Cooper Union NFT Marketplace

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Table of Contents

Abstract

With the rapid advancement of technology in the past few decades, art has carved out a significant market for itself in the digital realm. As digital currencies and cryptocurrencies have come into existence using blockchains, engineers have merged these technologies and produced the idea of a non-fungible token (NFT). In essence, artwork can now be uniquely minted with a set of contract rules, and ownership can be verified in a novel, decentralized manner. Our motives as engineers at The Cooper Union are to apply these concepts and create a Cooper Union NFT marketplace, so that students can be introduced to their respective markets at a low risk, while benefiting the institution as a whole and body that it contains.

Our primary goal is to develop an NFT marketplace based on Ethereum smart contracts that follows the ERC-1155 token standard, similar to marketplaces such as Foundation or Mintable. The marketplace would restrict minting to Cooper Union students alone and would be driven by the Cooper Union name brand. This proof-of-concept would display the possibilities of applying an NFT marketplace to an academic institution and would initiate conversations within Cooper Union on its development.

Introduction

The art market is an incredibly difficult industry for recent art graduates to earn a living in. A national study on the lives of art graduates and working artists reported that “out of 2 million art graduates nationally, only 10 percent, or 200,000 people, make their primary earnings as working artists” [1]. Therefore, according to this study, a majority of art graduates are required to work in non-art fields in order to pay bills. One of the primary reasons for this disparity is the reliance of an artist’s success on their reputation, which an artist would grow by displaying their works in a market, show, or museum. However, relying on these methods of exposure often leads to burnout and sub-par work, since artists must rush and struggle to work around these venues’ schedules.

An additional barrier to success in the art market is its informality and lack of transparency. Most agreements and transactions between an artist and an art curator, as well as between an artist and a buyer, are handshake deals without written agreements. This adds an element of trust to all interactions, which can lead to price-gouging or worse. Issues such as “clarity of pricing, terms of purchases, condition and its impact on the value of the artwork, consumer claims, provenance, market manipulation, history of the piece in question, certificates of authenticity, etc” can arise, which are difficult to solve given the manner in which the transactions were made. [2]

Given the circumstances described above, building a reputation early is extremely important for all aspiring artists. However, in order to do so while still in school, students would need to produce artwork to meet fair and museum schedules while also completing their regular coursework. This overload of work is not sustainable for most full-time students and can lead to

negative consequences, including burnout. Yet, if students wait until graduation to begin entering the industry, they will likely have a period of minimal income, as they create art and wait for sales to increase. Lack of income combined with a possible debt from student loans can form a massive barrier of entry for recent graduates. Therefore, a solution is needed that would allow students to begin exposing themselves to the industry on their schedule, while also fulfilling their own responsibilities and coursework.

One such solution is a digital NFT marketplace, which allows artists to create unique digital artworks and sell them online. However, while students could list on such marketplaces, their art would be hidden amongst thousands of more well-known digital artists. For this reason, we wish to create a Cooper Union NFT marketplace with the sole purpose of giving Cooper Union artists a platform on which their art can be seen and purchased.

Background

Before the specifics of our implementation can be discussed, the idea of smart contracts, beginning with blockchains, must be introduced. Unlike traditional databases, which are centralized, usually tabular, and mutable, blockchains are decentralized, composed of ‘blocks’, and immutable. These characteristics, as well as specifics of its implementation, are what make blockchains extremely useful in many industries.

A blockchain, as the name suggests, is composed of a growing list of blocks. Each of these blocks contains a batch of hashed and encoded transactions, as well as a cryptographic hash, identifying the block. The cryptographic hash, or digital signature, is created by hashing the previous block’s hash, the root of the block data’s Merkle tree, and the block’s nonce that was generated by the miner. The data within each block is contained in a structure called a Merkle tree or a hash tree. In a Merkle tree, the leaf nodes are hashes of data, while all other nodes are hashes of its children. Therefore, altering any data contained in the block will invalidate the corresponding Merkle tree leaf node, as well as all nodes above it. This will, in turn, invalidate the root of the Merkle tree, the block’s digital signature, and the hash of all blocks following. Due to this property, blockchains are considered secure against modifications. [3][4][5]

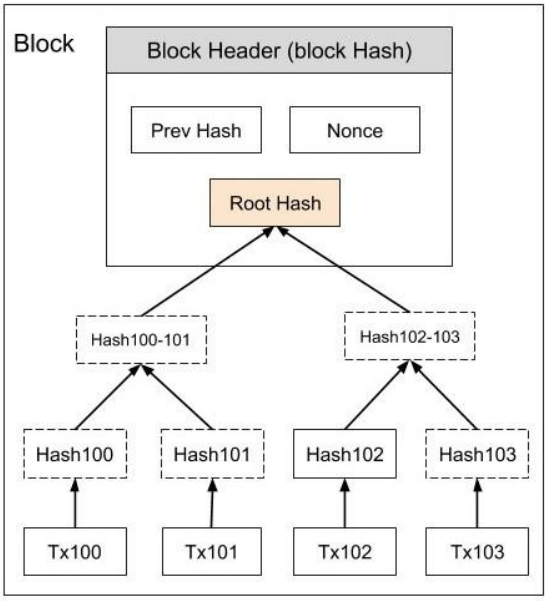

Image 1: Block and Merkle Tree

In order for a transaction to be added to a blockchain, it must be validated by a majority of nodes, or computers, in the network. Each user in the network has a public key, an address that functions similar to an email, and a private key, which functions similar to a password. When a transaction occurs, it is authenticated, or signed, by the required private keys and broadcasted onto the network of nodes. Miners, or nodes on the network, will receive transactions, verify the private keys contained within, and decide whether to add it to their next block. This decision is based on the transaction fees; transaction fees are included in each transaction as a reward to the miner, incentivizing them to add a given transaction to their newest block. The average fee price fluctuates with supply and demand. Once a miner creates a block, they must add it to the blockchain by solving the complex math problem of determining the nonce that will result in the proper cryptographic hash. [6][7]

It is possible for separate blocks to be created simultaneously, resulting in different versions of the blockchain. In this scenario, nodes will keep and retransmit the highest scoring

blockchain available to them using a scoring algorithm specified by the blockchain, generally based on chain length. There is no guarantee that a node will remain on the blockchain, but given the incentive to add new blocks rather than overwrite, as more blocks are added, the probability of a block being overwritten decreases exponentially. [3]

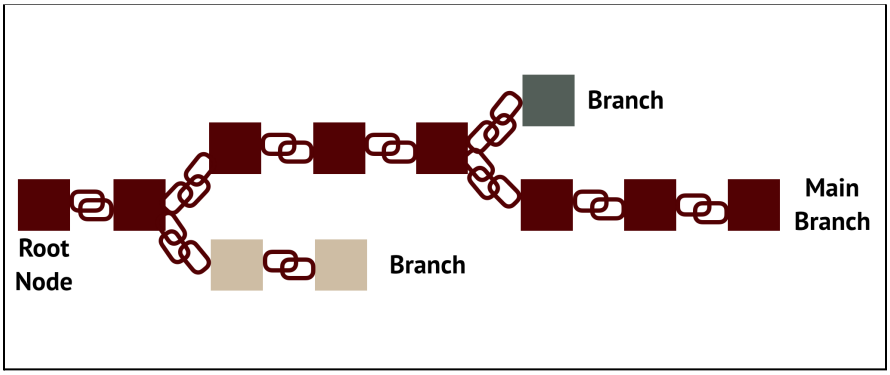

Image 2: Blockchain with Branches - The longest branch is scored the highest

There are currently two popular methods for validating a new block and adding it to the blockchain: proof of work & proof of stake. Proof of work, the most commonly used method, determines the current blockchain through computational effort, namely solving for a block's nonce. The complexity of the mathematical equations involved in verification make this method significantly more secure and dependable, yet it also makes proof of work a much slower option. This method is also hotly debated as it involves all nodes on the network using immense computational resources, leading to the consumption of an excessive amount of electricity. Proof of stake, on the other hand, completely removes the computation requirement and works by selecting a collection of block validators in proportion to their associated holdings, or stake, in the blockchain who determine the validity of a new block. The basis for this method is the idea that users with a large stake in the system will be unlikely to attempt to manipulate it and risk having their authority removed. While this method is less secure and places more trust in a

relatively small number of users, it forgoes the immense electricity consumption and is significantly faster. [8][9]

