Preserving Natural and Cultural Heritage with the power of transient Non-fungible Tokens

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ABSTRACT

This dissertation project explored the development of an alternative licensing model for NFTs and a mobile-based NFT marketplace to promote and protect cultural and natural heritage, which are vital resources to tell our story to future generations, defining our essence, history, and adding dignity and uniqueness to our legacies for future generations. Therefore, it should be protected, and awareness needed to be created. By incorporating evidence about the state of the art, leveraging blockchain and NFTs technologies at the service of heritage, two important and unique aspects were highlighted: ensuring the usage of a zero-carbon blockchain solution and the creation of temporary NFTs, valid for a certain period, enabling continuous income sources for the asset owners. With this, a User-Centered Design methodology was followed to tackle users' needs and concerns and to validate the idea behind this alternative licensing model. This was combined with design and usability principles. A series of interviews and prototype testing techniques were conducted for this purpose, to understand design implications. As a result, two smart contracts were implemented, under NEAR Protocol's blockchain framework, and a Flutter-based application emerged. This generated a financially sustainable solution capable of showing the actual state of the lineage (for example, the changing aspect of a landscape over seasons) and promoting a continuous source of donations used to preserve the assets, with excellent results in terms of usability and design, proving the effectiveness of the chosen methodologies and frameworks.

KEYWORDS

Heritage, UNESCO, Blockchain, Non-Fungible Tokens, NEAR Protocol, User-Centered Design, Human-Interaction Design, UI/UX, Flutter, RUST, MVC

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1 INTRODUCTION

Building on blockchain technology, the concept of Non-Fungible Tokens (NFTs) had been gaining attention since its creation. Inheriting blockchain properties, NFTs represent a cryptographic token that lives on the blockchain, representing something unique and not mutually interchangeable [1]. NFTs' application range from arts to games, but their potential is still vast, including questions about how to use this technology to help humanity and the planet.

Natural and Cultural Heritage is recognized by UNESCO as vital resources to tell our story to future generations, so, it is imperative to protect them, as most are non-renewable. Besides this information, the existent protection of these resources creates a tendency to exclude human activities such as tourism [2]. Heritage can also be damaged by increases in pollution, for example, the rise in the average sea level temperatures can lead to the wearing of monuments close to coastal areas.

Technologies have been extensively used in the presentation and preservation of Cultural Heritage [3] and its values, in particular, in the form of augmented-reality technologies guiding visitors through physical spaces, such as museums [4]. Users can be guided through the complexities of the information, presenting historical and artistic details of the artifacts through characters and interactive plots. This allows a form of virtual tourism that could be extended to restricted areas.

This dissertation project explored how NFTs could be used to preserve and protect our heritage. Natural heritage, for instance, plays an important role in this project as ecosystems, supported by fauna and flora, are extremely dynamic. NFTs were the perfect candidate to enable users to contemplate the vivacity and dynamism of natural heritage where different seasons or weather conditions can influence the aspect of a certain asset. The previous statement can be supported by how popular NFTs are and by their capability to transform physical assets into digital ones, safeguarding inherent information. However, how can NFTs capture this dynamic behavior? By developing a new NFT licensing model whose NFTs will be time-constrained. In other words, the developed licensing model will enable transient, time-sensitive NFTs to be created. Those have the property to expire within a time defined by its creator, limited according to what they are portraying.

Two main methodologies/frameworks were used to develop this project. NFTs provided the core for this application to work through the creation of two smart contracts. User-Centered Design (UCD) allowed the creation of a solution that met users' requirements and desires, validating not only the user interface but also the idea behind the NFTs framework.

2 STATE OF THE ART

The union between blockchain and NFTs to save natural and cultural heritage is preliminary. However, it is good to see how some solutions use NFTs to do good and to sustain our history and the planet, immortalizing past generations and making our heritage last for future generations to enjoy.

By exploring how to simplify the resulting transactions and bureaucracy involved in traditional donation systems, promoting transparency to preserve cultural heritage, and increasing awareness around this area, "Heirloom" was one of the first NFT-based fundraising systems. This project achieves the protection of natural and cultural assets by connecting them to the blockchain, allowing a business model where foundations and governmental organizations

receive donations to protect cultural assets without intermediaries [5].

Korea Heritage and History NFT (KHHN) is a recent project to protect Korea's natural and cultural heritage. Relying on NFTs, this project guarantees immutable and irreversible operations to record Korea's heritage information. One feature that stands out in this project is the ability to transform multiple types of assets into a token, for instance, images, videos, sounds, and storytelling, some with more than 5.000 years [6].

These two examples explore, in a creative manner, the union between technology and heritage. However, some identified gaps fruited the envisioning process that served as a foundation for this project: the non-participation in the climate impact, caused by some blockchain solutions and the demonstration of the current state of cultural and natural heritage assets. The first aspect was solved by studying existing blockchain platforms and using a "carbon-neutral" certified one. The second consisted of a creation of a new licensing model for NFTs, allowing these tokens to be time constrained.

3 USER-CENTERED DESIGN

User-Centered Design is an interactive design process, defined by ISO 13407, where usability, with a better understanding of the user, can vastly improve productivity and ease of use through more efficient designs that better support users' tasks and requirements.

This methodology influenced the two main components of this project. The front end was directly impacted as it was the main target of this methodology. For the back end, it did not have a direct impact, but rather a validation of the concept.

