It is interesting to see that the survey and AI art PoC attracted art professionals and students from all over the world such as Barcelona, Berlin and Melbourne. It is also important to note that this group of participants do not represent the art community as a whole.

6.3 Survey design

The questions in the survey were designed to capture insight on different aspects of the proposed system and the overall thesis. They were further refined through feedback rounds to ensure validity.

The survey was organized into several sections:

- Background: Participants were asked to provide gender, age and other background data such as their primary area of interest regarding art, how often they engage in collaborative work and their sources of inspiration.
- Provenance, Scarcity and Authenticity: Participants were asked to rate the importance of provenance, scarcity and authenticity in art when it comes to determining the value of an artwork(on a scale of from 1 not important to 5 extremely important). This section aimed to get an idea of how important participants find these factors when it comes to the art industry.
- Art, Blockchain and NFTs: Participants were asked about their familiarity with blockchain technology and their level of experience with NFTs in the context of art. They were also asked to rate the potential of blockchain-based technology to enhance provenance, authenticity and addressing the challenges in art in general.
- AI art: Participants were asked about their familiarity with AI art and the importance of provenance, scarcity and authenticity in the context of AI art. Follow-up questions were asked to better understand their perspectives and insights.
- Proof of Concept Evaluation: Participants were asked about their usage of the collaborative mode in the proof of concept and their level of understanding the system and its objectives. They were also asked to select potential benefits of the collaborative mode and saving AI art on the blockchain.
- Future Perspective: Participants were asked to rate the importance of collaboration in AI art. They were also asked to select features in an ideal platform for collaborative AI art using

blockchain-based technology. Lastly, they were asked to share their thoughts on the role of blockchain, NFTs and AI collaboration in shaping the future of the industry.

This way the survey captures the participant's experiences, perceptions and opinions related to the proposed system and the idea of AI art and blockchain. The analysis and results of the survey are included in section 7.

6.4 Data analysis

The data collected from both quantitative and qualitative sources will be analyzed separately. They will then be used together to get a comprehensive understanding of the participants responses.

The Quantitative data will be analyzed using descriptive statistics and correlations using Spearman's Rho due to the survey having many likert scale questions which provide ordinal data. Qualitative data will be analyzed using semantic analysis and thematic analysis. The semantic analysis will tell if responses are negative, neutral or positive in relation to the question. The thematic analysis will be used to find recurring themes and concepts.

Combining both quantitative and qualitative data provides a comprehensive analysis of the survey findings. This survey study aims to gather both numerical and descriptive data to provide valuable insights and identify challenges and potentials for the further development of the AI art industry, this is done by using the previously mentioned mixed-methods approach.

6.5 Limitations and challenges

When conducting the survey study, some limitations and challenges were encountered such as:

- Limited Access to Google GPU: For the live demo of the proof of concept client, a powerful GPU was needed to run Stable Diffusion. It is not possible to run the current Stable Diffusion model, without significant changes, effectively on-device as is mentioned by Chen et Al. [8]. Google Colab offered free, but limited, computational units. Exploring alternative platforms, such as Azure, incurred financial cost that were not feasible. This meant that specific timeslots needed to be scheduled with the participants.
- Participant Recruitment: Finding the right participants initially was challenging, as the correct connections weren't there. This led to approaching art students at art schools and requesting their participation. Resulting in the participation of seven students, after which the ball started rolling.
- Time commitment: Scheduling time slots for the proof of concept as well as setting up the proof of concept and survey took 30 minutes to an hour per participant. This demanded a substantial amount of time.

7 Survey results

The survey study aimed to gather valuable insights from art professionals and scholars regarding the proof of concept, as well as providing their view on AI art and blockchain.

Participants were asked to provide their demographic information, familiarity, experiences and opinions on topics such as provenance, scarcity, authenticity, collaborative work, blockchain technology, NFTs and AI-generated art.

7.1 Demographics

To get a better understanding of the participants demographics, their age ranges and gender were collected. Next to that, the survey also explored preferred areas of interest within the field of arts, as well as their engagement in collaborative work and their sources of inspiration.

7.1.1 Age and Gender

The age and gender of the participants provides valuable information which can be used to understand how different generations and genders might think about the asked questions.

Age Range	Number of Participants
18-30	16
30-45	1
45-60	2
60+	0

Figure 8: Age distribution

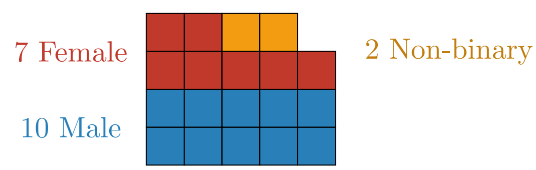


Figure 9: Gender Distribution

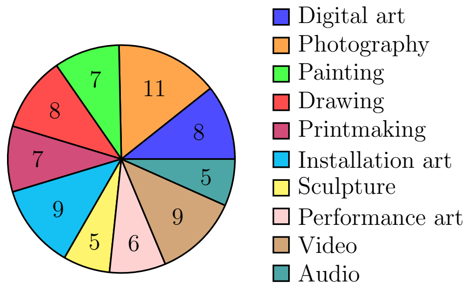
The majority of the participants fall within the age range of 18-30, 16 out of 19 which is approximately 84% of all participants. The age range 30-45 only includes 1 participant, and the age range 45-60 includes 2 participants. It is worth nothing that there are no participants above the age of 60 as seen in table 8.

When examining the gender distribution in figure 9 a gender imbalance can be observed. Although the differences are smaller. Out of the total of 19 participants, 10 identify as male, which is approximately 53% of the participants. There are 7 female participants, which account for approximately 37% of the sample. 2 participants identify themselves as non-binary, which accounts for 11% of the participants. Interestingly enough, no participants indicated that they prefer not to disclose their gender.

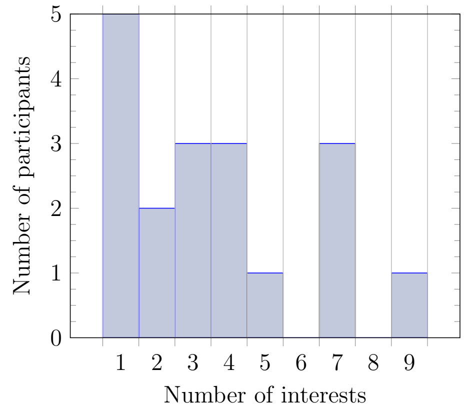
The data shows that the majority of the participants are within the 18-30 range, with males making up the largest gender group. It is important to note that these observations are specific to the sample size and does not necessarily represent the overall population.

7.1.2 Areas of interest in art

Understanding the participant's areas of interest allows us to identify the specific domain they are interested in. This might be helpful when identifying different views on the questions at hand, which may depend on the area of art they are in.



(a) Number of Participants and their preferred areas of interest in art



(b) Number of interests participants have in the field of art

Figure 10: Analysis of Participants area of interests

When looking at figure 10.a and table 1 it can be observed that the participants have the most interest in the following areas:

- Photography: This area of interest was chosen by 11 participants which is with 57.9% the highest field of interest.
- Installation art and Video: Both of these areas were selected by 9 participants, which indicates a significant level of interest.

This can be compared to the areas of interest that received the lowest amount of participants interest, such as Sculpture, audio and Performance art. These areas were chosen by 5 participants, which indicates relatively lower interest compared to others.

Another interesting overview is provided by the histogram at figure 10.b. It shows that the amount of interests in art varies among the participants. 5 of the participants only have one area of interest while others have 3, 4 or even 7 interests. Only one of the participants has 9 areas of interest.

Table 1: Participant's area of interest in art

Area of Interest	**Percentage**
Photography	57.9%
Installation art	47.4%
Video	47.4%
Digital art	42.1%
Drawing	42.1%
Painting	36.8%
Printmaking	36.8%
Performance art	31.6%
Sculpture	26.3%
Audio	26.3%

7.1.3 Collaborative work

This is asked to get a background on their experience with collaborative work. Understanding how often participants are involved helps to identify potential interest and the value participants place on collaborative approaches in the art industry.

When looking at figure 11 it is seen that most participants engaged in collaborative work before. One notable trend is that 8 out of 19 participants say they frequently collaborate with others, while 7 out of 19 do it rarely. Which still indicates that at least 15 participants collaborated in art before. This is important as it helps with evaluating the feasibility of implementing collaborative modes in AI art projects, as well as indicate possible benefits or challenges in AI collaborative art. The variation

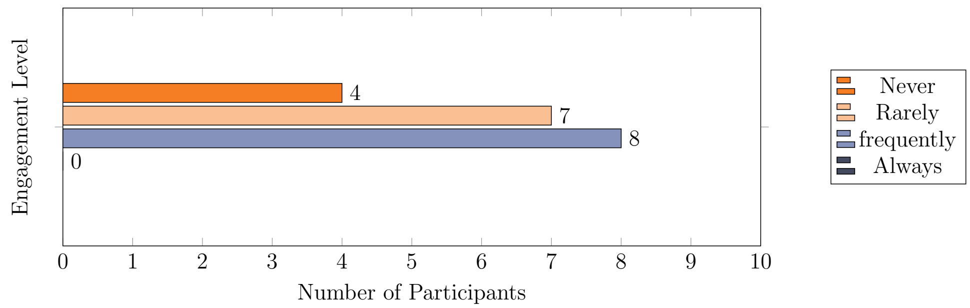


Figure 11: Engagement in Collaborative Work

in participants collaborative work experiences gives way for an opportunity to explore how AI can enhance and transform the collaborative art process.

7.1.4 Sources of inspiration

This is asked to get a better understanding of where the artist draw their inspiration from. It can also provide insights into the artist's creative process, which may relate to the way they will interact with the AI art proof of concept.

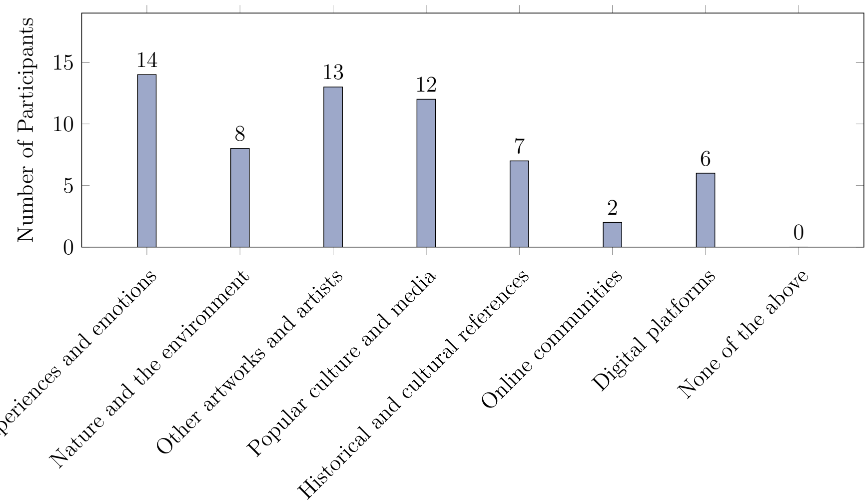


Figure 12: Participant's primary sources of inspiration

Most of the participants (73%) said that their sources of inspiration comes from personal experiences and emotions. Another notable one is seeing that 13 out of 19 participants state that they draw inspiration from other artworks and artists. Another popular one is culture and media, with 13 out of 19 participants.

Interestingly enough, all participants drew inspiration from at least one of the mentioned sources, since they didn't choose "none of the above".

7.2 Provenance, Scarcity and Authenticity in Art

This section of the survey aimed to explore participants perspectives on the influence of provenance, scarcity and authenticity on the value of art. Additionally, participants are asked to share possible challenges they see in ensuring long-term availability and integrity of digital art.

7.2.1 Importance of provenance, scarcity and authenticity in determining artwork value

In question 6 the participants were asked to evaluate what their perspectives were on the importance of provenance, scarcity and authenticity for determining the value of an artwork. Participants were asked on a scale of 1 to 5, with 1 being "Not Important" and 5 being "Extremely Important". This is relevant because the same question is asked specifically about AI art. This aligns with one of the goals which focuses on determining if there is a difference between general art and AI art in this matter and how participants think about provenance, scarcity and authenticity in general.