Due to blockchain's ability to act as a public, distributed, immutable ledger, it has been used extensively as the backbone of cryptocurrencies. Cryptocurrencies are decentralized digital tradable assets or currencies that are minted and traded on a corresponding blockchain [10]. The two most popular cryptocurrencies are Bitcoin and Ether. Ethereum, which is the focus of this paper, is the network / blockchain on which Ether runs. Unlike Bitcoin, Ethereum was developed with the intention of offering developers a means to deploy more than just cryptocurrency onto the blockchain. By providing a built-in Turing-complete programming language, Ethereum can host arbitrary state transition functions, allowing users to represent ownership of physical property, create non-fungible assets, or run blocks of code in contracts. [11]

Ethereum smart contracts allow developers to deploy code to the blockchain, which can be called through the use of transactions. Smart contracts can be as simple as adding numbers, or as complicated as managing marketplaces [12]. The execution of all transactions in Ethereum occurs within the Ethereum Virtual Machine (EVM), which is a state machine maintained by all computers, or nodes, connected and running Ethereum. Smart contracts are written in high-level programming languages, like Solidity, and then compiled to Ethereum Virtual Machine bytecode once deployed to the blockchain. [13]

The Ethereum state is made up of accounts; each account has a 20-byte address, a nonce for identifying transactions, a current ether balance, contract code (if applicable), and storage. There are two types of accounts: externally owned accounts are controlled by users with their private keys, and contract accounts act as autonomous agents, executing their contract code

whenever a message is received. In Ethereum, transactions are signed data packages sent from externally owned accounts containing: the recipient of the message, the sender's signature, the amount of ether to transfer, data, a STARTGAS value, and a GASPRICE value. The first three fields are standard in any cryptocurrency transaction, while the last three are exclusive to Ethereum; the optional data field can be used to pass data to the contract code that the transaction may initiate, and the STARTGAS and GASPRICE fields are related to the cost of the transaction, which is determined by the use of Ethereum's unit of computation, "Gas". [11]

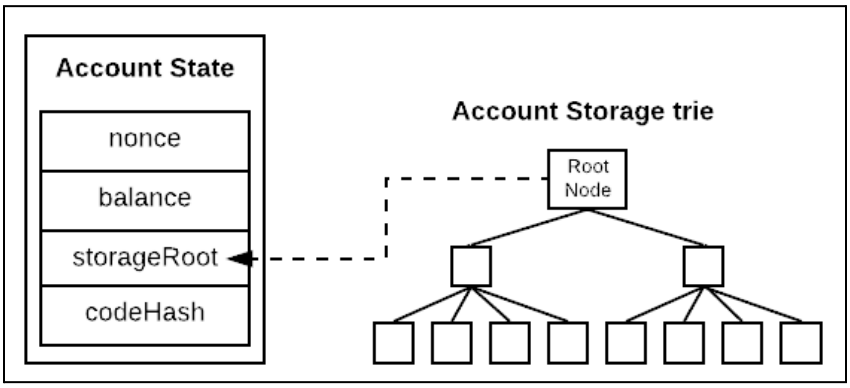

Image 3: Ethereum Account State

Gas refers to the amount of computational effort required by a miner to execute an operation on the Ethereum network; different computational steps cost varying amounts of gas to complete and users initiating a transaction will pay proportional to their gas usage. When a user wishes to complete a transaction they must pay a base block fee per unit gas expended to the Ethereum network, which is "burned" or removed from circulation. This base block fee is determined by the number of transactions in the current block and the previous block, penalizing blocks that get too large. Additionally, users will pay a priority fee, or tip, to the miner which is equal to the GASPRICE field times the amount of gas expended. The GASPRICE value, which states the price a user is willing to pay per unit gas, incentivizes miners to include transactions in

their minted block; since only a certain number of transactions can be added to a new block, miners must decide which transactions to add based on the reward they will gain. Therefore, while the GASPRICE can be manually set by the user, it is usually auto-determined by software based on the current supply-and-demand of block-space. This gas system is the core of Ethereum's anti-denial of service model, since attackers are required to pay for all the resources they use. [11]

In order to ensure that transactions do not run indefinitely and that users do not spend more ETH than planned, all transactions must include a STARTGAS value, which specifies the maximum amount of gas a user wishes to spend on the given transaction. The user is required to pay for the entire STARTGAS up-front to ensure they have the available ETH, but all unused gas is refunded once the transaction is completed. However, if the transaction requires more gas than allotted, the transaction will be reverted and the miner will still be paid for the computation provided. [11]

While end-users can send transactions that are stored and run on the blockchain, contracts have the ability to send messages to other contracts. These messages are prompted by contract code, use gas allotted by the initiating transaction, and only temporarily exist in the Ethereum execution environment's memory. The environment exists as one entity that runs an Ethereum client and is maintained by thousands of connected computers. Contract messages contain: the message sender, the message recipient, ether to transfer, data, and a STARTGAS value. The STARTGAS value determines the computational limit of the message, but the GASPRICE follows that given in the initial transaction. If at any point in the completion of a transaction the sender runs out of gas or money, all state changes are reverted but the gas fees are not returned.

Rather, they are paid to the miner. If a transaction completes with leftover gas, the extra funds are returned to the sender. [11][13]

One of the many things Ethereum smart contracts are used for is the creation and management of tokens. In the context discussed, tokens are crypto-assets that run on top of another cryptocurrency's blockchain [14]. Tokens can represent any kind of digital asset, and smart contracts can be developed that will mint specified tokens, track ownership, and manage transfers. Since this usage is extremely common, token standards have been introduced that define the functionally listed above and allow tokens to be compatible across marketplaces / exchanges. Token standards exist for the two types of tokens, fungible and non-fungible. Fungible tokens are equivalent and interchangeable, like currency, while non-fungible tokens (NFTs) are unique and distinct, like pieces of art [15]. The newest standard, ERC1155, is fungibility-agnostic, meaning it can mint tokens that are fungible and tokens that are non-fungible. ERC1155 is also more gas efficient than previous iterations due to the inclusion of batch operations, which allow operations on multiple tokens in a single efficient transaction [16].

In addition to the standards for tokens, there are standard libraries for other common smart contract functionality. One such library employed in this project is AccessControl. The AccessControl module provides methods to implement role-based access control mechanisms. This module can be used to assign all users involved a role, which can then be used to restrict access to certain contract functionalities, like solely minting [17]. Another standard of note is EIP-2981, the NFT Royalty Standard. Royalties, the idea that token creators are entitled to a percentage of all resales, have been prominent in NFT marketplaces for some time. However, this mechanism must be implemented by the marketplace itself and each marketplace's implementation is different, which causes issues if an NFT bought on one marketplace is resold

on another. This recent standard aims to standardize the method of collecting royalties, in an attempt to bridge the gap between different marketplaces [18].

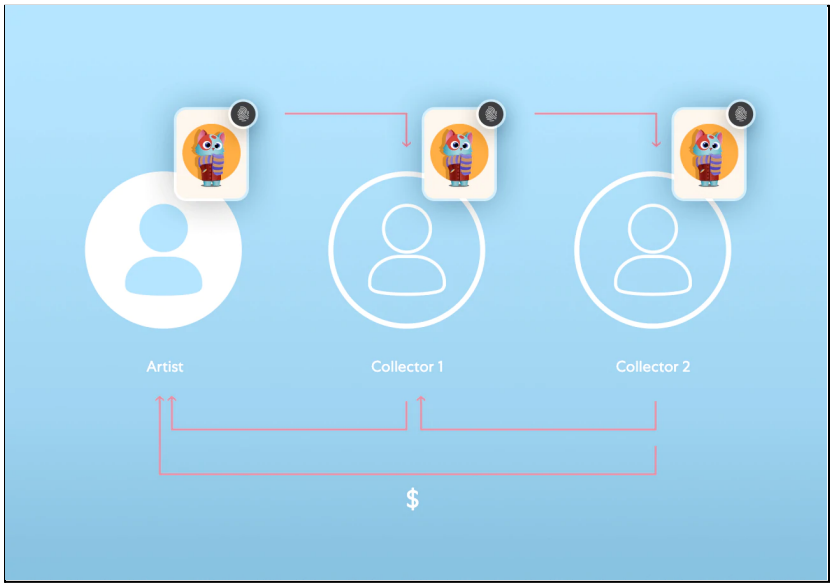

Image 4: NFT Royalties - Creator gains portion of profit each NFT resale

Once a token is minted, it is possible to store it on the blockchain. Block-chain based persistence, however, can become prohibitively expensive as each byte of data used incurs a fee. A more common approach is contract-based persistence, a method where the data is stored elsewhere and a hash of the corresponding token address is stored on the blockchain. At first glance, this may appear less secure, since tokens stored elsewhere can possibly be tampered with or deleted entirely. However, platforms exist that solve these issues. The system used in this project, and promoted by Ethereum, is InterPlanetary File System (IPFS) [19].