3.1 User Research

To start with this methodology, the first step was to study a group of possible users to better understand them and their needs. The main goal was a solution that adapts to the user, not otherwise. Thus, efforts began to create a plan to conduct further research to understand and specify the context of use and to specify user and organizational requirements.

A planning phase was conducted, using a brainstorming session, to define the usage context, the population, and the interviews. Most of these planning points, such as the usage context, would be validated during the user interviews.

- **Usage Context:** by analyzing current NFT marketplaces, such as OpenSea, Magic Eden, and others, it was noticed they could be used by a mobile application or a website. Moreover, it was noticed that an NFT Marketplace resembles a content-driven application like *Instagram* or *Tiktok*. With this in mind, further analysis was conducted to understand how web traffic was segregated nowadays. With this, it was concluded that mobile applications have a large amount of total web traffic and most people tend to prefer mobile applications rather than desktop apps or websites [7]. In short, the usage context of our solution comprised a mobile application that will bridge the user with an NFT Marketplace that incorporates the temporary NFTs licensing model to promote and save heritage;
- **Population:** using NFT marketplaces as a reference, two main user groups were identified: users and creators. Consequently, it made sense to define two groups for the solution: the clients (who can support the NFT) and organizations (curators who can create new NFTs but also support them). To better help with the study, clients were separated into three subgroups related to their expertise with NFTs: users without experience, users with some experience, and users with experience. For organizations, and to further improve the design concept to meet enterprise demands, Turismo de Portugal was invited to participate in the study;
- **Population study:** given the context of remote working, it was decided to proceed with remote semi-structured interviews. These semi-structured interviews were based on a defined plot, however, participants were open to raising questions and diverging from the main topics, broadening the spectrum of concerns, ideas, and needs. For the organization use-case, according to their work context, a form, based on some interview questions, was created and sent via email. This form recognized organizational needs and concerns through a set of questions, related to both professional and personal environments, concerning NFTs;
- **Interview Requirements:** before conducting the interviews, a consent form was sent to the participants. This step was important to guarantee their privacy and for them to express their free will and availability to participate in the study.

After the planning phase, initial interviews were conducted and the form was sent via email. The interviews were conducted individually, via a remote conference application, with 9 participants, ages from 20 to 48 years. This population was dived into the subgroups that were defined during the planning phase. Each interview took about 30 to 40 minutes, depending on the interviewee's time.

A code was attributed to each participant, for both form and interviews, to better distinguish them and to help with the anonymization phase (complying with the General Data Protection Regulation).

Preliminary results from these interviews demonstrated users' needs and concerns but also a validation of the whole concept, where even the expert users found the concept of having temporary NFTs to save heritage interesting and promising.

3.2 Synthesizing User Research

After collecting all the necessary data, an analysis and a treatment needed to be done to organize all the data in the best way possible. The first step performed before diving into details was to transcribe and anonymize the interviews with the created codes. When this was concluded, the next approach was to create a "Map of Ideas".

A "Map of Ideas" consisted of a spreadsheet where participant opinions were categorized into multiple groups. These groups corresponded to the ones created for the interviews (introduction and NFTs, online shopping, protection of natural and cultural resources with or without NFTs, and other opinions) or the questions applied to the form (usage contexts, opinions, how NFTs were used, what was is important when promoting Portugal's natural and cultural

resources and other opinions). This organization allowed the conception of a panorama with participants' opinions at the center, observing some convergent and divergent opinions. Here is an overview of the results, by participants group:

- **Users with no experience on NFTs:** A tutorial needs to be part of the final application to show what are NFTs, what users can do with them, and what the temporary means in the NFTs context. The second decision was to implement a quick way of proceeding with the payments, using biometric authentication features. Finally, interviewees referred that they like applications with personalized experiences and that are intuitive, with good usability;
- **Users with some experience on NFTs:** a tendency was observed where users prefer applications with easy and secure payment methods like Google Pay and Apple Pay. These applications have one aspect in common: the use of biometric features to authenticate. Another tendency is that interviewees prioritize the image while doing online shopping, so, representing the assets by giving priority to the image is another feature that will be implemented;
- **Users with experience on NFTs:** for this group, not much has been added apart from some technical aspects given the nature of their knowledge about NFTs. However, two suggested features will be implemented. One is to tackle a possible security issue, where companies need to be approved before creating NFTs. The second is to give a more personal touch, empathy, and a feeling of acknowledgment to the final solution - create an award program where users receive medals after supporting NFTs;
- **Organization:** Although these answers were given within a form, they provided insightful information about how patrimony needs to be pictured, besides the physical aspect. Another important point, in agreement with the interviewed groups, is the possibility of having an in-app tutorial that explains what are NFTs, how they can be used, what they do contribute, and what temporary NFTs mean in this context.

3.3 Personas and Scenarios

Based on the previous section, the next step was to create Personas and Scenarios. Given the nature of this project, personas seemed to be the right choice as they can represent and communicate client needs, providing the designer with a clearer picture of the design target. In contrast with actors, personas are much more detailed, highlighting software development needs and engineering requirements, and, consequently, actors can be derived from personas [8].

A set of three personas were created to match the gathered information. For instance, each person matches an interview group. The first persona matches the first interview group, without experience. The second persona matches the second interview group and the organization, as users with some experience. The third persona matches the final interview group as users with experience.