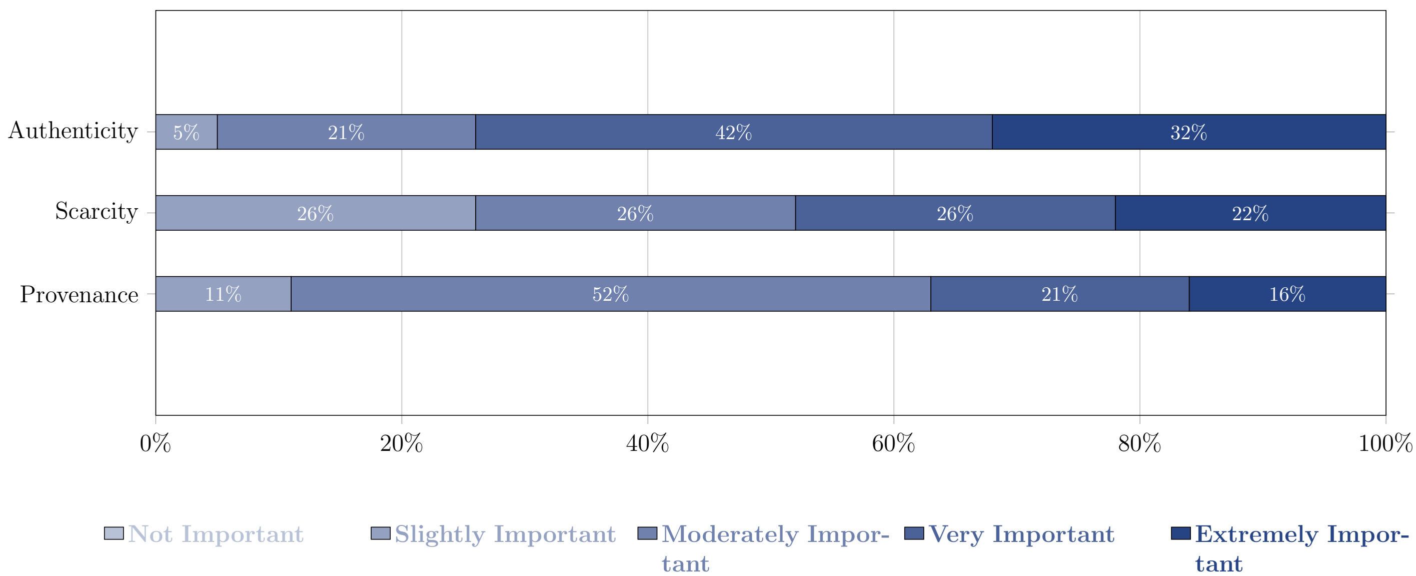


Figure 13: Importance of provenance, scarcity, and authenticity in determining artwork value

Figure 13 shows the importance of the three factors, provenance, scarcity and authenticity in terms of art value.

More than 50% of the participants found provenance moderately important. Together with the 21% and the 16% of participants that find provenance very and extremely important, that makes up for 89% of the participants. This indicates that almost all participants find provenance relevant for the determining of an artwork's value.

Scarcity has much bigger variety in answers, since there seems to be some different opinions about it. Although none of the participants found it not important, the specifics on how important are distributed in almost equal parts. It shows that the majority of the participants see the significance of scarcity in determining the value of an artwork (74%). Compared to provenance, it still shows that most participant feel that limited availability or rarity of artworks (scarcity) contribute to a higher value. This is interesting because limited availability aligns with the idea of integrating blockchain and creating NFTs.

Participants found authenticity most important in determining the value of an artwork, with almost half(42%) of the participants finding it very important and another third(32%) extremely important. In total, 74% of all participants find authenticity very to extremely important, indicating that there is a widespread recognition on the importance of tracking owner and authorship of artworks in determining its value. Only a small percentage (5%) found it slightly important.

In summary, all the participants found provenance, authenticity and scarcity important in determining an artwork's value. In general participants find authenticity most important followed up by scarcity and then provenance. This shows that the three factors are all relatively important for determining an artwork's value.

7.2.2 Top three Challenges in Ensuring the Long-Term Availability and Integrity of Digital Art

This general question aims to discover what participants find important related to long-term availability and integrity of digital art. This is asked before relating it to AI art to get an unbiased opinion. The participants were asked to select the top three challenges.

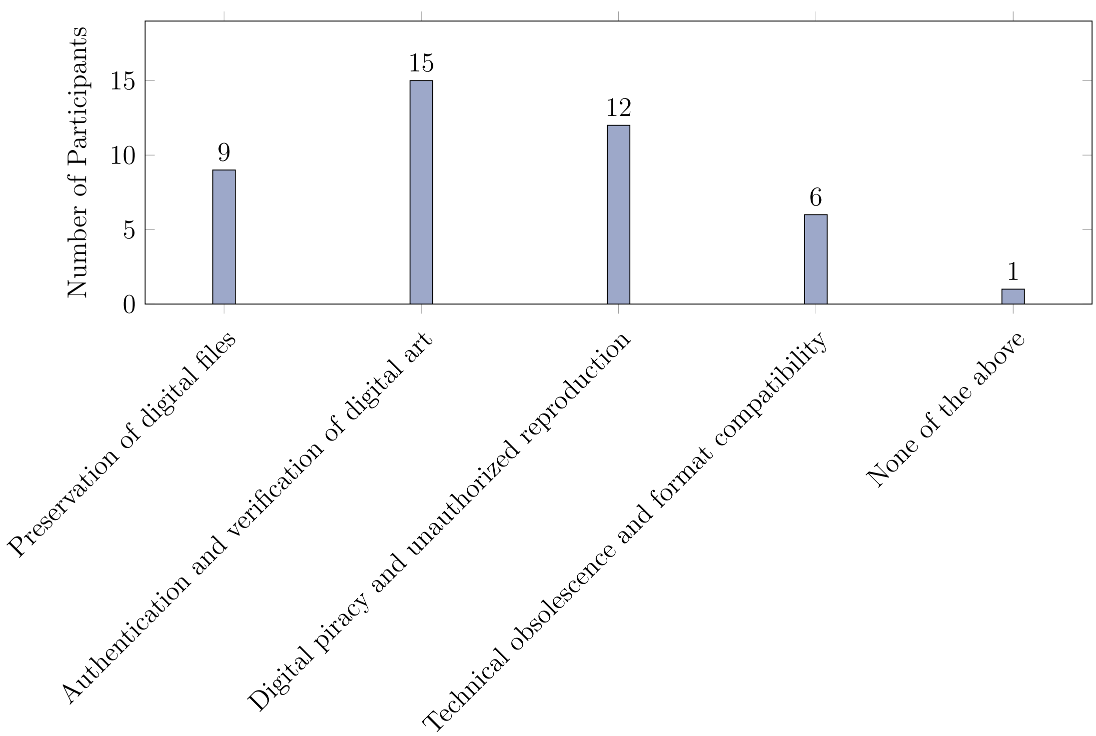


Figure 14: Top Three Challenges in Ensuring Long-Term Availability and Integrity of Digital Art

Figure 14 shows a clear picture of what participants find important. The challenge with the highest frequency was "Authentication and verification of digital art" which was chosen by 15 out of 19 participants. This reflects the significance participants place on trust and credibility in digital art.

The second most important challenge was "Digital piracy and unauthorized reproduction" with 12 out of 19 participants selecting it as the top three most important challenges. This is especially interesting as it shows the need for mechanisms to address copyright infringement and protect artist rights, which could be relevant for future work, as blockchain-based technology is a suitable solution for this.

The third most important was the challenge of "Preservation of digital files" with 9 out of 19 participants finding this important. This shows that participants are aware of the need for long-term storage solutions for maintaining the artistic value and historical significance of digital art. This is particularly interesting as current methods of storing art on the blockchain are not suited for the long-term, as mentioned in 2.2 and mentioned by Das et al. [11].

Other challenges such as "technical obsolescence and format compatibility" were selected by six participants. This indicates that participants see the problems with the fast evolving of technology and the need for compatibility.

7.3 Art, Blockchain, and NFTs

This section of the survey aimed to narrow down the participant's level of knowledge of both Blockchain and NFTs in relation to art. The last question of this section focused on evaluating if participants, in relation to their knowledge level, thought that blockchain could enhance provenance, address the challenges of scarcity, and its ability to ensure authenticity of art.

7.3.1 Level of knowledge blockchain technology in the context of the art industry

This question aimed to determine the participant's level of knowledge in relation to blockchain technology in the art industry. It is expected that the level of knowledge influences their thoughts on using blockchain technology to enhance art and AI art in general. Figure 15 shows a right skewed

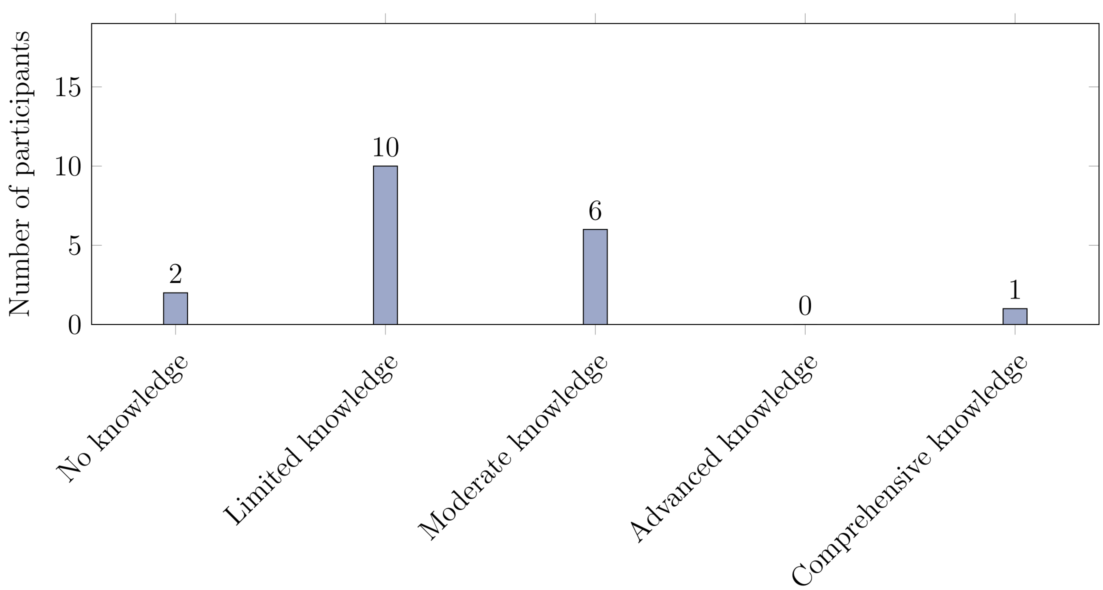


Figure 15: Level of knowledge blockchain technology in the context of the art industry

distribution. Indicating that the majority of the participants have moderate to no knowledge. Not shown in the figure 15 is the descriptions given to the different knowledge levels. Participants that chose moderate knowledge indicate that they "understand the basic concepts of blockchain technology and have some awareness of its applications in the art industry." while participants that chose limited knowledge have "a basic understanding of what blockchain technology is, but are not familiar with its specific applications in the art industry.".

53% of the participants fall under the limited knowledge category, indicating that they have heard about blockchain but never heard of its uses in the art industries. The second-largest group, 32%, indicated that they have moderate knowledge and have heard about some uses in the art industry. This is interesting, as the follow-up question about their experience with NFTs will further narrow this down. Understanding this baseline is useful for the interpretation of their opinions about the use of blockchain-based technology in enhancing provenance, authenticity and scarcity in the art industry.

7.3.2 Level of experience with Non-Fungible Tokens in the context of art

Participants were asked to indicate their level of experience with NFTs to further narrow down their specific knowledge.

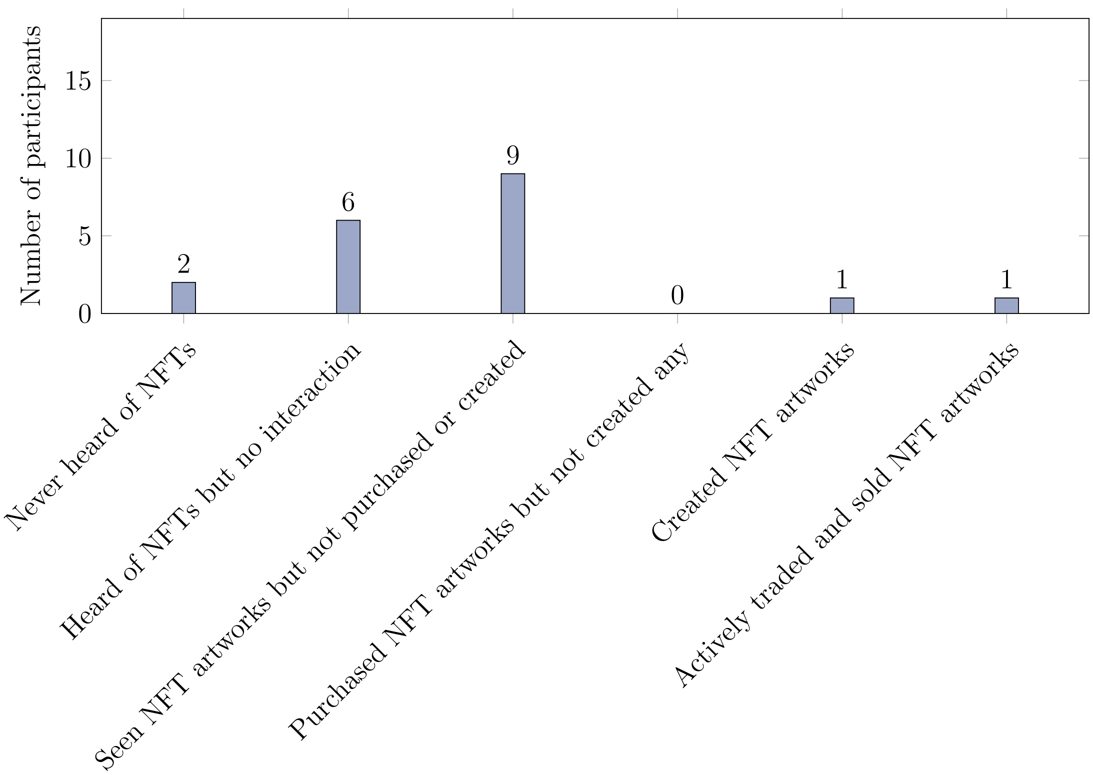


Figure 16: Level of Experience with NFTs in the Context of Art

The chart in figure 16 shows the different levels of experience.