IPFS is a distributed system for storing and accessing files, websites, applications, and data. The two main features of IPFS are decentralization and content addressing. Instead of a file being stored on a single server or a group of servers within a single entity, files are stored across all nodes participating in the system. This allows for data resiliency, so if a server goes down, the

token will not be lost. One issue with storing a file in multiple places, though, is that the traditional method of addressing, server name then nested directory names, does not work. IPFS's solution, content addressing, creates an address using a cryptographic hash of the content contained. Therefore, the address for a given block of data, or token, will never change, and if the content of the data changes, it will be given a new address. Meaning, once an IPFS address is stored on the blockchain, the content it references cannot be modified or tampered with. [20]

When a token is added to IPFS, it is split into smaller blocks, cryptographically hashed, and given a content identifier (CID). This CID is the unique identifier, or address, of the token. If the token purchaser were to follow the CID to view their token, IPFS would determine which nodes in the network contain a copy and draw it from the nearest nodes. When an IPFS file is viewed, it is stored in one's cache and provided to others requesting it in the network; the data will remain on one's IPFS node until the cache is cleared or indefinitely if the file is 'pinned'. [21]

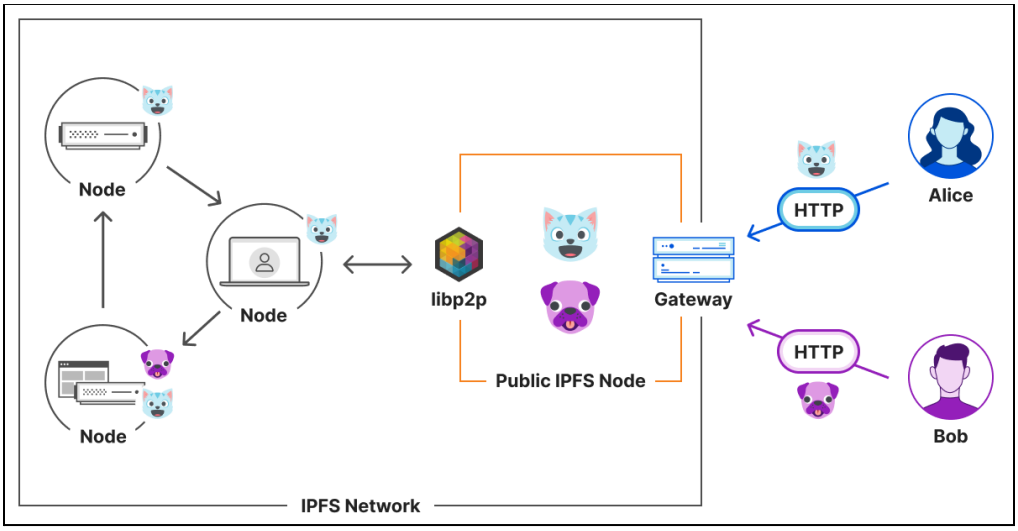

Image 5: Retrieving File From IPFS

Related Work

With the increasing adoption of cryptocurrencies and NFTs, many popular blockchain and marketplace options exist and more are created each day. One alternative prominent blockchain that was researched for this project is Tezos, a self-governing proof-of-stake blockchain. Unlike Ethereum, which is heavily criticized for its use of proof-of-work block validation, the Tezos blockchain implements a variation of the proof-of-stake validation algorithm, named liquid proof-of-stake, which makes it a popular choice amongst those searching for a more eco-friendly blockchain. [22]

While in Ethereum, miners race to mint a new block, in Tezos, bakers or block creators are assigned block publishing rights based on the amount of XTZ they control; XTZ, or tez, is Tezos' native currency. In order to become a Tezos baker, one must control at least six-thousand XTZ. Each block, once produced by a randomly assigned baker, is then endorsed by thirty-two other random bakers. Tezos incentivizes bakers by forcing them to put up a safety deposit; if they honestly approve valid transactions, they will receive a reward with their returned deposit. If they attempt any malicious behavior, their deposit will be forfeited. Users owning XTZ below the baking threshold or users who do not wish to partake can decide to delegate their XTZ to another baker. The chosen delegate will not have the ability to use the delegated XTZ, but will have it treated as part of their stake, making the delegate more likely to be chosen. In return, delegates will give a portion of their validation reward to their supporters. Since users can change their delegate at any time, delegates are incentivized to promote an honest system, fairly split profits, and vote according to the interests of those they represent. [23][24]

Another unique aspect of the Tezos blockchain is its self-governance mechanism. While other blockchains, including Ethereum, rely on teams of developers and communities of miners to design and develop updates to the system, Tezos is a self-amending blockchain, meaning users can submit, vote on, and implement system changes. The Tezos amendment process is broken into four periods: the proposal period, the exploration vote period, the testing period, and the promotion vote period. In each of these periods, bakers' votes are weighted according to their stake in the system. During the proposal vote period, bakers have the ability to submit proposals that they wish to be voted upon. Each baker has the ability to add their vote of approval to up to twenty proposals. Once this period concludes, the top proposal is moved to the next round; if there is a tie, the proposal period begins anew. During the exploration vote period, each baker can submit a ballot containing "yay", "nay", or "abstain". If a predetermined quorum of voters is met and eighty percent of non-abstaining voters approve, then the proposal continues; if not, the amendment process reverts back to the proposal period. Once in the testing period, the proposal is deployed on a fork of the main blockchain, so that its effects can be studied and understood. At the end of the testing period, the promotion vote period begins and all bakers can vote whether or not to implement the tested proposal. If passed, the proposal is activated on the main blockchain. This on-chain government allows Tezos users to change the blockchain over time, as new developments are invented. [25]

An additional blockchain used by prominent marketplaces is the Flow blockchain, which was developed to be a primary blockchain for crypto infused games and similar interactive experiences. Most blockchains, in order to scale and grow, implement a technique known as sharding; sharding is a horizontal scaling method, derived from database management technology, that reduces the load on nodes by partitioning computational and storage workloads

across the network, such that each node is not responsible for storing and processing the entire blockchain. While this allows blockchains to grow as new users join, it introduces various issues since nodes no longer have direct access to the entire blockchain. A core functionality of Flow, though, is its ability to supply a sharding-free blockchain and provide fast transactions [26][27].

In addition to being built to solve the scalability issue, Flow, similar to Tezos, employs its own variation of a proof-of-stake validation system, reducing its carbon footprint. Flow also allows the deployment of upgradable smart contracts; smart contracts can be deployed in beta and then built upon until they are finalized and made immutable [26].

Tezos and Flow are promising blockchains and include appealing characteristics to an institution-run marketplace. Given Cooper Union's core values and focus on the environment, a proof-of-stake blockchain would be the ideal choice for the marketplace being built. Ultimately, though, we chose to use the Ethereum blockchain due to the extensive documentation and development resources available. The Solidity development environment is quite robust and many standard libraries exist to assist in building custom smart contracts. Similarly, we can benchmark our marketplace with established marketplaces on the Ethereum blockchain. While a marketplace developed using Ethereum may lead to prohibitive gas fees or unwanted energy consumption, this project is meant to be a proof-of-concept, and we are sure that if Cooper Union decides to move forward with the idea of an institution marketplace, they will choose a blockchain that better reflects their values.