Then, a subsequent set of activity scenarios were produced for each persona, showing an abstraction of users performing tasks. The creation of scenarios allows the designer to move from the problem space to the solution space, starting with the creative process [8]. This set of activity scenarios comprised essential functionalities that were further implemented.

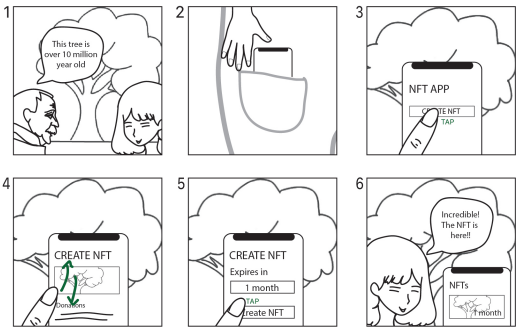


Figure 1: An example of an activity scenario.

After creating personas and scenarios, a quick ideation process using sketching took place to draw some ideas for the elements of the main user interface (UI). As described by Nisi and Nunes, ideation is the process that goes between the insights (user research) and the start of the prototyping phase (2021). This phase departs from the scenarios and is used to inspire the design process, and uses, among other techniques, sketching "to express ideas/potential solutions and explore the design space" (Nisi & Nunes, 2021), being quick to make and provided when needed. The final iteration of this process resulted in ideas for some elements like the "Main App Navigation Bar". As this bar had rounded corners, this tendency was followed across the other elements of the application, including the navigation/tab buttons and the NFTs boxes, as described in the next paragraph. The decision to make a single navigation bar that adapts to the screen and to maintain a similar UI aspect across the application was made considering some of the Shneiderman "Eight Golden Rules" for designing User Interfaces [9] and Norman's Design Principles [10].

Embracing the user study done until this point, including the personas that capture the needs and concerns of the users, the scenarios that describe the personas using the solution and their functionalities, and the ideation phase, the prototyping phase took place. The main goal of prototyping was to gain information about the design of the interactive system at a fast pace. When used in an organizational environment, prototyping, combined with user studying, can save costs and development time. Fidelity refers to the proximity of the visuals to the final solution in terms of fonts, sizes, messages, colors, and other aspects.

3.4 Low/Mid-Fidelity Prototype

Usually, Low-Fidelity (Lo-Fi) prototypes are represented by sketches that omit lots of details to focus users, when testing, on the functionality rather than visuals. Today, we have applications that allow designers and developers to quickly build prototypes with some functionality and basic visuals. For instance, Adobe XD was the elected application because it provides multiple functionalities inside their free-tier accounts, like real-time collaboration and prototype testing using a web browser, allowing some interaction without increasing development costs and times.

With this, and before the creation process started, it was decided that all the designed screens and functionalities needed to be coherent with the previous problem space, following users/personas' needs, taking into account scenarios and the ideation phase. The screen types were also defined as follows:

- The splash pages (layer 0): the first pages that the user will see when installing the application for the first time;
- The main pages (layer 1): the main screen pages that will appear after user registration/login;
- The secondary pages (layer 2): the pages that will proceed main pages. In other words, secondary pages will represent NFT details and organization details.

It was also defined that all the design steps would take into account Norman and Shneiderman's rules and principles, as this could bring usability to a high level from the beginning.

This process followed the components created during the ideation phase and also the users' requirements and needs. From this, the main pages were designed, followed by the secondary pages and ending with the splash pages. After the design process, all the interaction flow was defined on Adobe XD, by "drag-and-dropping" an element into another (for example, a button to a new page). Finally, with the design and interaction flow defined, Adobe XD created a link, allowing the application to be tested using a regular web browser. This enabled the user-testing phase to initiate.

Figure 2: The main screen page of the Lo-Fi prototype.

Before starting with the user testing, an initial plan was developed to define what was the goal, where the tests would take place, the duration, the population, the tasks, and the testing methodology. In short, the main goal was to evaluate usability aspects and gather participants' opinions with defined tasks, for 30 to 40 minutes. The tasks were based on the user scenarios and to conduct them, a "think-aloud" methodology was used, where participants were asked to externalize their thoughts and feelings while using the prototype. Since this was done remotely, a small questionnaire for each task was also applied to evaluate participants' critiques and opinions.

In addition to tasks with the think-aloud technique, two other techniques were used. The first one was the mental model technique, where the user was asked to describe, top to bottom, what they saw on the main screen. The second one was based on a System Usability Test questionnaire, at the end of all tasks, to evaluate the system's effectiveness, efficiency, and satisfaction through a single number (score) representing the overall usability of the system benign studied [11]. During the execution of the tasks by the participants, some usability metrics were collected, like the time to complete the task, the number of clicks, errors, and requests for help.

3.4.1 User-Testing Results. Starting with the usability metrics, the only task that didn't present positive results was task number four. This task consisted of the following procedure:

(1) Check the price of the NFT you added to your favorites;
(2) Check if you have enough NEAR crypto to support the NFT;
(3) Support the NFT that you added to your favorites;
(4) The task is complete when you receive an achievement.

From the think-aloud technique, the main hesitation was related to the user checking available crypto. the following comments were uttered:

- "There should be an easier way to check how much crypto you have";
- "The value that we have on wallet should be more evident when supporting, we should not need to exit the NFT to check our amount";
- "Try to put Wallet value inside the payment. Also, I didn't like the current profile icon with a smile";
- "I have no idea where I can check how much crypto I have".