The biggest group of the participants fall into the category of "having seen NFT artworks but not purchased or created any" (47%). The second-biggest group of participants, 32%,"have heard of NFTs but have not seen or interacted with NFT artworks". This indicates that most of the participants had some exposure to NFTs, which is most likely related to the NFT boom in 2021. Referring to the year that NFT total daily sales went from 183 thousand USD in 2020 to an average of 38 million USD in 2021 [28].

A few participants have specific experiences with NFTs, such as actively traded and sold NFTs and created NFT artworks. It is important to note that creating NFT artworks does not necessarily mean that the participant programmed their own smart-contract, as marketplaces like OpenSea offer online interfaces to upload NFT artworks. Other outliers are 2 out of 19 participants that never heard of NFTs before, and none of the participants only purchased NFTs.

In the previous question, the majority of the participants indicated having limited knowledge of blockchain technology (53%) and 32% had moderate knowledge. When compared to this question, a correlation can be observed that participants with limited knowledge of blockchain technology still have some exposure to NFTs. It shows that even without extensive knowledge of the underlying blockchain technology, some participants still interacted with NFTs.

7.3.3 Potential of blockchain technology in enhancing provenance, scarcity and authenticity in art

After evaluating the participant's knowledge level on blockchain and NFTs, they were asked to think about the potential of blockchain enhancing provenance, addressing scarcity and ensuring Authenticity.

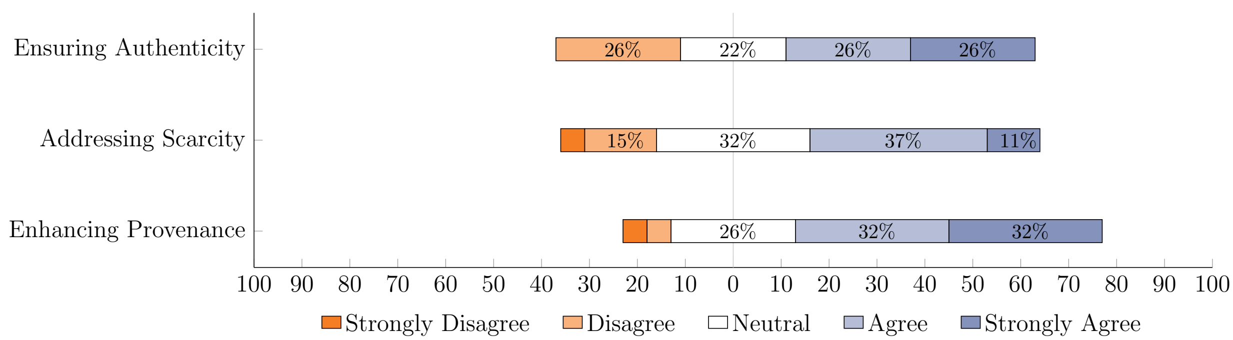


Figure 17: Potential of blockchain technology in enhancing provenance, addressing scarcity, and ensuring authenticity in art

The stacked bar chart, figure 17 gives a clear overview on where participants think the potential lies for blockchain technology.

Examining enhancing provenance shows that the majority of participants(64%) either somewhat or strongly agree that blockchain technology can enhance the provenance of art. Roughly 10% of the participants have a strong opinion that they do not believe that blockchain can enhance provenance. 26% of the participants remain neutral, which may be related to their level of experience with blockchain and NFTs.

Most participants somewhat agree that blockchain can address scarcity in art (37%) but it varies more than with enhancing provenance. There is still a total of 48% who agree but the second-biggest group remained neutral (32%) indicating that they are unsure if blockchain can address scarcity. This indecisiveness aligns with the ongoing debate of digital scarcity. This is described by Brekke at al.

“the culture around blockchains is still young, and it remains highly politicised and polarised. This polarisation contributes to the confusion surrounding digital scarcity as it relates to ideas of value” [4]

Participants beliefs regarding ensuring authenticity show that there are mixed opinions. Although none of the participants strongly disagree and more than 50% of participants agree that blockchain can ensure authenticity, a quarter of the participants disagree. This is the biggest group of participants disagreeing of all the different factors. There seems to be a more formulated opinion, as the indecisiveness is relatively small.

These observations provide a basic understanding of the participants opinions. Correlation analysis is needed to further provide insights in the relationships between the variables.

7.4 AI Art

This section aimed to measure the participant’s familiarity with AI art. After that, participants were asked to give their opinion about how important the three factors (provenance, scarcity and authenticity) are in the context of AI generated art. If participants found this moderately to extremely important, they would get a follow-up question to further delve into what ways they think blockchain can enhance these factors. If they responded with slightly important or not important, they were asked what factors they find more important than the three previously mentioned.

7.4.1 Familiarity with AI art

This question aimed to determine the level of familiarity with AI art. Together with the level of knowledge on blockchain, it might indicate an interesting correlation later on. It would also be interesting to see if there is a difference between the context of art and the context of AI art regarding the three factors (provenance, scarcity and authenticity).

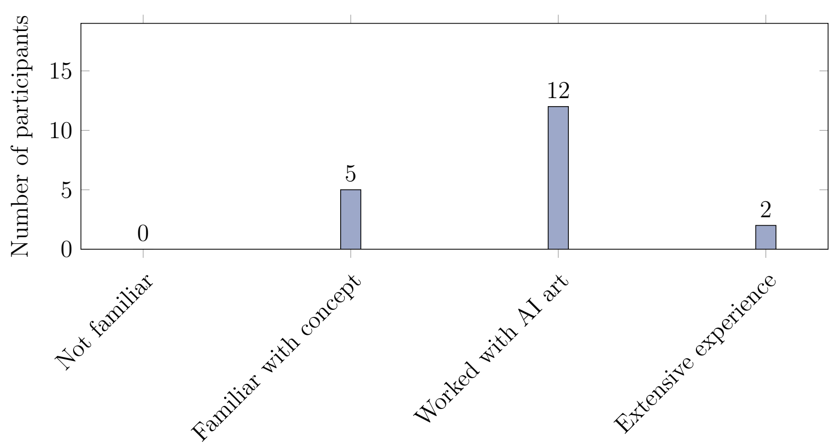


Figure 18: Familiarity with AI-generated art

Figure 18 shows how familiar participants are with AI art, from ”Never heard of AI art before today” to ”Extensive experience and expertise in creating or working with AI art.”. Most participants, 12 out of 19, worked with AI art before, which is interesting to see compared to the other familiarity questions. The mean of 2.842 indicates that on average, participants are either familiar with the concept or worked with AI art before. It is important to note that all the participants were at least familiar with the concept.

7.4.2 Importance of enhancing provenance, addressing scarcity and ensuring authenticity in AI-generated art

The aim of this question was to get the participant's opinion on the importance of the three factors on AI generated art. This question has more relevance than others, as it is an important factor of relevance in the validity of this thesis. This question is followed up by two possible follow-up questions depending on the participant's response. If the participant chooses moderately to extremely important, the follow-up question would be "In what ways do you think blockchain technology can enhance authenticity, provenance, and scarcity in the context of AI-generated art?". If participants choose not or slightly important, they were asked what other aspects they found more important in the context of generated art than the three factors.

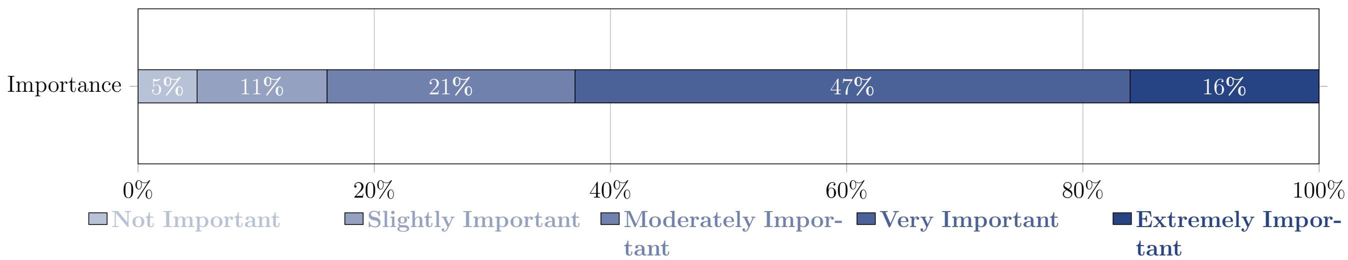


Figure 19: Importance of ensuring authenticity, provenance, and scarcity in AI-generated art

Figure 19 shows that the majority of the participants(47%) found the three factors in the context of AI art to be very important. Which, together with the 16% of the participants that found the three factors extremely important, makes up for 63% of the participants. This strong recognition shows the importance of enhancing provenance, addressing scarcity and ensuring authenticity in AI art, which aligns with the thesis.

7.4.2.1 Follow up: if not important what is more important

Participants that choose not and slightly important were asked what they considered to be more important than the three factors in context of AI generated art.

Aspect	Count
Technical innovation	0
Artistic expression	2
Emotional or aesthetic impact	1
Ethical considerations	0
Social/Cultural relevance	0

It is important to note that a total of 3 participants choose not/slightly important, which makes it difficult to draw definitive conclusions. Among the participants, 2 considered artistic expression to be more important than provenance, scarcity and authenticity. One of the participants found emotional or aesthetic impact more important.

None of the participants found technical innovation, ethical considerations and social/cultural relevance more important.

7.4.2.2 Follow up question: Ways in which blockchain can enhance AI art

Participants that choose moderately to extremely important were asked in what ways blockchain could enhance provenance, scarcity and authenticity in AI art.

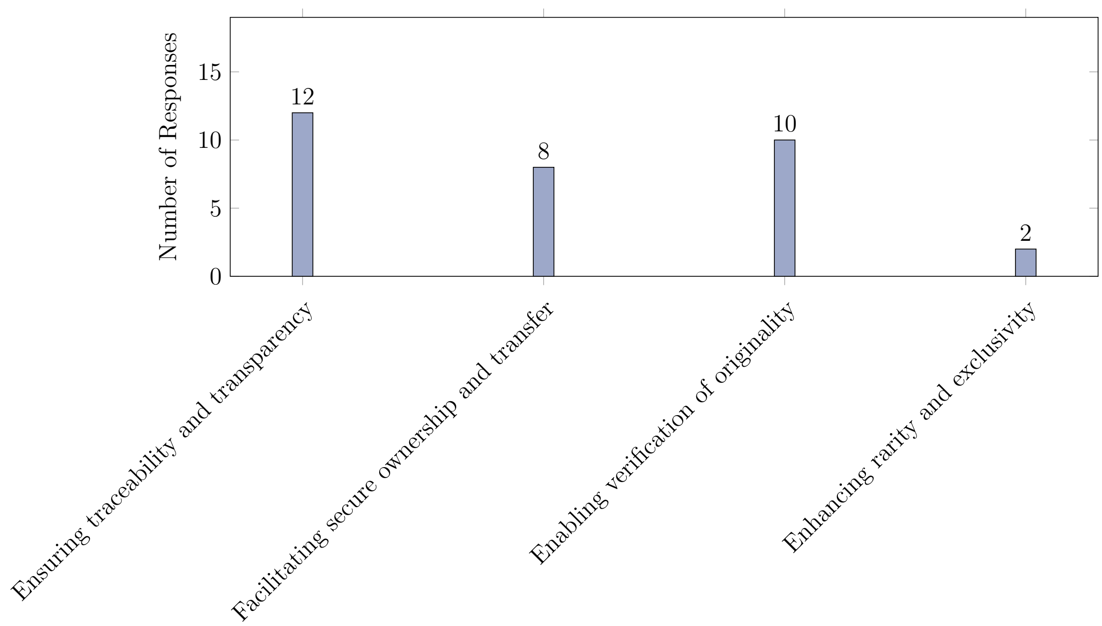


Figure 20: Ways in which blockchain-based technology can enhance provenance, scarcity and authenticity in AI-generated art

As shown in figure 20 the highest number of participants (12 out of 19) said that it would help with ensuring traceability and transparency. This indicates that participants see the potential of blockchain for tracking provenance (record of creation and ownership). The second-biggest group, 10 out of 19 participants, found that blockchain could be useful in verifying originality of AI art. This is an indication that they feel that blockchain can enhance authenticity and uniqueness, but also confirming concerns around the rapid increase of AI art essentially addressing scarcity.

8 out of 19 participants found that blockchain could facilitate secure ownership and transfer of AI art. Which paves the way for possible future research into managing ownership rights and protecting intellectual property.

Only 2 participants thought that blockchain could enhance rarity and exclusivity. This is interesting as it again feeds into the discussion of digital scarcity mentioned in 7.3.3.

7.5 Proof of concept evaluation

This section of the survey aimed to evaluate the proof of concept. As mentioned in 6, participants were first asked to interact with the proof of concept by creating both their own unique artwork and to collaborate on an AI artwork of one of the previous participants.

7.5.1 Understanding the proof of concept

The goal of this question was to assess their understanding of what they were trying to accomplish with the proof of concept. This is relevant because it shows the participant's ability to evaluate the proof of concept.