In addition to alternate blockchains, various popular marketplaces were viewed and discussed in order to determine which features are important to users and what functionality would set this project apart. One such marketplace is NBA Top Shot, which is a platform that

allows NBA fans to buy, sell, trade, and earn clips of NBA games as NFTs, or ‘moments’. This network is unique in that it operates on the Flow blockchain and incorporates a “challenges” mechanism that allows users to earn NFTs through the completion of tasks. [28]

Another popular marketplace is Hic et Nunc, an open source volunteer-run marketplace hosted on the Tezos blockchain. Due to its use of Tezos’ proof-of-stake validation, the marketplace offers substantially lower gas fees than similar Ethereum based alternatives, and consumes significantly less energy. Hic et Nunc also implements a new Tezos NFT standard called OBJKT; the OBJKT framework allows for the storage of a wide range of media types using IPFS, can implement royalties up to twenty-five percent, and incorporates a two-and-a-half percent transaction fee paid to the protocol. Artists selling art on Hic et Nunc also have the option to create fungible tokens, with edition sizes up to ten thousand. [29]

Rarible, another open source NFT marketplace hosted on the Tezos blockchain, was also considered throughout the development of this project. At its inception, Rarible was an Ethereum based non-custodial marketplace, meaning any user can create and sell artwork. However, Rarible recently relaunched, in an effort to lower the barrier to entry and decrease their carbon footprint. Following the relaunch, Rarible added support for the Tezos blockchain, which, as described above, requires significantly less gas fess and implements a proof-of-stake block validation. Rather than completely remove Ethereum support, Rarible has partnered with Nori to address climate concerns. [30] [31]

Currently, Rarible implements a form of user validation. If a user provides enough information and participates in the marketplace, they will be verified by the system and their art

will be displayed; if not, their listed NFTs will not appear on the explore page or in search results. [32]

Another distinct feature of Rarible is their implementation of a decentralized autonomous organization (DAO). Similar to Tezos' self-governance mechanism, Rarible's DAO would allow users to vote on changes to the marketplace based on the amount of Rarible's currency, RARI, they own. The Rarible team capped the total RARI supply at twenty-five million units and split its distribution as follows: Ten percent was distributed to all users through an "airdrop"; thirty percent is reserved for the development team and investors; sixty percent is reserved to be rewarded for completed transactions on Rarible. [31]

While these marketplaces each have pros and cons, and can all be used by students to sell digital art, they all present the same issue; student artwork will be lost among the artwork of thousands, especially those of more prominent digital artists. Therefore, this project intends to fill that niche need of Cooper Union students. By creating a marketplace on which students alone can sell art, student art can be displayed prominently for all users to see, instead of hidden beneath hundreds of search results. The drawback to this solution and the benefit of these alternate marketplaces is the number of viewers; while the marketplace will not draw a similar user count, it is our hope that the Cooper Union reputation will help promote the student artwork being listed. The various marketplace described also provided insight into desired features on a marketplace, some of which have been implemented and some will hopefully be implemented in the future.

Project Description

The purpose of this project was to develop a proof-of-concept NFT marketplace for the Cooper Union. It would allow students to sell works of art under the Cooper Union name-brand and expose themselves to the art market, while earning money to help pay tuition and assist them once they graduate. As described above, we chose to develop this marketplace on the Ethereum blockchain, since there is an abundance of development resources available. The newest token standard, ERC1155, was used for its ability to mint both fungible and nonfungible tokens, as well as for its increased efficiency. NFTs are stored on IPFS, due to its ability to properly store immutable NFTs off the blockchain and due to its widespread use and popularity among the blockchain developer community.

The backend of the marketplace consists of two Ethereum smart contracts, developed using the Solidity language; one smart contract controls the minting and ownership of NFTs, while the other contract runs the marketplace. Functionality of the marketplace contract includes: assigning roles; creating, editing, selling, and canceling market listings; and various methods to fetch desired information. When the Marketplace contract is deployed, it is given the address of the NFT contract in its constructor, linking the two contracts and allowing the marketplace access to the NFTs. The address of the marketplace contract is then stored in the NFT contract, using functionality only available to the contract owner, in order to ensure that only the marketplace can access certain functionality of the NFT contract.

The core feature of this marketplace is the restriction of minting art to current students. This is accomplished through a system of account roles built into the marketplace smart contract, which is implemented using OpenZeppelin's AccessControl library. Users are not required to have a role, but the available roles are: Cooper Union, Admin, Current Student, and Previous

Student. The Cooper Union role is automatically assigned to the account that deploys the marketplace contract. This account, presumably run by Cooper Union administration, would have control over main aspects of the marketplace; currently, this is limited to the marketplace transaction fee, but more customizability could be added in the future as required. The marketplace owner also has the ability to assign the Admin role to other accounts; these admin accounts would be responsible for validating students, assigning them the Current Student role, and changing the role to Previous Student upon graduation. Realistically, these admins would be Cooper Union administrators working in tandem with the registrar. Current students have the ability to mint new artwork, while previous students have no distinct functionality, but are tracked in case future features require it. All accounts, though, including those without a specified role, have the ability to purchase art on the marketplace and resell all owned art.

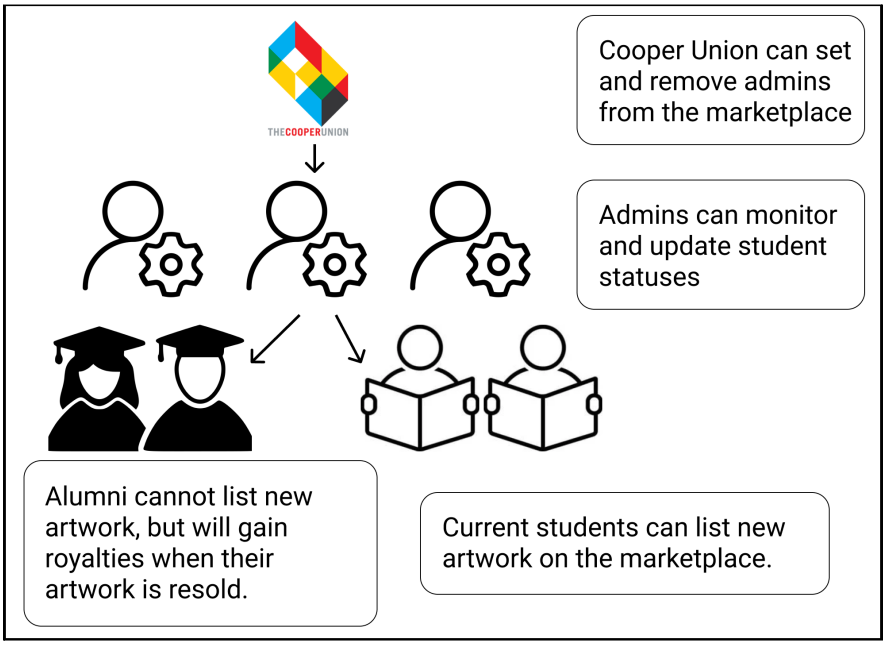

Image 6: Marketplace Roles Hierarchy

Another essential feature of the marketplace is creator royalties; when an NFT is resold, a percentage of the sale price is paid to the creator of the NFT, or another Ethereum wallet of their

choosing. This functionality is accomplished by implementing the EIP-2981 NFT Royalty Standard in the NFT smart contract. When a creator mints a new piece of artwork, they may specify a royalty percentage up to fifteen percent as well as the desired royalty receiver; these fields cannot be changed and are stored within the NFT smart contract, where they can be requested by any marketplace implementing this standard. Therefore, since most marketplaces are adopting this royalty standard, NFTs minted and sold on the Cooper NFT Marketplace can be integrated into the wider Ethereum marketplace network.

While NFTs can be stored on the blockchain itself, that would require a substantial fee in gas payments. The most common alternative, which is implemented in this project, is storing NFTs on IPFS. The pipeline for minting an NFT on this marketplace is as follows: Once the necessary information is acquired, the file or artwork is uploaded to IPFS. IPFS, as described above, will return a content id (CID) referring to the file. This CID is packaged with other information to create the NFT metadata, which is then uploaded to IPFS. The CID referring to the metadata is passed to the NFT contract where it is used as the token ID of the newly minted NFT.

Due to ERC1155's new system for generating metadata URIs from token IDS, which does not work with IPFS CIDs, a custom URI generator function had to be developed for this NFT contract. Additionally, IPFS CIDs are too long for NFT token IDs, so they are hashed to a shorter string before being sent to the smart contract, and converted back within the custom URI function before being returned.