It was clear that the current flow of checking the user balance wasn't ideal, as participants needed to exit the screen when they were to support the NFT, go to the profile screen to check the balance, repeating the procedure.

As what concerns tasks 1, 2, 3, 5, and 6, comments and results were very positive. All tasks were completed without problems, in an acceptable time. Some opinions were given regarding some elements and other flows, such as: removing the wallet login from the login screen to the profile page (allowing users without wallets to check the available NFTs), changing the create NFT button from the profile page to the main navigation bar and to reduce the "roundness" of the user-interface.

By exploring System-Usability Scores, it was noticed that the application usability score was high, with an average score of 98 points out of 100. This value showed concordance with the overall satisfaction and opinions collected during the think-aloud and mental model techniques.

3.5 High-Fidelity Prototype

Departing from the Lo-Fi prototype and based on the user-testing requests and opinions, the High-Fidelity (Hi-Fi) prototype was

designed. The first thing that was considered was the development framework. Since Adobe XD is a prototyping/design tool, we wanted to prepare the Hi-Fi prototype to receive all the blockchain functionality (back end) without changing the development platform. With this in mind, the chosen platform was Flutter, given its versatility to adapt to code changes and to multiple devices and platforms.

The next step was to better study and chose design principles and usability rules, for instance, one of the chosen design principles was repetition, to ensure the presence of consistency across the application. Proceeding this study, some visual aspects of the application were defined, such as the color palette (both for light and dark mode, as a requested feature by the users) and topography.

After this definition, the development process began following a "bottom-up" approach, since each element UI for flutter is a Widget, and Flutter works by encapsulating Widgets. For each iteration of this bottom-up approach, users' complaints, suggestions, and improvements were taken into consideration, as well as all the defined design and usability principles.

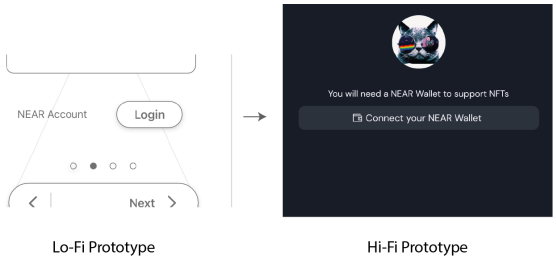


Figure 3: Example of an improvement from the Lo-Fi prototype - changing the location of the login button.

After completing the design and basic functionality development, it was defined that the user study of the Hi-Fi prototype would take place after implementing the back end functionality, related to the blockchain and NFTs. With this, participants would be apple to test the functional prototype, which would be very close to the final solution.

4 NON-FUNGIBLE TOKENS

The purpose of this project was to tackle the potential of NFTs to protect natural and cultural assets with a difference from similar projects - the creation of a new licensing model where the NFT expires after a defined time. This solution promotes the asset and intends to keep a continuous flow of "donations" to help in repairing and protecting the asset. To create this new NFT licensing model, it is necessary to implement and deploy a smart contract on a blockchain platform that supports them. In the present context, a smart contract is a piece of executable code that runs on top of the blockchain [12].

The idea behind this second methodology was validated during the first methodology and directly impacted the back end component of the solution. The back end would enable a bridge between the front end and the blockchain, allowing the final solution to be created.

The first approach for this framework was to choose a good blockchain platform, with smart contracts support and a carbon-neutral footprint. After choosing the platform, two smart contracts were created to tackle all the required functionalities for the back end. To end, an Application-Programming Interface was developed to connect Flutter to the chosen blockchain platform, given the nonexistence of existing libraries.

4.1 Platform

In order to choose the blockchain platform, the first step was to analyze multiple blockchain solutions such as Bitcoin, Ethereum, and Monero. However, it was perceived that these solutions were mostly based on the Proof-of-Work consensus mechanism, which is known for consuming large amounts of energy, increasing their carbon footprint [13]. Departing from these platforms, platforms like Avalance, Tezos, Algorand, and NEAR Protocol were studied, as they were promoted as "low-carbon" solutions.

To compare these platforms, some criteria were defined, such as smart contract support, smart contract scripting language, emissions per transaction, and carbon-neutral certification. Starting with emissions per transaction and smart contract support, the only two platforms that had a near value of 0 *g CO2 eq* in terms of emissions were Algorand and Near Protocol. However, NEAR Protocol was the elected blockchain platform for this project, given their "Climate Neutral Product" certification given by the South Pole in 2021 and their user-friendly developer documentation and community.

4.2 Smart Contracts

Following NEAR Protocol documentation, it was noticed that two smart contracts were needed. The first smart contract would be responsible for minting and enumerating temporary NFTs. The second smart contract would be responsible for managing the minted NFTs, that is, performing the NFTs transfer between the actual owner and the buyer with a set of requirements, like a sales price. NEAR Protocol allows the development of smart contracts in Javascript and RUST. RUST was the chosen language as it allows granular control of the code, and was designed for performance and safety.

4.2.1 Temporary NFTs Contract. The main goal of this smart contract was to create a solution, that comprised the following requirements:

(1) Mint temporary NFT by providing a timestamp that represents the date when the NFT will be flagged as expired;
(2) Have enumerating functions to correctly display minted NFT;
(3) Allow NFT transfers via cross-contract calls;
(4) Have royalties support.