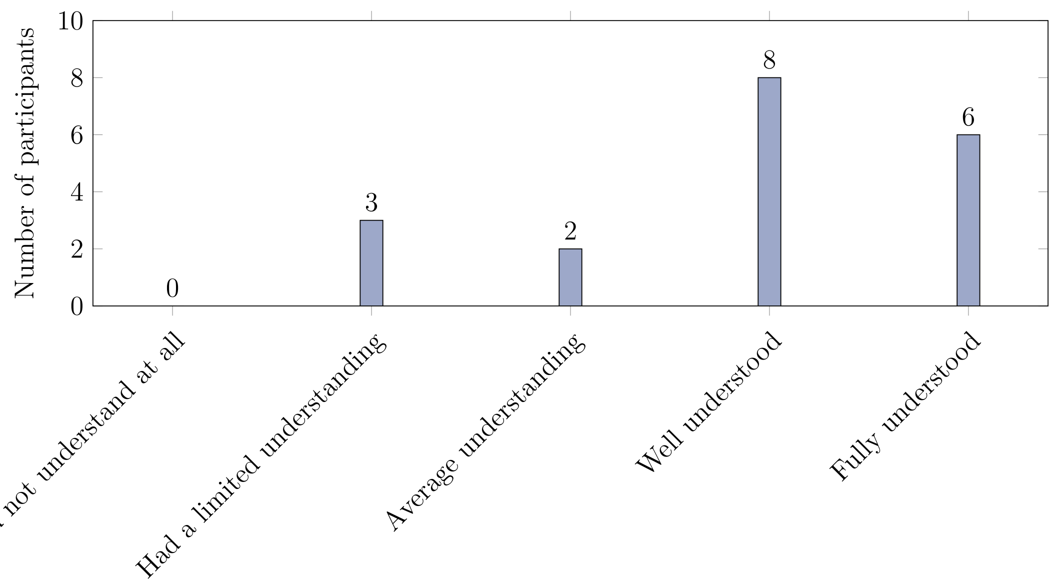


Figure 21: Understanding of the proof of concept

Figure 21 shows that most participants understood what the proof of concept was trying to accomplish. 8 out of 19 participants well understood the proof of concept (42%) and 32%, 6 out of 19, fully understood.

Only 3 out of 19 participants had a limited understanding of the proof of concept. It is good to see that approximately 85% of the participants had an average to full understanding of what they were trying to accomplish with the proof of concept.

It is important that participants understood the proof of concept and what they were trying to accomplish with it. This shows that they were able to evaluate the effectiveness of the proof of concept and their own interactions with it.

7.5.2 Benefits of the collaborative mode in the proof of concept

This question aimed to gather participants insights on the benefits they see in using the collaborative mode of the proof of concept. This is relevant because it is a big part of the proof of concept and one of the core objectives as described in 3.2.

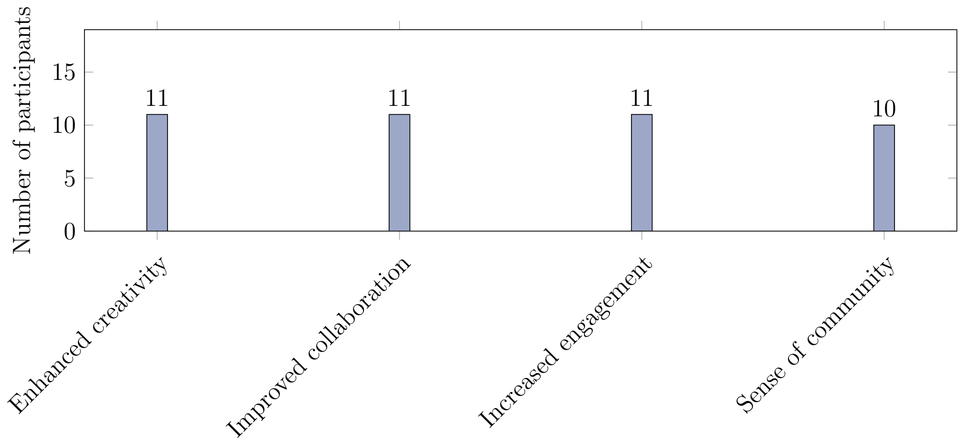


Figure 22: Benefits of the collaborative mode in the proof of concept

As seen in figure 22 participants see many benefits in the proof of concept. The majority of the participants found enhanced creativity as well as improved collaboration and increased engagement to be an advantage (all 11 out of 19). Only sense of community had 10 out of 19 participants, which is still more than half of the participants.

It is interesting to see that out of all the participants there are differences in what they find beneficial in the proof of concept, but every one of these aspects were found to be significant by more than half the participants.

7.5.3 Benefits of saving AI art on-chain

This question specifically focuses on what the benefits are for saving AI art on the blockchain. In the proof of concept, parameters of the AI artworks are saved on-chain, which also makes it possible to collaborate in the way as presented by the proof of concept.

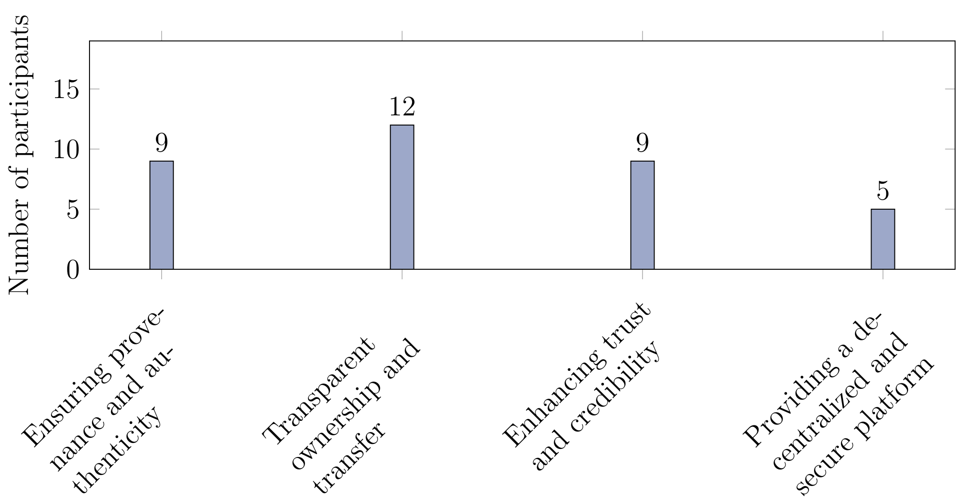


Figure 23: Key benefits of saving AI art on the blockchain

The majority of the participants 12 out of 19 found facilitating transparent ownership and transfer one of the main benefits of saving AI art on-chain as seen in 23. This is connected to the second and third-biggest benefits: ensuring provenance and authenticity (9 out of 19 participants) and enhancing trust and credibility.

These top three benefits come together as one, showing that the participants don't trust AI art and saving AI art on-chain helps in enhancing trust with decentralized ownership and authenticity. 5 participants choose to provide a decentralized and secure platform as a benefit. This is likely in relation with their specific knowledge about blockchain-based technologies and what it has to offer.

7.5.4 Insights participants gained from the collaborative process

Participants were asked to share their experiences and insights from the collaborative process. Sentiment analysis was used to uncover the participant's sentiment towards their experiences and insights. A pretrained NLP model (provided by MonkeyLearn) was used to analyze a total of 55 phrases over 14 participants that gave an extensive response to this question.

An overall overview of the sentiment can be seen in figure 24.

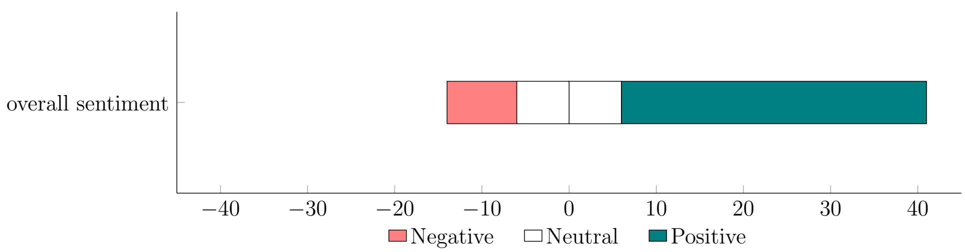


Figure 24: overall sentiment analysis of the collaborative process in the Proof of Concept

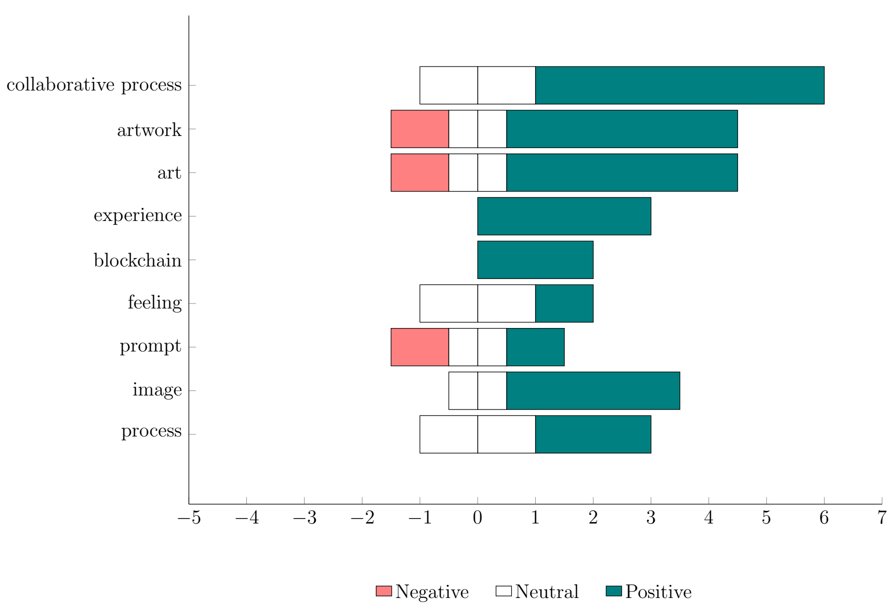


Figure 25: Topic-based Sentiment Analysis

Figure 25 shows the topic-based sentiment analysis. Collaborative process received the highest number of positive sentiments, suggesting that participants perceived the collaborative process as positive and valuable.

The Art and Artwork topics received mostly positive sentiments. These topics are related mostly to the artistic output of the proof of concept.

While the collaborative process itself and the artworks generated received mostly positive sentiments, other aspects such as prompts received a more balanced distribution. This either suggest that participants still found prompt engineering difficult or were not expecting certain prompts to result in certain images during the collaborative process.

The positive sentiments towards blockchain suggest its importance in the collaborative process.

To have a better understanding of the different thoughts of participants, here are some quoted comments highlighting their experiences and insights of the collaborative process:

Positive Experiences and Insights

- *"Playing in a collaborative way may result more interesting and rich in terms of cognitive knowledge, you will always learn something from others."*
- *"By using collaborative generation, using an image that you already resonate with or that already somewhat resembles where you want to take the image you want to create, you save on the initial 'tinkering' phase of getting an AI artwork in the right ballpark. This saves time and adds value to the discovery work others have done before you. Communal, transparent sharing of research can cause higher productivity for artists using AI software to generate content/art/etc."*
- *"What I think is most interesting, is that you can see the changes made to the AI art so it gives you an overview of what happened to it. I think that part is very interesting"*
- *"I was able to see the creative thought process of the invidual[sic] who wrote the prompt before me which can help with future creative decisions"*
- *"I have gained a more positive view towards AI-generated art. Before, I was a bit averse of it because I only associated manual creation of art with the creatively and mentally stimulating benefits and the feeling of true reward. This experience has shown me that these benefits can also be generated by creating art with AI and in a collaborative process. I don´t know if it will be as rewarding in the long-term as manually created art, but for now I have a positive impression."*
- *"Positive experience. I think the collaborative process enhanced my ability to think outside of the box."*
- *"Contrary to the keywords I had used individually, this person had written out a complete setting including camera position. I hadn't realized that this was possible (learning moment)."*

Negative Experiences and Insights

- *"In the collaborative process I did not feel a sense of community and collaboration as I would have expected. Given the physical absence of the creator of the original prompt, I did not feel like I was complementing their artwork, but that I just recycled their idea and made it my own. On the perspective of the creator of the prompt, I feel that the added input of another artist would add a lot of value to 'my' (our) artwork."*
- *"I think the concept is interesting. But I'm a little bit against AI generated art because I find it important to take up the creative process yourself. Instead of writing it in a certain way."*

7.6 Future Perspectives

This section of the survey was designed to capture the participant's future perspectives on AI art, and specifically the proposed proof of concept. It focuses on validating the idea of collaboration in AI art and ensuring provenance, authenticity and scarcity through blockchain-based technology.

7.6.1 Importance of Collaboration for the development of AI Art

In this question, participants were asked to rate the importance of collaboration in the development of AI generated art.