For the purposes of this project, Infura was used to access IPFS. Infura is a platform that provides dedicated IPFS nodes for blockchain-based applications; testing of the marketplace did not reach the threshold of Infura's free tier, but constant access from the Cooper Union student

body most likely would. Therefore, if this project is further developed upon and ultimately deployed, Cooper Union would benefit from hosting their own IPFS node, which they could use to store all NFTs listed on their marketplace.

Many choices exist for connecting Ethereum wallets to marketplaces, but one of the most popular options, which is used in this project, is MetaMask. MetaMask is a crypto wallet browser extension that allows users to link their wallets with websites. Wallets, on this marketplace and most others, act as a user's unique identifier and account. Once linked, this marketplace will have the ability to initiate Ethereum transactions on behalf of the user, which must then be accepted and paid for through MetaMask. In order to access any account-based functionality, including viewing owned NFTs and purchasing NFTs, users would have to connect their MetaMask wallet. [33]

The marketplace frontend was developed with ReactJS and interacts with the Ethereum smart contracts using the EthersJS library. All pages of the marketplace are responsive to screen size and will work on mobile devices. When entering the site, users will be greeted with a home page containing a 'Discover New Art' button that redirects to the explore page, a carousel displaying recently listed NFTs, and basic information for sellers and buyers.

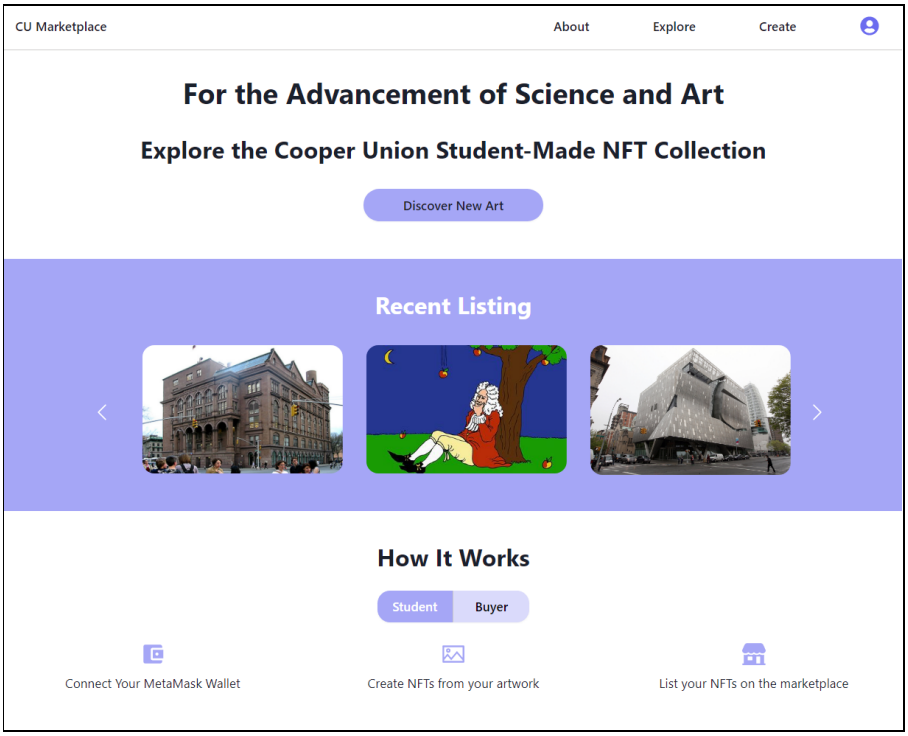

Image 7: Home Page

Regardless of whether a user has connected a wallet or not, they will be able to access the home page, the about page, the explore page, and individual NFT pages. On the about page, users can learn more about the Cooper Union marketplace and its core functionality. Users who access the explore page will be able to view all NFTs currently listed on the marketplace, displayed as a grid of NFT cards. Each NFT card displays the NFT image, which will enlarge on hover, the seller, the price in ETH, and an approximate price in USD, using a conversation rate from the Coinbase API. If a user has connected a wallet, they will be able to click on the heart icon to add the NFT to their favorites, so that it can be viewed at a later time on the favorites page.

Any page that displays NFTs, like the explore page, will contain a filter bar that allows the user to search NFT names and descriptions, or select a desired sort order; the possible fields to sort by are date listed and price, ascending and descending. Selecting the icon right of the sort

selector will open a filters modal with more filter options depending on the page, and clicking the rightmost button will reset all filters.

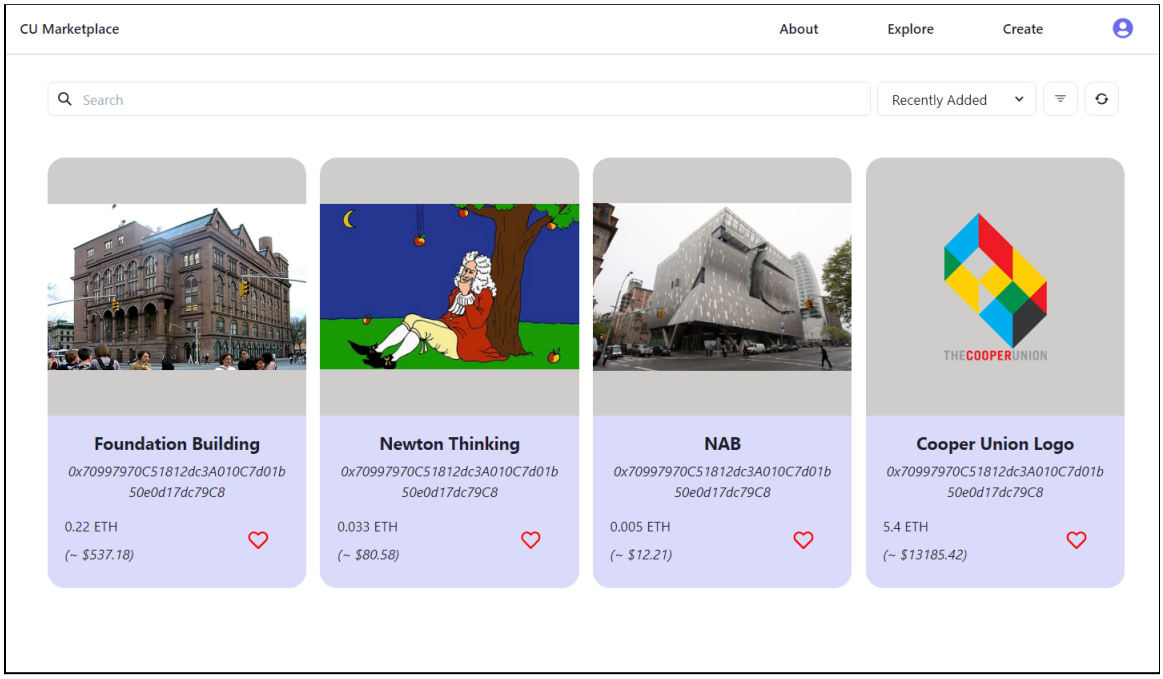

Image 8: Explore Page

If a user selects an NFT image, they will be redirected to that NFT's page, which will display all information shown on the NFT card as well as the NFT's description. The buttons, or actions, available on the individual NFT page will depend on if the user owns the given NFT. If the user does not own the viewed NFT, then it will be available to purchase; clicking the purchase button will open a prompt from MetaMask to accept the transaction and pay the desired sale price. If the user owns the NFT, then they will have access to a 'cancel listing' button and an 'edit listing' button, which will open a modal to update the sale price.