However, the first challenge was created, as we needed to deal with time constraints and synchronization in a decentralized system (a sub-type of a distributed system). Concretely, for the proposed licensing model, synchronization and clocks are issues in this context as the temporary NFTs idea needs to keep track of the current time. The main idea behind this model was to apply an expiration

time timestamp to the NFT metadata, comparing it to the current time timestamp to evaluate if the token has or has not expired.

The first solution candidates were not ideal as they belonged to the "user space". In other words, the first candidate was to use the users' local clock, which could be a problem given different time zones, incorrect clocks, and possible malicious behaviors conducted by the user. The second candidate was to use a time server running a known synchronization and clock algorithm, like Network Time Protocol (NTP). However, we could not have guarantees that the server output was correct. Moreover, it became a single point of failure, which breaks some properties of a decentralized system. To overcome these issues, a trusty timestamp, agreed upon by the majority of the nodes, and as close as possible to the current time was needed.

By exploring NEAR Protocol's RUST Software Development Kit (SDK), a function called **block_timestamp()** was noticed, returning a 64-bit unsigned integer with "current block timestamp, i.e, number of non-leap-nanoseconds since January 1, 1970, 0:00:00 UTC.". In other words, each block that enters the chain has a timestamp that is agreed upon by the blockchain nodes. As this output comes directly from the NEAR Protocol blockchain, it was expected that this value was trusted, making it a potential candidate to solve this challenge.

Some tests were conducted where a benchmark command was created. This command outputs the block timestamp number from NEAR Protocol's blockchain, by making a call to a test contract that was developed to return this number, and a query of the local machine time, which was made sure to be correct and precise. Considering the network latency and the time that the first contract call needed, the average difference from timestamps was calculated. This resulted in an approximated time of 850 milliseconds, which was a "less-than-one-second" difference. It was considered to be acceptable, validating the second candidate and solving this first challenge.

The temporary NFTs smart contract was then implemented, based on a skeleton provided by NEAR Protocol's documentation. During the implementation, all the aspects regarding the NFT metadata, minting, enumerating, transferring and payout-related functions were modified and reinforced to make sure that expired tokens (where the block timestamp was lower than the NFT metadata expires_at field) were not allowed to perform these operations. With these reinforcements and modifications, a testing phase took place.

In this testing phase, the modifications and reinforcements were working as expected. For example, while minting an NFT using NEAR Protocol's Command-Line Interface (CLI) package, it was possible to create a new NFT passing the required metadata information, including the expires_at parameter. After creating the NFT with an expiration time fifteen minutes ahead of the current time, it was possible to see the NFT both on NEAR Protocol's Wallet UI and CLI (by calling the modified enumerated functions). Passing these fifteen minutes, the NFT was no longer displayed on NEAR Protocol's Wallet UI and CLI.

As the implementation of this smart contract was a success, providing a foundation for users' (in the context of this project, organizations) to create time-constrained NFTs. It was needed to implement a second smart contract. This second smart contract was responsible for listing the NFTs created with this temporary NFT contract and allowing their purchase, paying to the owner (organization), and proceeding with royalties payments.

4.2.2 NFT Marketplace Smart Contract. The main goal of this smart contract was to create a solution, that comprised the following requirements:

(1) List all the NFTs present within the Temporary NFT Smart Contract, including the expired ones for visualization purposes on the front end;
(2) Transfer non-expired tokens between the owner and the supporter.

This smart contract had no relevant challenges, as the relevant logic regarding temporary NFTs was already defined in the previous smart contract. With this, and based on NEAR Protocol's marketplace smart contract skeleton, it was needed to ensure that marketplace functions were time-sensitive. In other words, this means that any operation needed to be done with a non-expired NFT, from putting it to sale to selling it.

However, before starting with the implementation, it was important to illustrate how this contract will communicate with the previous one. Through cross-contract calls, the two contracts were able to communicate, as demonstrated in the figure below. This diagram shows the process since Organization "A" mints the NFT (1) and User "B" decides to support it (7), finishing with the respective payments (8, 9, and 10).

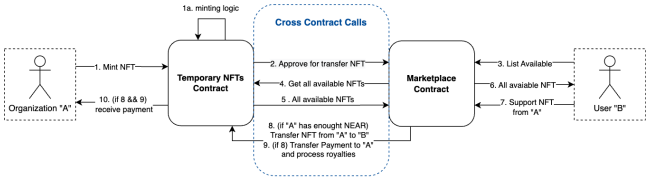


Figure 4: Minting through supporting the NFT - Cross Contract calls.

As observed from Figure 4, everything that comprises the NFT support phase was done via cross-contract calls. The flow on which the back end was based for minting/creating NFT does a cross-contract call after minting the NFT to approve the Marketplace contract to display and transfer NFT.

Concerning skeleton modifications, it was necessary to change the Sale structure to return the NFTs with the *expires_at* parameter and to change internal functions to prevent selling and/or supporting expired NFTs.

4.3 Communication with Flutter

NEAR Protocol did not provide any library to materialize the connection between their Blockchain and Dart/Flutter by the time of this dissertation project. Third-party libraries were not ready yet to be used either. This situation created a new challenge, which was, how these two components would communicate and how to create, display, and sell NFT from the final solution UI.

After reading NEAR Protocol's documentation, it was noticed that they offer an API for doing Remote Procedure Calls (RPC). However, this was a great solution to perform view calls (any call

used to query the contract). Function calls used to modify the blockchain needed to be signed with the caller's NEAR Wallet private key, and the documented way for creating a transaction from scratch seemed virtually impossible. By doing web research, it was found that a NEAR Platform's Representational State Transfer (REST) server existed, based on their JavaScript API, simplifying how these transactions were created. However, one of the problems remained - these transactions needed to be signed with a private key.