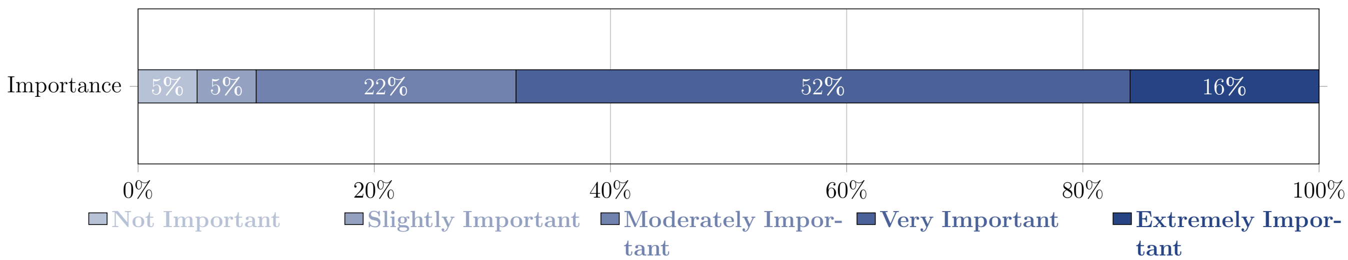


Figure 26: Importance of collaboration in the development of AI-generated art

Figure 26 shows that a significant amount of participants found collaboration important for the development of AI art. The biggest group, 52%, find it very important and 16% finds it extremely important. This underscores the importance of enabling collaboration in AI art.

Four participants (22%) are on middle ground indicating moderately importance, which shows that they do see the value but not find it the most important factor for the development of AI art.

Smaller portion of the participants found it not important(5%) and slightly important (5%) this shows the difference in perspectives among the participants.

7.6.2 Essential features of an ideal platform for collaborative AI art using blockchain-based technology

This question aimed to get the participants view on the possible future implications of using blockchain-based technology to enhance collaborative AI art.

Figure 27 shows that among the participants, 84% or 16 out of 19 find easy sharing and attribution of contributions one of the most important features. Almost all participants think that an ideal platform should facilitate sharing while giving proper recognition of individual contributions to an AI artwork, or any recognition to an AI artwork important.

79% (15 out of 19) of the participants think that secure and transparent ownership verification through NFTs would be an essential feature for an ideal blockchain-based Collaborative AI art platform.

11 out of 19(58%) of the participants choose access to a global community of artists and collaborators to be one of the essential features. This shows that participants value different perspectives that come from communities and other artists.

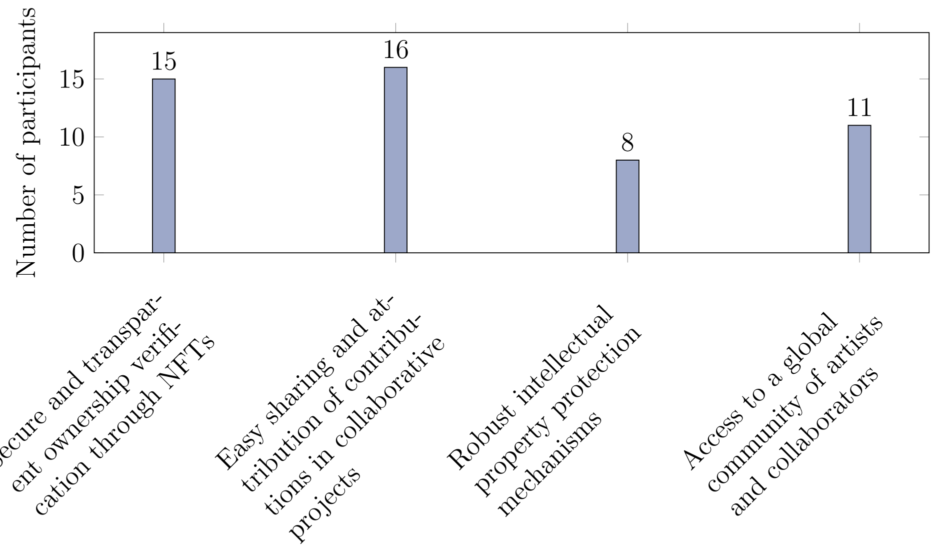


Figure 27: Essential Features in an Ideal Platform for Collaborative AI Art

The least essential feature was robust intellectual property protection, with 8 out of 19 participants (42%) choosing this. Indicating that there is a moderate level of importance of protecting intellectual property rights in collaborative AI art.

7.6.3 Primary reason for using a full-featured blockchain-based AI art editor

This hypothetical question asked participants what their primary reason would be for using a full-featured blockchain-based AI art editor.

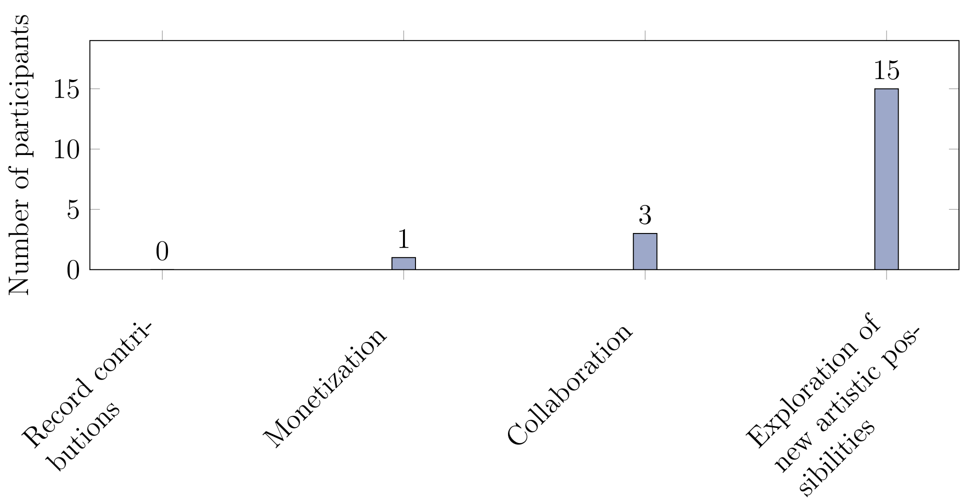


Figure 28: Primary reasons for using a full-featured blockchain-based AI art editor

Figure 28 shows a clear favorite. 15 out of 19 (79%) choose exploration of new artistic possibles as their primary reason for using a full-featured AI art editor. 3 choose collaboration and 1 choose monetization, indicating that they thought about the other possibilities that blockchain can bring to the world of AI art.

7.6.4 How do you envision the role of blockchain, NFTs and AI Art collaboration in shaping the future of the art industry?

This question focused on gathering the participant's opinion on how they envision the role of blockchain, NFTs and AI art collaboration in shaping the future of the art industry. Similar to the previous open question 7.5.4, sentiment analysis was used to uncover the participant's sentiment towards their experiences and insights. A pretrained NLP model (provided by MonkeyLearn) was used to analyze a total of 53 phrases over 14 participants that gave an extensive response to this question.

An overall overview of the sentiment can be seen in figure 29.

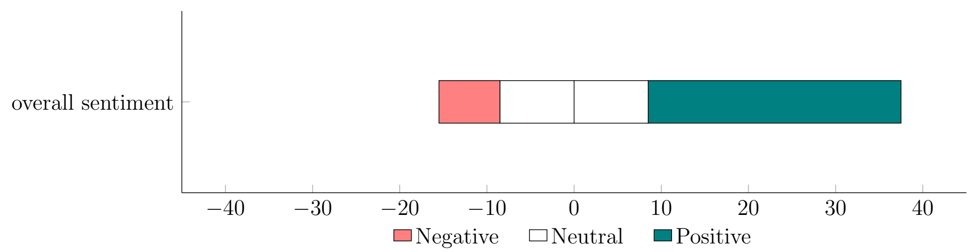


Figure 29: Overall sentiment analysis of the role of blockchain NFTs and art collaboration in shaping the future of the art industry

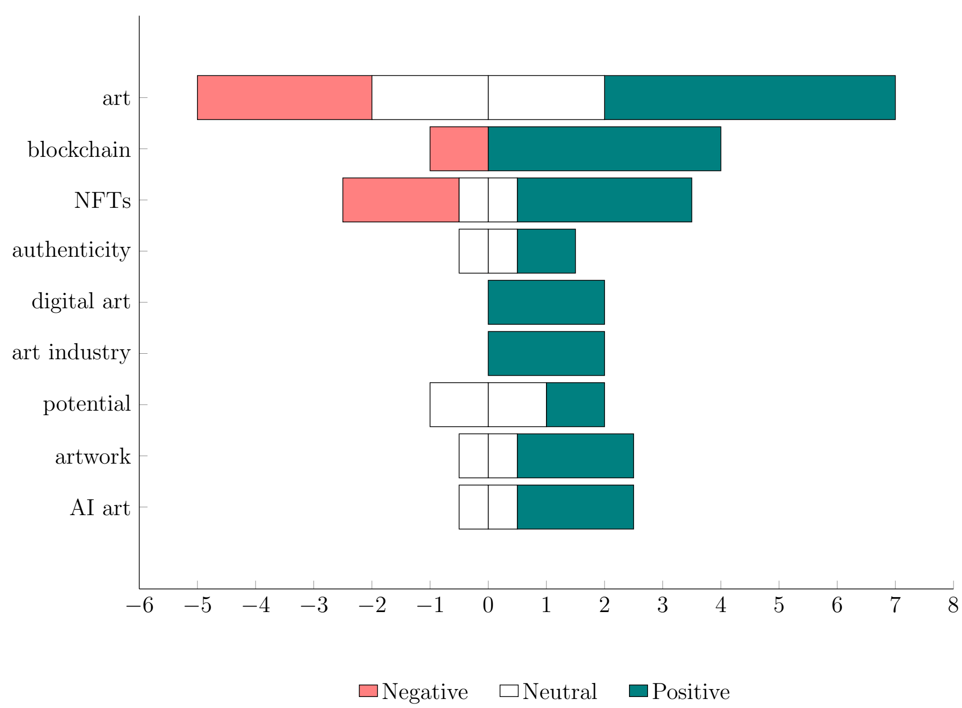


Figure 30: Topic-based Sentiment Analysis on the role of blockchain, NFTs and AI art collaboration in shaping the art industry

In Figure 30, the topics of AI art, artwork, potential, art industry and digital art receive mostly positive sentiments. Suggesting that participants associate optimism with AI art collaboration in relation to shaping the future of the art industry.

The Art and NFT topics receive a mix of different sentiments, although leaning more towards the positive. While some participants see the potential of NFTs, others expressed concerns or skepticism.

Blockchain received mostly positive sentiments, which may suggest that participants see its potential in shaping the future of the art industry.

Overall, the sentiment analysis shows a range of different sentiments indicating that participants have different viewpoints on the role of Blockchain, NFTs and AI art collaboration in shaping the art industry.

Some of the comments highlighting the perspectives of participants in the role of blockchain, NFTs and AI art in shaping the future of the art industry are:

Positive Perspectives

- *"I feel that blockchain, NFTs, and AI will be a new medium and construct that artists will be able to use, both for inspiration and to create original artworks and to collaborate. Blockchains and NFTs are a strong concept to ensure authenticity and provenance for AI created artworks."*
- *"I see it as a place where innovation can be accelerated and expand to places that are limited now."*
- *"I think collaborative generation is one of the most defining and potentially one of the most valuable features of AI art."*
- *"I think blockchain can be valuable in facilitating a system like this to ensure that everyone gets credited and potentially also rewarded for their contributions to the collective database."*
- *"I think a lot will be done in the field of monetization and distribution of art. I think the art market will get bigger thanks to the digital world, and that we will also see many new art forms, such as artists working with AR and VR."*
- *"I do not own enough knowledge on blockchain, NFTs and AI collaboration to form an opinion, but from this experience I believe these technologies will open a new path of possibilities of creation of a different kind."*

Negative Perspectives

- *"I don't think its connected with the art world as it is. Maybe it is going to be a new way to express but art is not what I would call it. Art is a process done by humans. From creative thinking to making it with your hands. With AI there is still a phase in witch[sic] you have not all the control."*

- *"I observe and acknowledge that the blockchain would also facilitate easy publishing as NFT, but personally I am yet to be truly convinced of the potential of NFTs and their use-cases so far. So this isn't a great benefit for me."*

- *"As far as I can noticed, the actual art industry is getting a massive overproduction of "artistic images" related to NFTs that has nothing to do with the appreciation of aesthethics[sic] rather than economic or capitalists interests."*

7.7 Correlation analysis

Spearman's rank correlation coefficient is used to explore possible relations between different questions and how participants answered them. It is important to note that given the small sample size (19 participants) this correlation analysis should be seen as an exploratory analysis highlighting potential relationships rather than making definitive conclusions.

Spearman's Rho can be used to find potential relationships between ordinal variables(e.g. likert scales). Following this statistic method, a null hypothesis was set. The initial correlation analysis was conducted across all ordinal variables and multiple variables were confirmed, but most p-values were too high to reject the null hypotheses.

Variable 1	**Variable 2**	**Spearman's rho (p-value)**
Provenance importance in determining artwork value — fig(13)	Engagement in collaborative work — fig(11)	0.627 (** 0.004)
Scarcity importance in determining artwork value — fig(13)	Primary use of full-featured AI Art editor — fig(28)	0.563 (* 0.012))
Authenticity importance in determining artwork value — fig(13)	Belief in blockchain enhancing provenance in art — fig(17)	-0.459 (* 0.048)
Belief in blockchain provenance enhancement — fig(17)	belief in blockchain addressing scarcity challenges — fig(17)	0.513 (* 0.025)

Significance levels: $*p \leq .05, **p \leq .01, ***p \leq .001$.