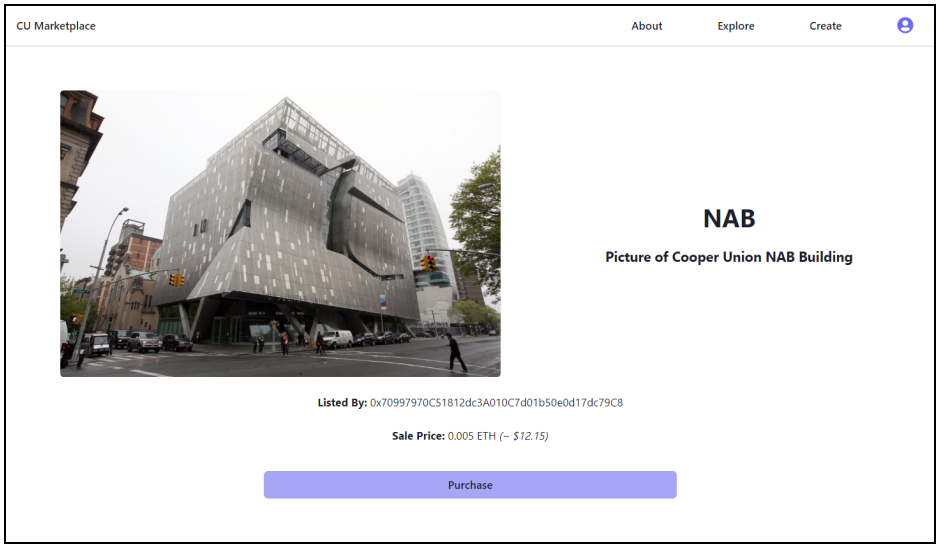

Image 9: NFT Page - Unowned

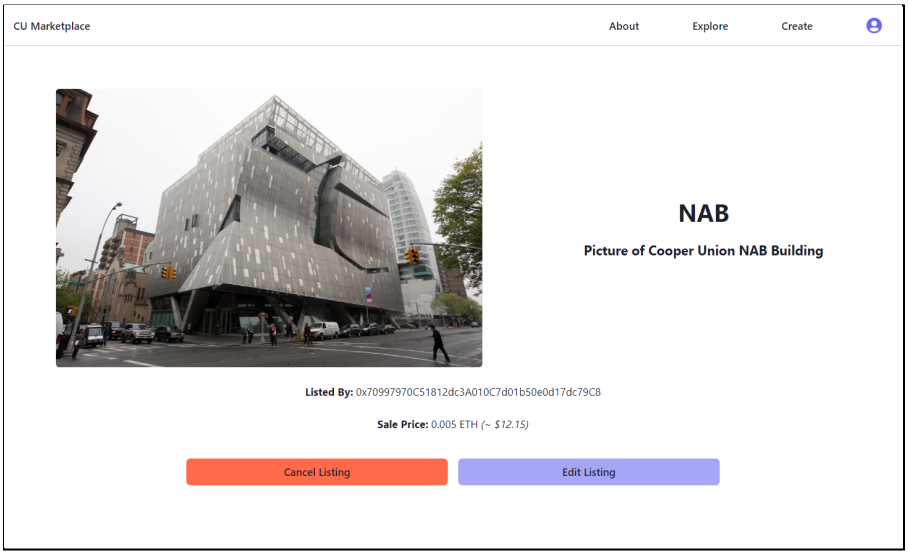

Image 10: NFT Page - Owned

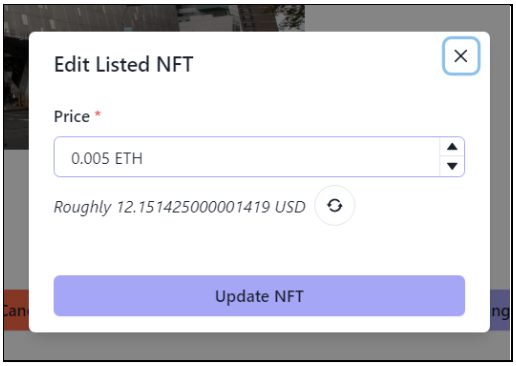

Image 11: Edit Listing Modal

If a user has not connected their MetaMask account, a login button will appear in the navbar and all attempts to access wallet-required pages will redirect to the login page. On the login page, if the user has installed the MetaMask browser, a button will appear that will open a MetaMask connection prompt; this MetaMask prompt will ask the user to select which wallets they would like to connect. If the user has not previously installed MetaMask, the page will supply a short description of the extension and offer a link to its download page.

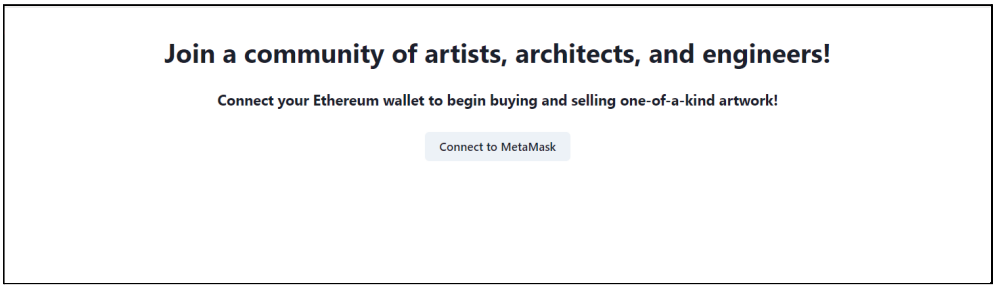

Image 12: Login Page - MetaMask Installed

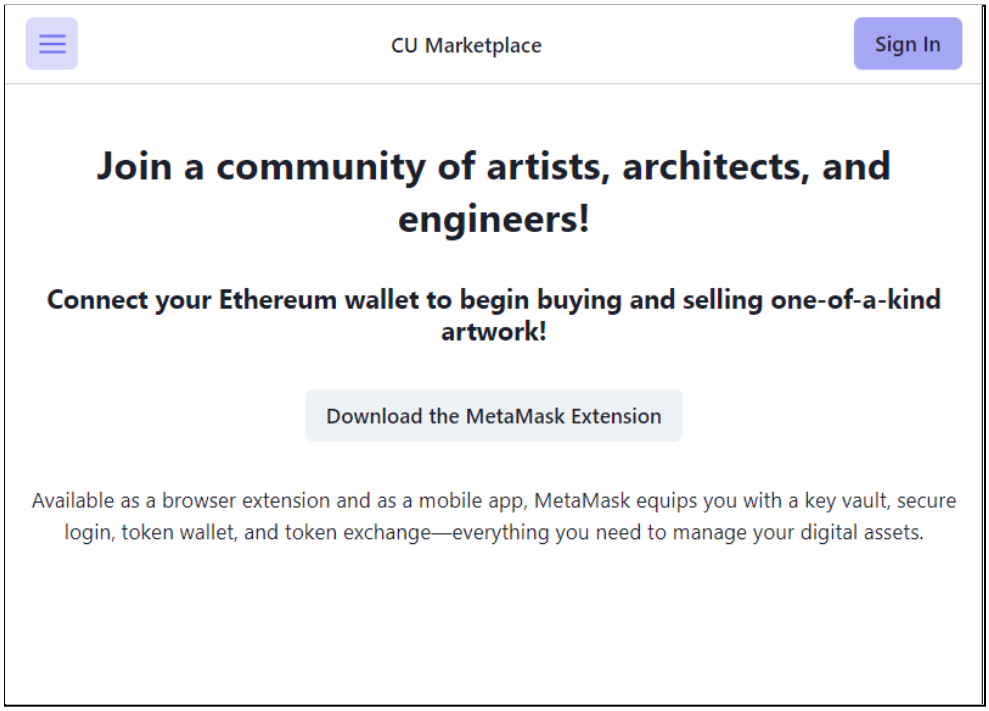

Image 13: Login Page - MetaMask Not Installed (Mobile View)

Once a wallet is connected, users will be able to access the favorites page and the My NFTs page, which allow them to view NFTs they have favorited and NFTs they own, respectively. On the My NFTs, users can toggle between viewing listed and unlisted NFT, as well as set a maximum and minimum price, through the filters modal.

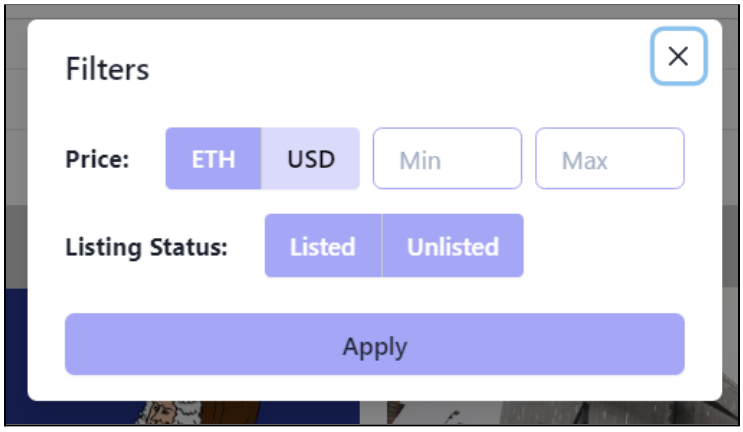

Image 14: Filters Modal

If an NFT is unlisted, the NFT card will display a "List NFT" button instead of the price. Selecting this button will open a modal that will allow the user to easily list the NFT.