4.3.1 Getting users' NEAR Wallet Private Keys. The first approach conducted to understand how web browsers save wallet private keys were to open Chrome Dev-Tools and search for evidence. It was found, after the first login attempt, that the NEAR Wallet website saved a cookie with the users' private key. From this observation, a solution candidate was created: having an in-app browser that opens when the Wallet Login button was pressed by the user. After completing the login using NEAR Protocol's Wallet website, the private key needed to be securely stored, in the user device only.

To materialize the described solution, an in-app browser was added to the Hi-Fi prototype. If the application detects a user without a Wallet, a "Connect your NEAR Wallet" appears on the Profile Page. After pressing this button, an in-app browser appears, showing the default NEAR Wallet Login website (*wallet.testnet.near.org*). From the moment that this in-app browser is created, it keeps listening for a cookie with the private key. When the user completes the log-in, this cookie is created and the browser closes, saving the cookie value. As cyber-security was a concern, these private keys were saved locally, using in-device encryption provided by each operating system. For example, iOS saved this value on their Keychain and Android on Keystore. This process was simplified by using a Flutter package called *flutter_secure_storage*.

4.3.2 Communication with NEAR Protocol for calls and transactions. After getting users' private keys, transactions could be easily signed, enabling organizations to create NFTs and "normal" users to support them. As the communication is based on RPC and REST servers, all requests need to be made using HyperText Transfer Protocol (HTTP) through the Secure Sockets Layer (SSL), for extra security. For this, all the endpoints were defined in a constants file and a class was made to handle the HTTP communication. This allowed the creation of signed JSON requests to be sent and processed by the remote servers.

This chapter concludes the description of the two main methodologies and components used for this project, allowing us to move to the final solution space.

5 FINAL SOLUTION

The initial analysis of existing NFT marketplaces and platforms also helped to identify their strengths and weaknesses, creating the perfect environment to seek an opportunity. This opportunity comprises not only the new licensing model but also the need for a solution that was able to:

- instruct users about NFT, concerning their nature, application, and usage;
- create/mint NFT directly from a mobile application using a carbon-neutral platform;
- create a new use-case for NFTs, trying to demonstrate a part of their true potential.

After carefully studying the user, understanding their needs and desires, developing the Hi-Fi prototype based on the Lo-Fi user testing, and developing the two smart contracts with communication integration with Flutter, the final solution could be created.

5.1 Requirements

Taking into account the research full research performed for this project, including the related work, existing NFT markets, and understanding the potential users and their needs/desires, the following list of requirements was created:

- Creating a tutorial where users could learn more about NFTs and the created licensing model;
- Having an easy-to-login flow where users were able to log in with an existing account provider;
- Allowing organizations to register in the solution and their accounts to be verified and approved prior to their first login;
- Display existing NFTs in an intuitive way, showing the right information about the asset and focusing on the image;
- Allowing users to support non-expired NFTs from the application;
- Allowing approved organizations to create new NFTs from the application;
- Making sure that all user requirements, concerns, and desires are met, for example, enabling biometric authentication each time that NEAR Protocol Wallet balance needed to be changed;
- Follow design and usability concerns to create a cohesive, easy-to-use, aesthetic application.

5.2 Architecture

From an architectural point of view, this solution was crafted following a layered "Three-Tier Architecture". This architecture allows local changes on individual tiers given the low dependency between them (the upper depends on the immediate below) [14], creating a fertile field to use User-Centered Design methodologies given the nature of its interactive process. From a development point of view, Model-View-Controller (MVC) was the pattern chosen to comply with the architectural pattern and to promote more flexibility. Before proceeding with architectural details, an entity-relationship model was created to better conceptualize and plan each solution and the inherent architecture.

In short, the three tiers were:

- **Data Tier:** responsible for accessing, processing, and storing all the information that is needed for the application to present information successfully, according to users' requests [15]. For this tier, Google Cloud Firestore and FireAuth were used to store relevant data and user authentication data, respectively, in a secure and responsive way. Besides Google solutions, the NEAR Protocol blockchain was the primary source of information for this project. Queries to NEAR needed to be made to keep the system reliable and to track updated information. To comply with MVC, models were created for each structure;

- **Logic Tier:** This second tier is the heart of the system, responsible for low-level details to enable reliable communication between data and presentation tiers, ensuring that business rules are met [15]. For this tier, some logic features were based on Google's Firebase business logic. For example, Firebase allowed the implementation of multiple login providers. Besides Firebase logic, the implemented logic in the system ensured aspects like Pages interaction, location and distance calculations, activation of message pop-ups to inform users of their actions, and others. This also includes the NEAR Protocol communication part that was implemented from scratch. To comply with MVC, controllers, and providers were created;
- **Presentation Tier:** This final tier is responsible to hide all the logic underneath the application, showing users what they really need to see, in order to create an accessible and easy-to-use solution. With this, the UI runs on a mobile device with iOS or Android, with a Flutter-based application. To comply with the MVC pattern, views were created for each Page, allowing them to talk with the controllers to present all the necessary data to the UI.