Table 2: Correlation Analysis with Spearman's Rho

Table 2 shows the potential relationships as well as their Spearman's rho value and significance. These potential relations can be described as followed:

1. Participants who engage in collaborative work frequently also place a higher importance on provenance in determining the value of an artwork. This might suggest that participants who collaborate more see the potential of the proof of concept and the importance of provenance as "collaborative" ways to give more value to their work.

2. Participants that value scarcity in artworks are seem to be more likely to explore new artistic possibilities in a full-featured AI editor.

3. The negative correlation suggests that participants that highly value authenticity in determining an artwork's value do not think that blockchain can enhance provenance. With the highest P-value, this is the least reliable correlation.

4. Participants that belief that blockchain can enhance provenance also seem to believe that it can address scarcity.

There may be relationships between the variables, but it is important to note that the correlation does not imply causation. These relations seem arbitrary and should be interpreted with caution. Especially considering the small sample size as previously mentioned. Bigger sample sizes are needed in future research to draw conclusive relations.

8 Discussion and limitations

This section delves into the discussion and limitations of the study. The findings of the preliminary study and the main experiment are analyzed, the research questions and objectives are addressed, and the implications and limitations of the results are explored and discussed.

8.1 Discussion

The purpose of this study is to explore the intersection between DLT and AI-generated art. By investigating this intersection, the study aims to uncover the transformative potential of blockchain-based technology in the context of AI-generated art, offering new perspectives and opportunities for artists, enthusiasts and researchers.

This study uses research questions, aims and objectives as further guidance. The research questions serve as the overarching inquiries. The research aims and objectives are derived from the research questions. Each research aim and objective aligns with one or more research questions and provides a focused direction.

Research Question 1: Is it feasible to store AI art parameters on-chain and regenerate the original image?

Research Aim 1: Investigate the feasibility of On-Chain Storage for AI Art parameters.

Research Objective 1.1: Develop a proof of concept to explore the practicality of storing AI art parameters on-chain.

Research Objective 1.2: Evaluate the ability to regenerate the original image from on-chain stored parameters.

Research Question 2: How can DLT be used to preserve and enhance the provenance of the creative process in AI-generated art?

Research Aim 2: Explore the use of DLT for preserving and enhancing Provenance in AI Art.

Research Objective 2.1: Develop a proof of concept that uses blockchain-based technology to capture and document the creative process of AI-generated artworks.

Research Objective 2.2: Conduct a survey to assess the contribution of including provenance information to the value and assess their acceptance and/or awareness towards blockchain-based technology enhancing provenance in AI art.

Research Question 3: What is the potential of DLT in addressing challenges related to scarcity and authenticity in AI-generated art?

Research Aim 3: Assess the potential of blockchain-based technology in addressing Scarcity and Authenticity challenges in AI Art.

Research Objective 3.1: Develop a proof of concept using blockchain-based technology to ensure originality and traceability in AI art.

Research Objective 3.2: Conduct a survey to assess the perceptions and beliefs of participants regarding the potential of blockchain to enhance scarcity and authenticity of AI art.

Research Question 4: Can DLT foster collaboration and community engagement in the field of AI art?

Research Aim 4: Evaluate the role of DLT in fostering collaboration and community engagement in AI Art.

Research Objective 4.1: Develop a proof of concept to enable collaborative AI art creation and contribution using DLT.

Research Objective 4.2: Conduct a survey to assess the impact of DLT on enabling AI art collaboration, creativity enhancement, and the sense of community in the AI art field.

8.1.1 Preliminary study

The preliminary study focused on exploring the feasibility of storing AI art parameters on the Ethereum blockchain as NFTs. The study investigated the platform gen.art, which stores generative artworks code fully on-chain but still uses IPFS to store AI art. This discrepancy raised the question of why AI art hasn't been stored on-chain before. Eventually leading to the exploration of saving AI art on-chain, building a proof of concept to evaluate its feasibility and the forming of this thesis.

By examining the underlying parameters of Stable Diffusion, such as latent vectors, model parameters and prompts, it was hypothesized that it may be possible to store the necessary information on-chain to regenerate the original AI-generated image.

The study divided the research questions and objectives into several steps in order to answer. These steps were: Investigate the feasibility of storing AI-generated images entirely on-chain, identify the essential parameters required for reconstructing the original image using Stable Diffusion, develop a technical implementation by building a smart-contract and deploying it on the Ethereum blockchain, demonstrate the ability to regenerate the AI-generated image using on-chain data and assess the benefits and challenges associated with on-chain art storage

After trying out regeneration in Stable Diffusion 2.1 it was determined that Parameters such as prompt, guidance scale, steps, width, height, seed and attention slicing were essential to allow for image regeneration.

It is important to note that the deterministic properties of the Stable Diffusion model is a key aspect for regeneration. While the model's sampler, in this case a Diffusion Probabilistic Model, is not necessarily deterministic, using a specific seed reproducibility can be ensured as it produces the same initial noise signal [21]. The model offers a wide range of additional parameters and customization options that can further refine the image generation process and possibly influence the regeneration, which has not been explored by the preliminary study

To answer Research Question 1, "Is it feasible to store AI art parameters on-chain and regenerate the original image?" and achieve Research Aim 1, "Investigate the feasibility of On-Chain Storage for AI Art parameters," several research objectives were defined.

Research Objective 1.1 involved developing a proof of concept to explore the practicality of storing AI art parameters on-chain. This objective was successfully accomplished through the implementation of the smart-contract (On Chain Art V1) based on the ERC721 token standard. Inside the contract was the OCAData object. This object represented an individual NFT and contained the necessary parameters for regenerating the AI-generated image.

Research Objective 1.2 focused on evaluating the ability to regenerate the original image from the on-chain stored parameters. This objective has been successfully accomplished by examining the underlying parameters of Stable Diffusion, such as latent vectors, model parameters and prompts and proofing that it is possible.

The proof of concept proved it was feasible by successfully storing AI-generated images as NFTs on the Ethereum blockchain. Effectively answering research question 1. Yes, it is feasible to store AI art parameters on-chain and regenerate the original image. The retrieval of parameters from the blockchain and their utilization in the Stable Diffusion environment allowed for accurate regeneration of the original AI-generated image, showcasing the potential for preserving AI art in a decentralized manner.

But several challenges were identified in the preliminary study. The scalability of the smart-contract was a significant concern. Storing all the AI-generated artworks in one smart-contract does not seem optimal, and the storage and processing requirements on the Ethereum blockchain may become more demanding. Indicating that a modular approach is needed to save AI art on-chain.

Another challenge was the possible high transaction fees, which potentially impact the affordability of on-chain storage for artists and users. Optimization of smart-contracts and the exploration of function modifiers, storage operations reduction, upgradability and modularity were proposed as strategies to mitigate these challenges.

The findings from this preliminary study, mainly the feasibility, parameters needed to regenerate an AI-generated image and the challenges, provide valuable insights and lay the groundwork for the main experiment. By building upon the preliminary study, the main experiment dives deeper using a modular technical implementation and focuses on providing provenance of the creative process and enable collaboration.

8.1.2 Main Experiment

The main experiment conducted in this study focused primarily on developing a proof of concept to explore the practicality of blockchain-based technology to enable collaboration, preserve provenance, ensure authenticity, enhance scarcity and promote community engagement in AI art.

The objectives of the experiment align with the research aims and objectives stated in the research design section 3.1:

- Use blockchain-based technology to capture and document the creative process of AI-generated artworks, thereby preserving provenance. (Research objective 2.1).
- Use blockchain-based technology to ensure originality and traceability in AI art, addressing challenges related to scarcity and authenticity. (Research objective 3.1).
- Use blockchain-based technology to enable collaborative AI art creation and contribution. (Research objective 4.1).

In the main experiment, Moxie Marlinspike's Autonomous Art was analyzed as a source of inspiration for the implementation of the proof of concept. Autonomous art enables artists/users to create and mint NFTs in collaboration through visual contribution.

This analysis provided valuable insights, it demonstrated that NFTs can present more than just images and can represent contributions to an overall artwork, for example. It also showed alternative models for generating revenue and rewarding contributors. Although Moxie used SVGs to layer each contribution on top of it, these findings contributed to the design and development of the proof of concept.

During the technical design and implementation of the proof of concept, careful consideration were made, such as the decision to use multiple smart-contracts instead of a single contract to manage all the images and their contributions. This modular setup has been a finding in the preliminary study but was also made for improved security and better separation of concerns. But the modular setup increases the cost of deployment and management of the smart-contracts. It was decided that in this stage, better security and separation of concerns weighted more than cutting transaction fees. The Artwork-Contribution Identifier Registry (ACID registry) was introduced to mitigate some of the downside by slightly reducing transaction fees. This is possible due to the ACID deploying the same highly optimized Artwork smart-contract for each new AI artwork.

Another possible solution to the gas-fee problem, and future research opportunity, would be moving the artwork and ACID registry contracts to a layer-2 decentralized network such as Polygon[4]. By leveraging layer-2 solutions, the transaction fees can be significantly reduced, which improves the scalability and cost-effectiveness of the system. Another interesting research opportunity would be

[4]https://polygon.technology

exploring the use of Zero-Knowledge roll-ups, since it provides a way to capture the entire provenance of AI-generated artworks in a single proof, without revealing the specific details of each transaction. This would provide enhanced privacy for artists and contributors while still maintaining the integrity and transparency of the creative process.

The Stable Diffusion client interface was simplified for the proof of concept, focusing on generating AI-generated artwork and enabling collaborative mode where users can modify existing artworks and add their contributions.

The system architecture consists of the artwork contracts, the ACID registry and the client. An overview of this can be seen in figure 2. Each unique artwork is represented by its own smart-contract. This contract contains information about the artwork itself and any contributions made to it. The ACID registry functions as a gateway and artwork contract deployer. Both the original AI artwork and every contribution made to it are unique NFTs with their own value and ownership. But deploying a new contract for a new AI image is more expensive in terms of transaction fees. This incentivizes collaboration, as it is cheaper for artists to build upon or enhance previously created artworks.

Future work could include changing the provenance structure of the artwork contracts. At this moment a contribution always adds to the previous but some artists may want to contribute to a specific contribution instead of the latest version of the artwork. A tree structure would make more sense. The genesis contribution is then the root of a tree, and the provenance is then shown by taking the route from root to leaf.

The implementation of the proof of concept successfully addressed the research objectives 2.1, 3.1, and 4.1:

Research Objective 2.1: Develop a proof of concept that uses blockchain-based technology to capture and document the creative process of AI-generated artworks. This objective was successfully accomplished. The artworks and its associated contributions, each containing all the information to create that specific artwork, allowed for transparent recording of the creative process. The use of NFTs ensures that each contribution is uniquely presented and traceable, the artwork contract provides a function such as $getFullProvenance()$ to support this.

Research Objective 3.1: Develop a proof of concept using blockchain-based technology to ensure originality and traceability in AI art. This objective is addressed as each contribution made to, or the creation of, an AI-generated artwork is recorded as a distinct NFT. Parameters are checked on uniqueness. The Ethereum blockchain ensures the immutability and transparency of the recorded information, accomplishing this objective and enhancing the authenticity and traceability of AI art.

However, it is worth noting that while the proof of concept perfectly addresses the traceability aspect, the originality needs further enhancement. One potential for future work is the use of ISCC codes, as previously mentioned in the preliminary study. Although they are not explored in this version of the proof of concept, ISCC codes can possibly identify content similarity and would thereby be a valuable direction for future research.

Research Objective 4.1: Develop a proof of concept to enable collaborative AI art creation and contribution using DLT. This objective is successfully accomplished with the implementation of the proof of concept. Users can collaborate effectively by adding contributions through the Stable Diffusion client. The artworks smart-contracts ensures that each contribution is recorded as a separate NFT, where each contributor has ownership/authorship of its own work while allowing for collaboration.

Overall, the proof of concept successfully demonstrated the feasibility of using blockchain-based technology to enable collaboration, preserve provenance, ensure authenticity, enhance scarcity and promoting community engagement in AI art. It provides a foundation for future exploration and development by paving the way for innovative and decentralized AI art ecosystems.

8.1.3 Survey

The survey results provide valuable insights into the perceptions of participants on the topics of AI art, Blockchain, NFTs, the three factors (Provenance, Scarcity and Authenticity), the proof of concept and the future.

The survey had a total of 19 participants, including participants from various art schools and art professionals. Most of the participants fell in the 18-30 age range, where 53% were male, 37% female and 11% non-binary. The participants had a diverse range of interests in art, with photography, installation art, and video being the most popular areas. Most participants had 2 or more interest, ranging to one having 9 areas of interest. This shows that participants are open to try new things.

8.1.3.1 Provenance, Scarcity and Authenticity

The survey results indicate a clear consensus among participants regarding the importance of provenance, scarcity, and authenticity in determining the value of artwork. Authenticity was the most important factor, with 74% of the participants finding it very to extremely important. After that provenance was found most important, 90% found provenance moderately to extremely important, 52% of that found it moderately important, followed closely by scarcity. This question directly relates to the first part of objective 2.2, to assess the contribution of including provenance information to the value of AI art. An in-depth view on these results can be found in section 7.2.1.

The participants were asked to rate the importance of enhancing provenance, addressing scarcity and ensuring authenticity in AI art, discussed in section 7.4.2. 47% of the participants found the three factors to be very important, 16% found it even extremely important. In summary, 84% of the participants find enhancing provenance, addressing scarcity and ensuring authenticity moderately to extremely important in the context of AI art.