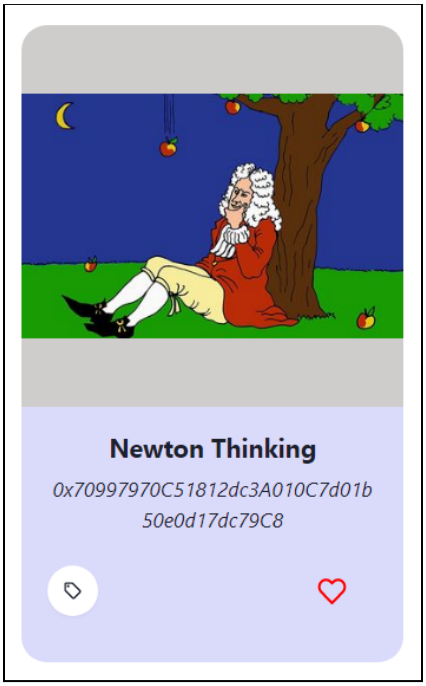

Image 15: NFT Card With "List NFT Button"

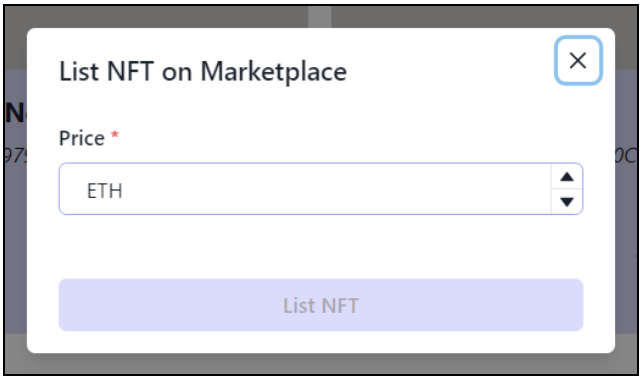

Image 16: List NFT Modal

On the create page, if the current user has been assigned the student role, then the create NFT form will be displayed. This easy-to-use form will walk the user through submitting all the necessary information to mint an NFT of their artwork. At the top of the form, users can drag and drop a file or click on the box to open a file viewer. Once uploaded, a preview of the file will be displayed. Selecting the "What are Royalties?" button will open a modal containing a short description of marketplace royalties. It is possible to opt-out of royalties, if the user is not interested; however, if the user decides to add a royalty percentage, which maxes out at fifteen percent, they can select to send the royalties to their own wallet, to Cooper Union, or to a wallet they write in. Listing the to-be-minted NFT on the marketplace is opt-in. If the user opts not to list the NFT, it will be minted and added to their owned, and unlisted, NFTs; if the user adds a sale price, then the minted NFT will be immediately listed on the marketplace. Listing the NFT at the time of minting saves the user some gas fees as one less transaction is required.

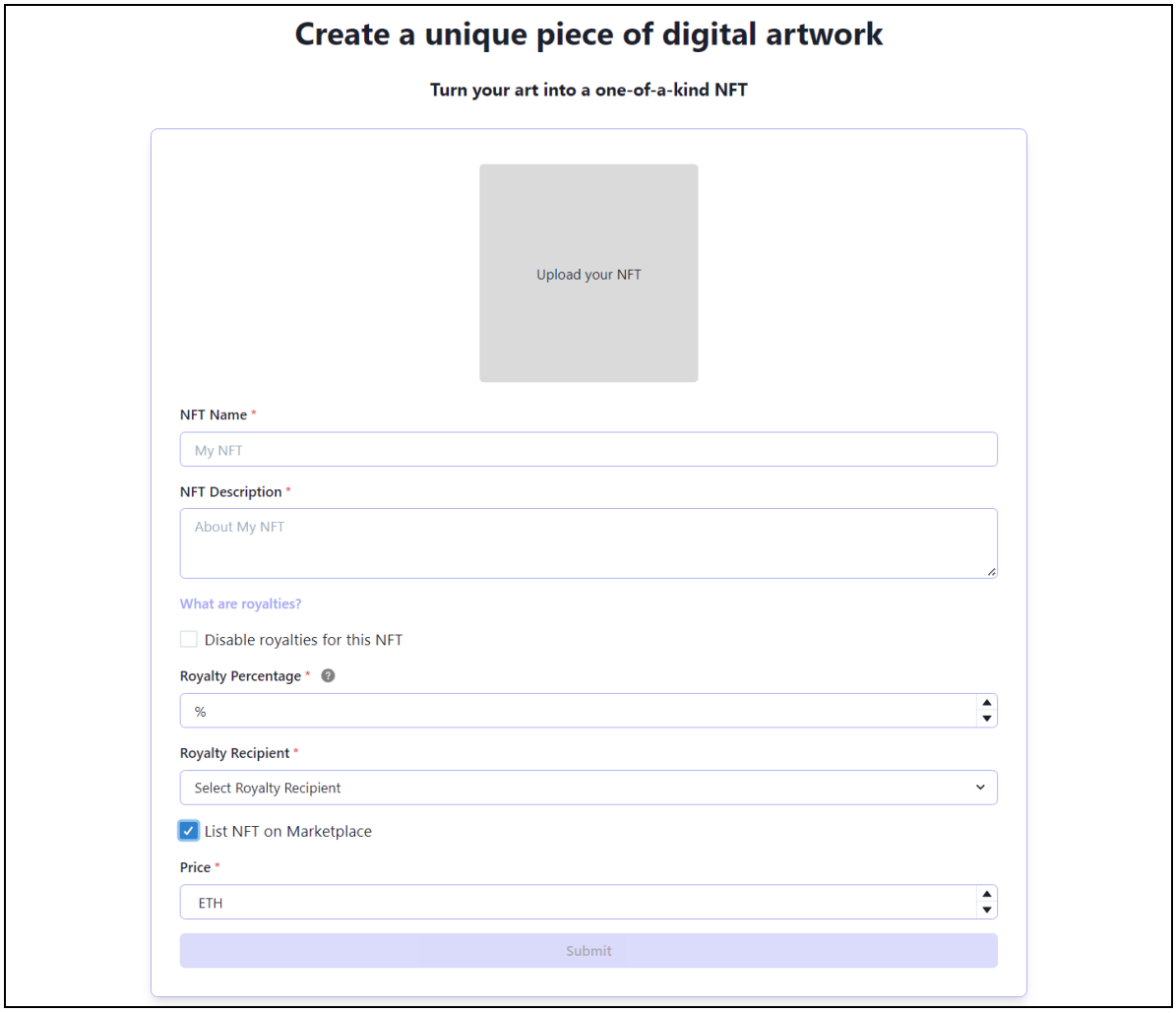

Image 17: Create NFT Form

If a non-student account attempts to mint an NFT, the page will instead display the option to request access. If selected, a modal will open requesting the student's information, which would then be sent to the marketplace admins.