6 FUNCTIONAL PROTOTYPE

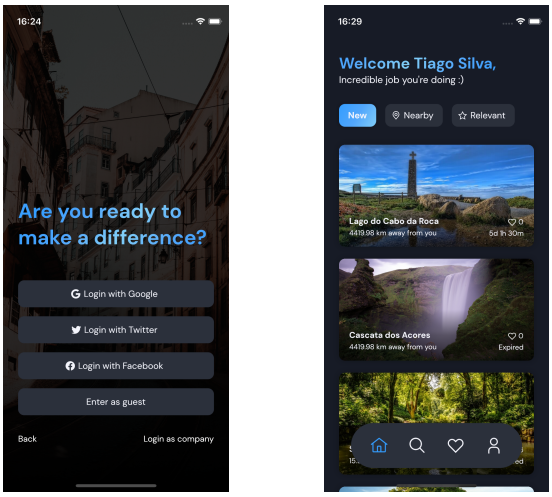
Based on the Hi-Fi prototype and on the developed blockchain integration, the third and final prototype was created. This prototype joins the two main components of this project - the back end (defined in the Non-Fungible Tokens chapter) and the front end (defined in the User-Centered Design chapter). This functional prototype was carefully crafted taking into account all the users' requirements and the studied design and usability principles. The following topics will cover the main functionalities of this prototype.

Splash Pages - Login/Register, Tutorial and Organizational Login

The splash pages comprise the first interaction that a user has with the application. They were composed of a Welcoming Page, where users can choose to do a tutorial or to proceed to the Login Page. The Login Page allows users to log in with 4 different providers: Google, Twitter, and Facebook, and enter as a guest (without the support for supporting NFTs and favorites functions). This page also shows an option to log in as a Company. The log-in as a Company Page comprises the log in via email field and a page to register the organization, with all the required fields and explanations.

Main Pages - Home, Search, Favourites, and Wallet Login

After the Splash Pages, users are presented with the Main Pages. These pages include the Home Page which shows a welcoming message from a set of defined messages, the new NFTs, and the options to see the Nearby NFTs (in a range of 5Km) and the relevant ones. The Search Page allows users to search for NFTs and organizations by their name or location. Then, the Favourites Page displays organizations and NFTs that users add to their favorites. Finally, the Profile Page where users could see their information, the supported NFTs, and medals, in case they have a connected wallet. Otherwise, it displays a button to use the in-app browser feature implemented to get users' NEAR Wallet private key.



(a) Login Page. **(b) Home Page.**

Figure 5: The prototype's Login and Home Page.

Secondary Pages - NFT and Organization details

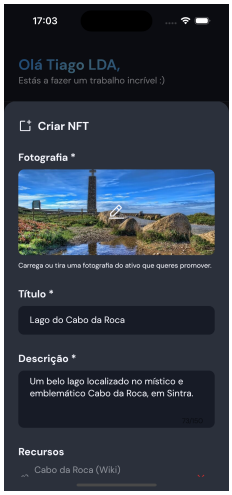
These secondary pages show the details related to the temporary NFTs and to Organizations. Regarding the NFT details page, it shows the image (as the most important aspect), followed by a title and the time remaining for expiration. Then, it shows its history, location, available resources, and how the funds will be used. Concerning organizations, it displays useful links to their website, email, and phone, their description, statistics, and active/expired NFTs. As described in the Hi-Fi Section, the Main Navigation Bar adapts to the actual screen. In Secondary Pages, the back button is present, together with other textual information that fits the context where its located, for example, to support the NFT for an amount of NEAR.

Creating temporary NFTs (Organizations Only)

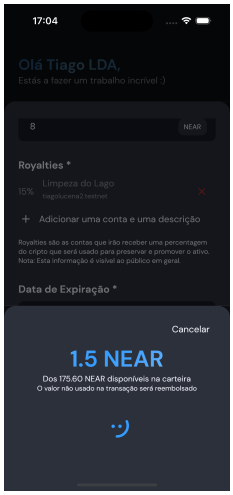
In the final solution, organizations are able to mint and put the created NFT on the marketplace, directly, with just one simple page. This page is an overlapping page that appears when organizational users click on the "Create NFT" button present on the Main Navigation Bar. The requested fields to create a new NFT are a photo, a title, a description, possible resources (links), location (opening a map picker), price, royalties definition, expiring date, and a consent checkbox. After pressing the create button, users are requested to authenticate using a biometric feature or, in case of the absence of this feature on the mobile device, the device PIN/Password.

Supporting NFTs

If the NFT is not expired, users are able to support them. By clicking on the "Support for X Near", where X is the selling value, users are prompted with the Confirmation overlapping page where they can use their biometric setting or phone PIN/Password. To provide users with feedback, a little animation appears after confirmation (which happens through the application when the overlapping confirmation page appears). If the supporting process is completed

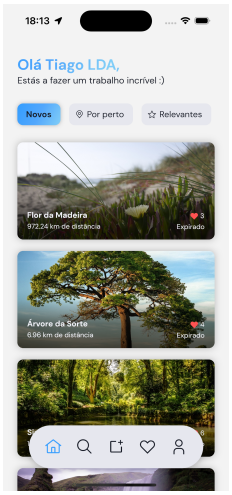


(a) Create NFT Overlay Page.

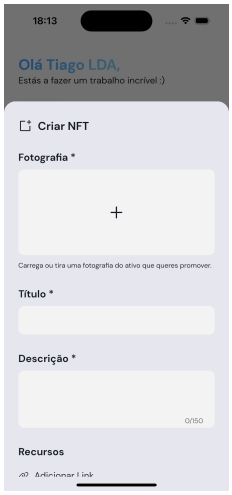


(b) After confirmation.