Lastly, participants were asked to score the potential of blockchain-based technology to enhance provenance, address scarcity and ensure authenticity in art. This question directly relates to research objective 3.2, which focuses on assessing participant perceptions regarding the potential of blockchain technology to enhance scarcity and authenticity of AI art. It also relates to the second part of objective 2.2 that focuses on assessing the acceptance and/or awareness towards blockchain-based technology enhancing provenance in AI art.

Provenance had the most consensus, where roughly 77% of the participants agreed that blockchain could enhance provenance. 64% of the participants believed that blockchain could address scarcity and ensure authenticity. Scarcity had the biggest group of neutrals out of three factors. This indecisiveness aligns with the ongoing debate of digital scarcity. Explained by Brekke et al. to be caused by blockchain being young and highly polarised which contributes to the confusion surrounding digital scarcity [4]. See section 7.3.3 for a more in depth analysis.

When participants were asked in which ways blockchain could enhance AI art next to what has been surveyed, most found ensuring traceability and transparency, enabling verification of originality and facilitating secure ownership and transfer to be ways to enhance AI art through the use of blockchain-based technology. See 7.4.2.2.

These results suggest a shared understanding among participants regarding the importance of provenance, scarcity, and authenticity in art, as well as the potential of blockchain-based technology to enhance these factors. This reinforces the significance of this research and the proof of concept.

8.1.3.2 Need for long-term availability and integrity

Participants were asked to rank the top three challenges regarding the long term availability and integrity of digital art. The biggest challenge identified was Authentication and verification of digital art, followed by Digital piracy and unauthorized reproduction and preservation of digital files. This shows that participants are aware of the need for long-term availability of digital art in a safe and secure way. This is particularly interesting as current methods of storing art on the blockchain are not suited for the long-term, as mentioned in section 2.2 by Das et Al. [11].

The proposed solution takes care of the decentralized authentication and verification of digital art as well as ensure long-term availability, as the information needed to regenerate the image is saved immutably on-chain. Digital piracy and unauthorized reproduction is something that has been deemed outside the scope of the current proof of concept but identified in preliminary study as a challenge, see 4.3.2. As previously mentioned, ISCC encoding[5] can be the solution to digital piracy and unauthorized reproduction of AI and digital art and would be interesting for future research.

8.1.3.3 Proof of concept evaluation

85% of the participants had an average to full understanding of the proof of concept, showing they were able to evaluate the effectiveness of the proof of concept and their own actions. See 7.5.1.

The proof of concept evaluation directly addresses research objective 4.2, to assess the impact of DLT on enabling AI art collaboration, creativity enhancement, and the sense of community in the AI art field.

When participants were asked to identify the benefits of the collaborative mode in the proof of concept, an almost equal distribution is observed. Enhanced creativity, improved collaboration and increased engagement were favorites, with 58% of the participants finding this a benefit. Followed by sense of community chosen by 52% of the participants. An overview is given in section 7.5.2.

Participants were asked to identify the benefits of saving AI art on-chain. The most favorable benefit was transparent ownership and transfers, followed by ensuring provenance and authenticity and enhancing trust and credibility.

It is interesting that participants emphasize on transparency, provenance, and authenticity, it suggests that there may be a lack of trust or concerns about the current distribution models for AI art. This

[5]https://iscc.codes

indicates the need for more transparency and accountability in the art market, as discussed in section 7.5.3 and seen in the top three challenges for ensuring long-term availability.

Finally, participants were asked to in an open question on insights they gained from the collaborative process in section 7.5.4. A total of 55 phrases were analyzed. The overall sentiment was positive, 40 out of 55 phrases. A deeper analysis on the different topics in the phrases can be found in figure 25. Topics such as the collaborative process and the artworks generated were mostly positive, other aspects such as prompts received a more balanced sentiment distribution.

The positive and negative insights can be summarized as followed:

- The participants mentioned that collaborating with others provided an opportunity to learn from each other. This suggests that the collaborative process fosters a collective learning environment where participants can benefit from the expertise and ideas of each other.
- Participants highlighted that using the collaborative mode allowed for saving time and that they benefited from the previous work done by others. This indicates that collaborative AI art generation can accelerate the creative process and add value because they developed ideas more easily together.
- Participants appreciated the transparency in the collaborative process. Seeing what others did allowed them to understand the creative thought process of others. This sparked their inspiration for future creative decisions and expanded their understanding of the possibilities in AI art.
- Some participants valued the manual creation of art and felt that AI art did not provide the same level of personal involvement and creative satisfaction.
- In contrast to were, other participants found the collaborative process to spark their inspiration and a great learning environment. One participant felt that their contribution was recycling someone else's idea rather than complementing and adding value to the original artwork. It suggests that, in future work, more attention should be paid to creating a community sense.

The proof of concept evaluation effectively addresses research objective 4.2. Participants acknowledged the benefits of collaboration in AI art, including enhanced creativity, improved collaboration (58%) and a sense of community (52%).

Overall, these findings suggest that the integration of blockchain-based technology can enhance transparency, provenance, and authenticity in AI art. It also has the potential to address trust issues, enhance creativity, and foster a more inclusive and engaging art ecosystem. Future research and development should focus on refining the collaborative process, addressing concerns about personal involvement, and further explore the role of blockchain in supporting the distribution and preservation of AI Art.

8.1.3.4 Future perspectives

Participants were asked about their view on the future of art, and particularly about AI art and blockchains role in that. The first question asked participants to identify essential features of an ideal platform for collaborative AI art using blockchain-based technology. 84.2% or 16 out of 19 participants find easy sharing and attribution of contributions important, closely followed by 15 out of 19 participants that found secure and transparent ownership verification and access to the global community of artists and collaborators to be important. The primary reason for using a full-featured blockchain-based AI art editor is the exploration of new artistic possibilities. Further analysis and charts can be found in sections 7.6.2 and 7.6.3.

Lastly, participants were asked how they envision the role of blockchain, NFTs and AI Art collaboration in shaping the future of the art industry. The overall sentiment is positive with 38 out of 53 phrases. Sentiment topic analysis on these phrases can be found in figure 30. The Art and NFT topics receive a mix of different sentiments. NFTs received mostly positive sentiments as well but some expressed concerns or skepticism. Noteworthy that no neutrals were observed in the sentiment topic analysis of blockchain, with 4 positive and 1 negative sentiment.

The positive and negative insights can be summarized as followed:

- Participants see blockchain, NFTs, and AI art as new mediums for artists to get inspiration and spark creation and collaboration. They recognize the potential of blockchain in ensuring authenticity and provenance for AI artworks.
- Participants believe that the combination of blockchain-based technology with AI art can accelerate innovation and expand artistic possibilities beyond current limitations.
- One participant shared that they saw collaborative generation as one of the most important features for the future of AI art. It is interesting to see that they introduced their own terminology, since they are referring to the collaborative mode in the proof of concept.
- One participant highlighted that blockchain could be used to have systems that not only credit, but also reward individuals for their contributions.
- Participants seem to show skepticism towards the term NFT. This has probably to do with the bad reputation it got since the NFT boom in 2021. Referring to the year that NFT total daily sales went from 183 thousand USD in 2020 to an average of 38 million USD in 2021 [28]. Participants still don't seem to understand exactly what properties an NFT has and associate them with a polluted art market.

Overall, the participants had a positive view on the future of AI art and recognized the potential of blockchain, NFTs, and AI art collaboration to shape the art industry. They found transparency, authenticity and collaborative generation by using blockchain-based technology to be important factors. Participants see these emerging technologies as a stimulant for innovation, expanding artistic possibilities and creating a global community of artists and collaborators. However, some participants raised concerns about the personal involvement and the satisfaction of creating AI generated art. Some also showed skepticism surrounding NFTs and their role in the art market. This suggests the need for more education and clarification, so people fully understand or even embrace the transformative power of blockchain and AI art in the art industry.

8.1.4 Significance of the findings

The findings of this study have significant implications for the field of AI art and blockchain technology.

First, the research question ”Is it feasible to store AI art parameters on-chain and regenerate the original image?” which was part of the preliminary study was answered positively. The proof of concept in the preliminary study showed that it is indeed feasible to store AI art parameters on-chain and regenerate the original image. This has the potential to revolutionize the way AI art is stored and preserved by providing a decentralized and transparent approach.

Next, the study addressed the research question ”How can DLT be used to preserve and enhance the provenance of the creative process in AI-generated art?”. The main experiment showcased the ability of blockchain-based technology to capture and document the creative process of AI-generated artworks, thereby preserving provenance. Recording each contribution as a separate NFT has enabled the creative process of AI art to become transparent and traceable, enhancing the value and authenticity of AI art.

This is confirmed by 89% of the participants finding provenance important in determining the value of an artwork and 77% of the participants agreeing that blockchain could enhance provenance, as demonstrated in the main experiment.

The third research question addressed was ”What is the potential of DLT in addressing challenges related to scarcity and authenticity in AI-generated art?”. The findings indicate that blockchain-based technology has the potential to address these challenges. The proof of concept ensured originality and traceability but future work can focus even more on the originality aspect as mentioned in 8.1.2.

This is significant since authenticity was found to be one of the most important aspects of art in determining its value (very to extremely important by 74% of the participants). Figure 17 shows that 64% of the participants thought that blockchain-based technology has the potential to address scarcity and authenticity effectively.

The fourth research question was ”Can DLT foster collaboration and community engagement in the field of AI art?”. The proof of concept successfully enabled collaboration in AI art creation and contribution using blockchain-based technology. Not all participants had a sense of community, since 10 out of 19 participants stated that it was a benefit of the collaborative mode in the proof of concept. One participant even stated in the open questions that they did not feel a sense of community given the physical absence of the creator of the original prompt. But participants left many positive sentiments on the collaboration part such as: *”Communal, transparent sharing can cause higher productivity for artists”* and *”The collaborative process enhanced my ability to think outside the box.”* and even *”I think collaborative generation is one of the most defining and potentially one of the most valuable features of AI art.”*.

The significance of the findings becomes even more apparent when comparing them with other platforms in the AI art landscape. One such platform is Midjourney[6], which like Stable Diffusion provides text-to-image AI art generation. However, Midjourney’s approach to AI art differs significantly from the research findings presented in this study.

Midjourney has transformed itself into a community but primarily showcases the generated images

[6] https://midjourney.com

without providing insights into the creative process. There is no way to determine how an image was created without looking up the prompt in the Discord server, hoping that it's not created in a private conversation. An artwork is only associated with a Discord username, lacking mechanisms to protect artists work or trace the artwork's origins and creative process. It is saved centralized on the Midjourney domain hosted in the Google Cloud. The preserving of the AI art images fully rely on Midjourney being able to pay their Google Cloud bills. On top of that, Midjourney does not offer ways to collaborate other than to take someone else's image as an input.

In contrast, the research findings of this study highlight the importance of transparency and traceability in the creation of AI art. The blockchain-based technology employed in the study enables the immutable documentation of the creative process and provides a decentralized and transparent approach.

Therefore, the comparison with Midjourney emphasizes the significance of the research findings in addressing the limitations of platforms that lack transparency and fail to immutably document the creative process and thereby fail to ensure provenance, authenticity, and scarcity of AI art.

Another relevant and previously mentioned platform in the AI art space is GEN.ART, a primarily generative art focused platform and community that releases art on the Ethereum blockchain. GEN.ART does release AI art but uses the Ethereum blockchain only to control ownership as the image is saved on IPFS. This highlights the significance of the research findings in using blockchain technology not only for ownership control, but also for preserving provenance of the creative process and enabling collaboration.

Additionally, the study findings show potential for blockchain-based technology to facilitate the development of a marketplace for AI art. GEN.ART produces artificial scarcity of their generative art by saving the code on-chain as an NFT. This suggests possibilities for a market. A more transparent marketplace for AI art could be realized. One that enables artists, collectors, and enthusiasts to buy, sell and trade AI Art NFTs.

8.2 Limitations

Important insights into the use of blockchain-based technology in the context of AI art has been gathered. But it is important to acknowledge certain limitations that should be considered when interpreting these findings.

The first limitations focused on the survey. One of these limitations was the relatively small sample size. The survey had a total of 19 participants and while the participants were individuals with professional experience or involvement in higher art education, the limited number of participants may restrict the generalizability of the findings. For future research, a larger and more diverse sample could provide a broader range of perspectives and further enhance the reliability of the results.

The small sample size is in direct relation with the limitations and challenges faced while conducting the survey. As stated in section 6.5, running the demo required a powerful GPU, and the limited resources available on platforms like Google Colab hindered broader participation. Another challenge was the time commitment, every participant at-least required 30 minutes to set up the proof of concept and participate in the survey.

Another potential limitation related to the survey study is the reliance on self-reported data, which may introduce subject bias. It is worth noting that efforts were made to ensure anonymity to mitigate this limitation and let participants freely express their opinions. Future research could consider using more objective measurements such as behavioral observations.

The technical aspect of this study had some limitations as well. One of the limitations and challenges in blockchain is scalability. This applies to the main experiment, as Ethereum may face performance issues as the number of AI artworks and participants grow. Future research could investigate the use of zero-knowledge roll-ups. Although, it is worth nothing that Ethereum 2.0 increased the maximum transaction throughput from its original 15 transactions per second [3]. Ethereum plans to increase their maximum transaction throughput to over 100,000 TPS according to the currently unreleased shard blob transactions[7] (EIP-4844) [6].