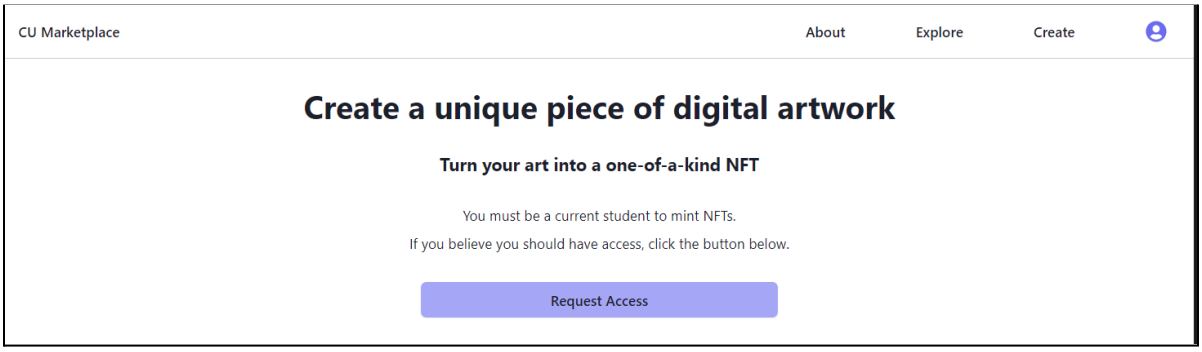

Image 18: Create Page - Not Student

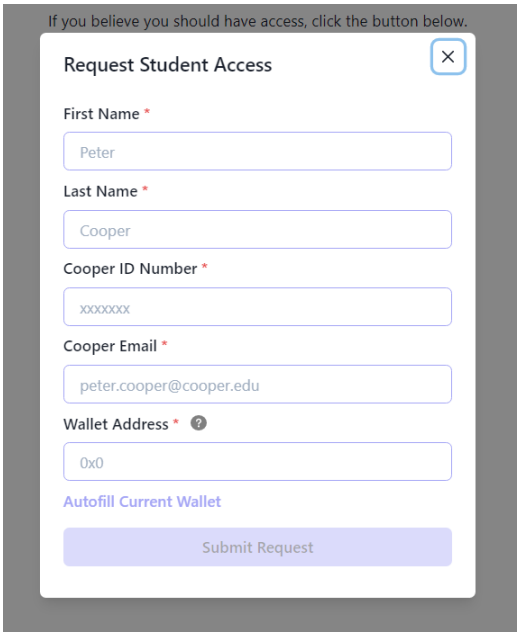

Image 19: Student Role Request Form

If the current user has been assigned as an admin, then they will have access to an admin page, which will appear in their navbar. This admin page would contain any settings relevant to admins, but at the moment only contains a form to update users' roles. In this form, an admin can add as many valid wallet addresses, or accounts, as they wish, and the selector options will display all role-changing actions applicable to all wallet addresses given.

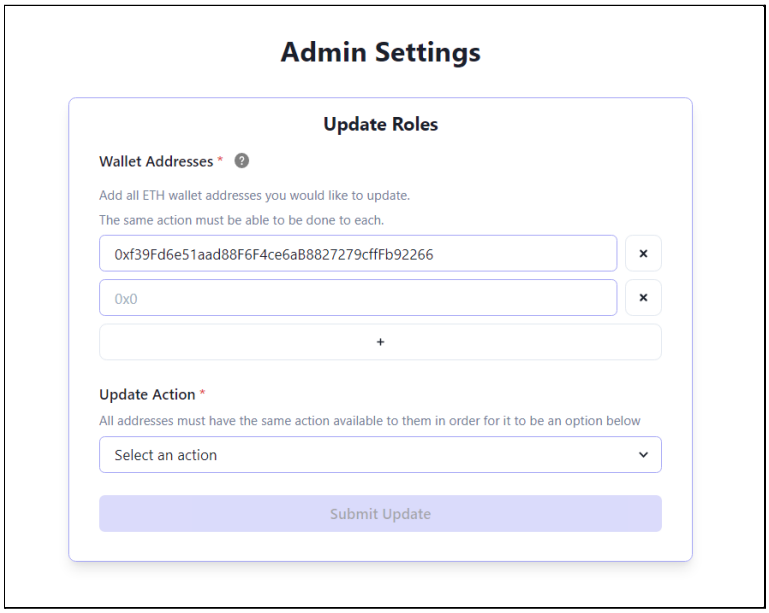

Image 20: Admin Settings Page - Update Roles Form

Future Work

Although the core implementation of the desired marketplace has been completed, there is still a lot more to accomplish. Future work on the current marketplace design would include fleshing out incomplete features and adding new ones that could not be completed in the allotted time. These additional features include user profiles, minting multiple NFTs in a single batch operation, minting fungible tokens with a specified edition size, auction style sales, listing end-times, favorited counter, and NFT collections. These features are similar to larger marketplaces and would greatly benefit this marketplace's user experience.

If an NFT collection system were implemented, users could search by collection name and sellers could choose to list the entire collection together or sell individual pieces. One potential application of collections is hosting generative art, where each collection is grouped by their progenitor. In this case, users would have the option to choose a set amount of pieces to generate and each token in the collection could have their own independent market price.

An idea discussed to improve the student community was to have student anonymity be a core feature of the marketplace. The goal would be to discourage competition among students and shift the focus of listed NFTs from the individual artist to the general Cooper Union name-brand. In this system, students would remain anonymous, merely listed by graduation year, until they graduate, after which their names would be revealed as to help build their reputation. This idea, though, was severely challenged by consulted architecture students. Their argument was that art reflects the artist, and therefore it would be easy to determine which art belongs to whom. Additionally, they would prefer to be able to create their own profile, using a pseudonym if they wish to remain anonymous, or their real name if not; in both cases, though, a buyer would be able to determine all art pieces created by a given artist.

Another core design decision discussed was the division of profits. While the exact percentages were never figured out, the idea of profits splitting amongst a grade was discussed and brought before the consulted architecture students. Similar to the previous idea, the students were not pleased and were unsure how the system could be developed fairly. Due to the pushback on these ideas, we chose to refrain from implementing them until they could be discussed further.

The current design of the marketplace requires the user to pay for all minting. However, in a marketplace run by an academic institution, this would create an unfair advantage to wealthier students who can afford to list more artwork. Two possible solutions to this issue were discussed, along with their drawbacks. The first possibility was to have Cooper Union pay for all gas fees; the issue with this system, though, is that Cooper Union would want to confirm that the art they are paying for is actual art, and not someone attempting to mess with the system and waste money. Determining this, however, would require a staff member acting as a marketplace gatekeeper, approving NFTs they believe to be genuine, and a database to store the NFTs until they are approved and minted. Implementing this would require hiring someone for the gatekeeper position, as well as open up the school to issues with determining which art is truly genuine.

An alternative solution would be to have Cooper Union allot each student a specific minting allowance. No gatekeeper would be required, since students attempting to waste money would just be wasting their own. If this could be implemented within the smart contract, then the school wouldn't need to be involved in the minting process other than supplying the funds. This is a promising solution, but would require significantly more discussion and thought before it would be approved by the school administration.

Connecting the marketplace to the institution's website is another potential application of our project. The donation page could potentially have a section to donate NFTs; these NFT would be on the marketplace and all proceeds and future royalties would go to Cooper Union.

Finally, the largest change that would need to be completed in the future, is moving the marketplace to an alternate blockchain. Throughout our discussions with students and faculty of the School of Art and Architecture, we received pushback and criticism for using the Ethereum blockchain, because of its environmental implications. Ethereum currently implements proof-of-work with the promise to transition to proof-of-stake in the near future, yet the actual timeline is unclear. Consequently, there is a lot of interest in using the Tezos or Solana blockchains as they are proof-of-stake alternatives that have gained a lot of popularity for their lower carbon footprint. If Ethereum does not transition to proof-of-stake and the administration wishes to proceed with this marketplace, then the smart contracts would need to be rewritten for the chosen blockchain.

Conclusion

The goal of this project was to develop a Cooper Union NFT marketplace that would allow Cooper Union students to monetize their work prior to graduation, while creating a reputation for themselves before entering the market. This marketplace would be open to all current Cooper Union students regardless of major and can serve as a great introduction to students' respective markets. Compared with alternative popular marketplaces, our platform is designed to best help students be successful in college while preparing for their future careers in the industry. This institution backed marketplace would allow students to sell artwork under the Cooper Union banner, while promoting the Cooper Union brand.

Moving forward, we plan to continue talks with the School of Art, School of Architecture and the Cooper Union administration about the future of this marketplace. We have developed a marketplace and smart contracts on a small scale to demonstrate its potential and the major design decisions that must be discussed. We are hopeful that this proof of concept demonstrates that an NFT marketplace can be feasible and adaptable to the Cooper community in the future.

Acknowledgments

We would like to thank Professor Sam Keene for advising our project and challenging our design decisions from the perspective of a potential contributor and as a member of faculty. We would also like to extend our appreciation to the School of Art and the School of Architecture for sharing their research on existing markets, concerns for an institutional marketplace, and suggestions for improvements. Additionally, we would like to thank the independent study with Daniel Gitzel and Walid Raad for inspiring us and giving us the opportunity to continue this idea.

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