Figure 6: Creating and NFT and authenticating with biometric settings.



(a) Light Mode - Home Page.



(b) Creating NFT - Light Mode.

Figure 8: Example of the application with Light Mode and Portuguese language.

successfully, users receive a medal depending on their actual context (number of supported NFTs, for example) to congratulate the user, making the phone vibrate too. Users are able to check their supported NFTs and Medals on the profile page.

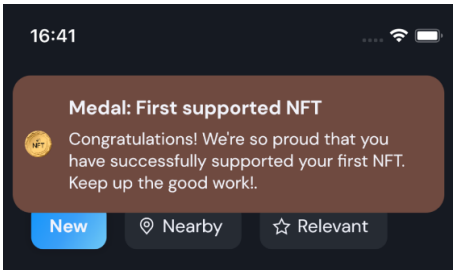


Figure 7: User winning a medal for its first supported NFT.

Extra Features - Light/Dark Mode and Localization

A requested feature by users since the initial interviews, where some participants demonstrated interest in apps with this functionality was Light and Dark mode. Some participants, during the Lo-Fi prototype testing, also requested app localization, both in Portuguese and English. By inquiring participants about these two features, they all showed a preference for apps where these features are automatically defined by the phone settings. With this, the final application is able to see the context where the device is into, a react according to it. For example, if a user has light mode and the device is in Portuguese, the app will obey these settings. If a user.

6.1 Evaluation

For testing the Functional Prototype (FP), the experimental plan was based on the Lo-Fi but less rigid, as usability and interaction flow was positively tested using the Lo-Fi prototype. Given the available time frame and participants' availability, only three participants tested the FP prototype, of which one is a UI/UX expert, with a degree in Graphic Design.

Regarding the testing techniques, it was asked to the participants to complete a set of tasks using the think-aloud technique. After completing the tasks, it was asked to participants to freely use the application and to give their feedback regarding the overall experience and look and feel. Finally, a small User Experience Questionnaire (UEQ) questionnaire was applied to the participants. All the tests were conducted in person, so participants could use the FP on a working phone, simulating the environment where this application was intended to be used.

Regarding the tasks, all users completed them correctly, without errors, and without hesitations. The overall feedback was extremely positive, with some compliments: "with was great that you added several login options and a detailed tutorial for those who don't understand what NFTs are", "the bottom sheet that appears from the bottom to create the NFT, sending back the previous content, looks amazing. The NFT details fields are also very organized" and "The medal after buying the NFT is a very personal touch that fits extremely when in the context, motivating application users' to support more".

Concerning the UEQ and after analyzing the resultant graphs, all values were above 2 (on a scale from -3 to 3), which was excellent in terms of the quality of the developed solution, showing user satisfaction. Although the population was small, the results are concomitant with the evaluations from the Lo-Fi prototype. The achieved results were validated by the UI/UX expert, which also participated in the previous tests.

The general opinion, collected from all the tests, including the Lo-Fi user testing, is represented in the following word cloud:

6.2 Discussion

From the final evaluation, it was possible to extract three conclusions:

Figure 9: Word cloud with the most used words during the testing of the prototype.

- UCD was confirmed to be an excellent approach for conceiving, designing, and developing solutions that met users' needs. All advantages were confirmed, showing great user satisfaction in the end;
- Users' participation from early stages helped to develop a cohesive product that met their requirements from the beginning, where production costs were devoid;
- Taking into consideration design/usability principles and rules since the beginning had multiple advantages through the creative process. For example, most user satisfaction concerning usability was met during the Lo-Fi prototype testing.

This demonstrates that the User Centered Design study was a success and the users' requirements and concerns were met. These results also demonstrate how the integration between the front end and back end was successfully achieved, solving the concerns and issues from the users' point-of-view and development point-of-view.

7 CONCLUSION

Because of the twin Nature and climate change crises, several problems are emerging, threatening our heritage. Human action, environmental issues, and forgetfulness are causing some cultural and natural patrimony to be on the brink of destruction. Recent solutions employ the robust capabilities of NFTs to promote culture and create a source of donations to preserve it.

This project explored a temporary licensing model, combined with a carbon-free certified blockchain platform, which provided the foundation to create a mobile-based NFTs marketplace application to promote and preserve Portugal's natural and cultural heritage. To validate both concepts, a User-Centered Design framework provided the tools needed to carefully listen to users' needs and context, gathering important data to design a solution that met their concerns, and desires.

Besides validating the concepts, User Centered Design allowed the design and development of Flutter-based usable and aesthetic application – the front end - based on users' opinions. For the NFTs – the back end - a set of two smart contracts was developed, one to implement the temporary licensing model and the second to implement marketplace functionalities. To enable communication with Flutter, a set of procedures were defined, including the development of a way to retrieve users' private keys to sign transactions.

Ultimately, the Functional Prototype, which integrates and bonds the front end and back end components was tested by users. It is important to mention that all the user-testing, from the Lo-Fi prototype to the Functional one presented very positive feedback and user receptivity, demonstrating that UCD is an excellent framework to envision and create solutions "from humans to humans". By interpreting all the results, it is possible to conclude that all of the objectives were achieved, meaning that a novel Temporary NFTs marketplace application, to promote and protect heritage, was created and validated.

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