A possible ethical limitation would be the need for further research into the issue of intellectual property rights in AI art. As AI art becomes more popular, questions arise about who owns the rights to these artworks. The use of blockchain technology for provenance and ownership control can help address this concern but further investigation is necessary to understand how intellectual property rights can be effectively managed and protected using a blockchain-based technology.

Lastly, time constraints imposed another limitation for this study, specifically in the depth and breadth. It was challenging to comprehensively explore the relevant aspects within the given timeframe, given that AI art and blockchain are both technologies that are rapidly involving. While the study did involve a blockchain expert, incorporating experts in different fields would have enriched the study's findings.

It is important to address these limitations and encourage future research to overcome them. Advancing our understanding of the intersection between blockchain technology and AI art.

[7] https://ethereum.org/en/roadmap/danksharding/

9 Conclusion and Future Work

This section presents the conclusions and future research directions based on the investigation of storing AI art parameters on the Ethereum blockchain and utilizing blockchain-based technology for collaboration, provenance, authenticity, scarcity, and community engagement in AI art. The findings affirm the feasibility of on-chain storage for AI art and demonstrate the transformative potential of blockchain-based solutions in the art industry. Future work furthermore outlines the areas that require further exploration including scalability improvements, digital piracy protection, content identification, community engagement strategies and the development of decentralized platforms and protocols.

9.1 Conclusion

This thesis has explored the feasibility of storing AI art parameters on the Ethereum blockchain and leveraging blockchain technology to enable collaboration, preserve provenance, ensure authenticity, enhance scarcity and promote community engagement in AI art. The research questions were answered and the objectives and aims were successfully achieved through a preliminary study, the main experiment and the survey.

The preliminary study proofed that it is feasible to store AI art parameters on-chain and regenerate the original image using Stable Diffusion, essentially laying the groundwork for the thesis. The proof of concept developed in the main experiment further validated the feasibility by successfully capturing and documenting the creative process of subsequent contributions to AI-generated artworks on the Ethereum blockchain. The implementation showcased the potential of blockchain-based technology to provide provenance, scarcity, authenticity and collaborative AI art creation.

The survey results provided valuable insights into the perceptions of participants on AI art, blockchain, NFTs and the three factors: provenance, scarcity, and authenticity. The majority of participants recognized the importance of these factors in determining the value of artwork and acknowledged the potential of blockchain technology to enhance them.

But several challenges were identified throughout the research. Such as the scalability of the Ethereum blockchain. To further mitigate these challenges, future research should explore layer-2 solutions such as Polygon, the use of Zero-Knowledge roll-ups and ISCC codes for enhanced privacy, content similarity identification and protection against digital piracy and unauthorized reproduction.

This thesis makes significant contributions to the field of AI art and blockchain. It showcases the potential for blockchain-based technology to revolutionize the way AI-generated artworks are created, shared, and valued.

It plays a crucial role in advancing the provenance of AI art. The creative process and ownership history of AI-generated artworks can be securely recorded and accessed by all stakeholders. This breakthrough ensures transparency, verifiability, and authenticity, addressing concerns regarding the origin and legitimacy of digital art.

It also shed light on the potential of blockchain in enhancing collaboration and community engagement in AI art. Artists are able to collaborate on the creation of AI-generated artworks, enabling collective creativity and shared ownership.

Lastly, this thesis showcased the role of blockchain-based technology in revolutionizing the concept of scarcity in the AI art market. Through the tokenization of AI-generated artworks as NFTs, it ensures limited availability. This introduces a novel dimension to the idea of scarcity in the digital art market, as it creates value and exclusivity for collectors and artists alike.

The closing of this thesis marks not the end, but a start to an exciting chapter, one that moves AI art into a future where decentralization becomes the cornerstone, fostering collaboration, redefining value and driving new ways of artistic expression.

9.2 Future Work

As stated in the previous section. The closing of this thesis is but a prologue. Referring to the future work needed to truly shape the AI art industry.

Addressing the scalability limitations of the Ethereum blockchain remains a priority. Further exploration of layer-2 solutions[8], such as Polygon, could significantly enhance the efficiency and throughput of blockchain transactions, making it more feasible for widespread adoption in the AI art community. Add to that the investigation of Zero-Knowledge roll-ups, which contribute to maintaining data privacy while ensuring the integrity and security of AI-generated artwork. Provenance can then still be proven by the use of a Merkle tree.

Other future work worth exploring is implementing International Standard Content Codes (ISCC). These unique identifiers make it possible to protect against unauthorized reproduction and digital piracy. This would safeguard the rights and interests of artists and collectors, which ensures confidence in the authenticity and exclusivity of AI art.

The last exciting opportunity for future research is exploring methods for enhancing community engagement, collaboration, and commercialization of AI art within a unified platform. Designing decentralized platforms and protocols that enable artists to collectively create and sell AI-generated artworks in a transparent, inclusive and economically sustainable manner could create a complete new market. Add to that the idea of a Decentralized Autonomous Organization(DAO) and you have a community that enables for shared decision-making, fair distribution of profits and one that empowers artists and stakeholders.

The potential for future work in the field of AI art and blockchain-based technology is vast. By continuing to push the boundaries of technological advancements and interdisciplinary collaborations, we can unlock new possibilities and shape the future of AI art in a decentralized world

[8]https://ethereum.org/en/layer-2/

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A Smart-Contracts

A.1 Artwork/Contribution ID Registry

```
contract ACIDRegistry {
    struct ArtworkContractInfo {
        address artworkContractAddress;
        uint256[] contributionIds;
    }

    mapping(address => ArtworkContractInfo) private artworkRegistry;
    mapping(string => address) private acidRegistry;

    event ArtworkCreated(address indexed artworkContractAddress, string title);
    event ACIDAdded(address indexed artworkContractAddress, uint256 indexed contributionId, string indexed acidId);

    modifier onlyArtworkContract() {
        require(artworkRegistry[msg.sender].artworkContractAddress != address(0), "Only artwork contracts can call this function");
        _;
    }

    function createArtworkContract(
        address artistAddress,
        ArtworkMetadata calldata artworkMetadata,
        string calldata modelParameters
    ) external returns (string memory) {
        ArtworkContract artwork = new ArtworkContract(
            "ArtCollab", // name same for all artworks
            "ARTC", // symbol same for all artworks
            artistAddress,
            artworkMetadata,
            modelParameters
        );
        ArtworkContractInfo memory artworkInfo = ArtworkContractInfo(address(artwork), new uint256[](1)); // create artwork info
        artworkRegistry[address(artwork)] = artworkInfo; // add artwork to registry

        // Generate a new unique ACID ID
        string memory newACID = string.concat("acid:", Strings.toHexString(uint256(uint160(address(artwork))), 20), ":1");

        // Add the new ACID ID to the registry
        acidRegistry[newACID] = address(artwork);
        // emit events
        emit ArtworkCreated(address(artwork), artworkMetadata.title);
        emit ACIDAdded(address(artwork), 1, newACID);

        return newACID;
    }

```

```
    function registerACID(uint256 contributionId, address artworkContractAddress) public onlyArtworkContract returns (string memory){
        // Check if the contribution has already been registered and if the contract address exists
        string memory acidId = getACIDByContractAndContribution(artworkContractAddress, contributionId);
        require(bytes(acidId).length == 0, "Contribution already registered");

        // Generate a new unique AC-ID
        string memory newACID = string.concat("acid:", Strings.toHexString(uint256(uint160(artworkContractAddress)), 20), ":", Strings.toString(contributionId));

        // Add the new AC-ID to the registry
        acidRegistry[newACID] = artworkContractAddress;

        // Add the contribution to the artwork's contributionIds array
        artworkRegistry[artworkContractAddress].contributionIds.push(contributionId);

        emit ACIDAdded(artworkContractAddress, contributionId, newACID);

        return newACID;
    }

    //can be used to validate AC-ID
    function getACIDByContractAndContribution(address artworkContractAddress, uint256 contributionId) public view returns (string memory) {
        ArtworkContractInfo storage artworkInfo = artworkRegistry[artworkContractAddress];
        require(artworkInfo.artworkContractAddress != address(0), "Artwork contract does not exist");

        string memory acidId = string.concat("acid:", Strings.toHexString(uint256(uint160(artworkContractAddress)), 20), ":", Strings.toString(contributionId));
        // Check if the contribution ID exists in the artwork's contributionIds array
        uint256 contributionIndex = contributionId - 1;
        if (contributionIndex >= artworkInfo.contributionIds.length) {
             return "";  // Contribution ID does not exist in the artwork's contributionIds array
        }

        // Check if the ACID ID exists in the registry
        address registeredContractAddress = acidRegistry[acidId];
        if (registeredContractAddress == artworkContractAddress) {
             return acidId;
        }
        return "";
    }
}
```

A.2 Artwork Contract

```
contract ArtworkContract is ERC721, Ownable {
    using SafeMath for uint256;

    struct Contribution {
        uint256 tokenId;
        address contributor;
        uint256 contributionTimestamp;
        string modelParameters;
    }


    // Array of ArtworkMetadata structs, including contributions
    ArtworkMetadata[] private artworkMetadata;

    // Array of Contribution structs
    Contribution[] private contributions;

    // ACID registry address
    ACIDRegistry public acidRegistry;

    // Event for when a new contribution is added
    event ContributionAdded(uint256 tokenId, address contributor, uint256
        timestamp);

    //Constructor inits the ERC721 contract and creates the first contribution
    constructor(
        string memory _name,
        string memory _symbol,
        address artistAddress,
        ArtworkMetadata memory _artworkMetadata,
        string memory _modelParameters
    )  ERC721(_name, _symbol) {
        acidRegistry = ACIDRegistry(msg.sender); //create ACID registry object

        // Add artwork metadata to array
        artworkMetadata.push(_artworkMetadata);

        // Create a new contribution struct
        Contribution memory newContribution = Contribution({
            tokenId: 1,
            contributor: artistAddress,
            contributionTimestamp: block.timestamp,
            modelParameters: _modelParameters
        });

        // Add the new contribution to the contributions array
        contributions.push(newContribution);
        // Mint NFT for contribution we use artistAddress since the msg.sender
            would be the deployer aka the ACID registry
        _safeMint(artistAddress, 1);

    }
```

```
    function addContribution(
        ArtworkMetadata memory _artworkMetadata,
        string memory _modelParameters
    ) public  returns (string memory){
        require(bytes(_artworkMetadata.artist).length > 0, "Artist name must not be empty.");
        require(bytes(_artworkMetadata.title).length > 0, "Title must not be empty.");
        require(bytes(_artworkMetadata.description).length > 0, "Description must not be empty.");
        require(_artworkMetadata.creationDate > 0, "Creation date must be specified.");
        require(bytes(_modelParameters).length > 0, "Model parameters must not be empty.");
        // Add artwork metadata to array
        artworkMetadata.push(_artworkMetadata);

        // Create a new contribution struct
        Contribution memory newContribution = Contribution({
            tokenId: contributions.length+1, //+1 because otherwise token already minted
            contributor: msg.sender,
            contributionTimestamp: block.timestamp,
            modelParameters: _modelParameters
        });

        // Add the new contribution to the contributions array
        contributions.push(newContribution);

        // Mint a new NFT for the contribution
        _safeMint(msg.sender, newContribution.tokenId);

        // Emit an event to indicate that a new contribution has been added
        emit ContributionAdded(newContribution.tokenId, msg.sender, block.timestamp);
        return acidRegistry.registerACID(newContribution.tokenId, address(this)); // Register the contribution in the ACID registry
    }

    // Function to get artwork metadata for a specific contribution
    function getMetadata(uint256 tokenId) external view returns (ArtworkMetadata memory) {
        require(_exists(tokenId), "Token ID does not exist");
        return artworkMetadata[tokenId-1];
    }

    function getContribution(uint256 tokenId) external view returns (Contribution memory) {
        require(_exists(tokenId), "Token ID does not exist");
        return contributions[tokenId-1];
    }

    // Transfer ownership of a contribution
```

```
    function transferContributionOwnership(address newOwner, uint256 contributionId) public {
        require(_exists(contributionId), "Contribution ID does not exist");
        address currentOwner = ownerOf(contributionId);
        require(msg.sender == currentOwner, "Only the current owner can transfer ownership");
        _transfer(currentOwner, newOwner, contributionId);
    }
    //returns the provenance and shows what contributions were made to the artwork before a specific contribution, leaving out the actual model parameters
    function getProvenance(uint256 tokenId) external view returns (Contribution[] memory) {
        Contribution[] memory provenance = new Contribution[](tokenId);

        for (uint256 i = 0; i < tokenId; i++) {
            Contribution memory contribution = contributions[i];
            //remove modelparameters, there is no null in solidity so we set it to empty
            contribution.modelParameters = "";
            provenance[i] = contribution;
        }

        return provenance;
    }
    //returns the provenance so the process of the changing artwork can be seen
    function getFullProvenance(uint256 tokenId) external view returns (Contribution[] memory) {
        Contribution[] memory provenance = new Contribution[](tokenId);

        for (uint256 i = 0; i < tokenId; i++) {
            provenance[i] = contributions[i];
        }
        return provenance;
    }

}
```

A.3 Shared struct

```
struct ArtworkMetadata {
    string artist;
    string title;
    string description;
    uint256 creationDate;
}
```