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

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Declaration
I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

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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

Resumo

A presente dissertação visa o desenvolvimento de um modelo alternativo de licenciamento de NFTs e de uma aplicação móvel representativa de um mercado de NFTs, aplicando o referido modelo. Tais criações tiveram, como seu ímpeto principal, a promoção e preservação do património cultural e natural, elementos cruciais à nossa identidade e indispensáveis à conservação da singularidade do nosso legado. Assim, fica ressalvada a importância destes recursos, os quais se demonstram imprescindíveis à formação de uma consciência à escala global. Ao indagar sobre o estado da arte, alavancando as tecnologias de blockchain e NFT ao serviço do património, foram destacadas a procura por uma solução de blockchain neutra em carbono, bem como pela criação de NFT temporárias, permitindo uma fonte de donativos contínua aos seus autores. Com isto, foi seguida uma metodologia de design Centrado no Utilizador, respondendo às inquietudes dos intervenientes, e sendo tal combinado com princípios de design e usabilidade, no intuito de validar o espírito subjacente a este inovador modelo de licenciamento. Ora, de forma a sedimentar tais conceções, assim como alcançar as suas implicações ao nível de design, foram conduzidas uma série de entrevistas e técnicas de teste de protótipos. Tendo, como resultado, a implementação de dois "smart contracts", através da plataforma de blockchain NEAR Protocol, surgindo uma aplicação baseada em Flutter. A solução demonstrou-se financeiramente viável e, sobretudo, sustentável, conseguindo descortinar o estado atual do património de forma a propiciar uma fonte contínua de proventos canalizados à sua manutenção, e com resultados favoráveis no que respeita à usabilidade e design, provando a eficácia das metodologias e plataformas elegidas.

Palavras Chave

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Listings

Acronyms

API	Application Programming Interface
CLI	Command-Line Interface
EU	European Union
FP	Functional Prototype
GDPR	General Data Protection Regulation
Hi-Fi	High-Fidelity
HTTP	HyperText Transfer Protocol
IPFS	InterPlanetary File System
JSON	JavaScript Object Notation
Lo-Fi	Low-Fidelity
MBaaS	Mobile Backend as a Service
ms	Milliseconds
MVC	Model-View-Controller
NFT	Non-Fungible Token
NTP	Network Time Protocol
PoS	Proof-of-Stake
PoW	Proof-of-Work
REST	Representational State Transfer
RPC	Remote Procedure Calls
SDK	Software Development Kit
SSL	Secure Sockets Layer
SUS	System Usability Scale

u64	Unsigned 64-bit Integer
UCD	User-Centered Design
UEQ	User Experience Questionnaire
UI	User Interface
UX	User Experience

1

Introduction

Contents

Nowadays, technology plays a fundamental part in our lives, from solutions that organize our daily tasks to large machines that filter the air we breathe [1]. Recently, the Blockchain phenomenon has brought us a range of technologies that could revolutionize our lives. Blockchain achieves this by enabling a secure and tamper-proof digital record, which aims at decentralization as a security measure. Information is added linearly and chronologically, creating consensus and trust in the communication between two or more agents [2].

Building on the blockchain technology, the concept of Non-Fungible Tokens (NFTs) emerged by representing a cryptographic token, "a digital unit of value that lives on the blockchain" (METACO, 2021) representing something unique, not mutually interchangeable [3]. Since NFTs application in arts, games, and music, the most prevalent is the sale of assets in NFTs markets [3]. They are a new power to art and artists by "tokenizing" digital content, securing property rights, avoiding unreliable art keepers, and promoting small artists [3, 4], but the potential is still vast. Questions about how to use this technology to help humanity and the planet, educate younger generations, and support elderlies are still to be answered.

As UNESCO recognizes cultural and natural heritage as vital resources to tell our story to future generations [5], it is imperative to promote protection and conservation, and technology can play an important role to solve these issues. Cultural and natural heritage resources are not renewable [5]. Preserving those resources created a severe tendency to exclude human activities, such as tourism, which cut their value significantly. Furthermore, there is a tendency to remove heritage sites and items from the community that owns them [6].

It is also important to mention that heritage can be damaged by increases in pollution, also caused in part by human action. This phenomenon contributes to the destruction of natural and cultural heritage [7]. For instance, the rise in the average sea level or temperatures can lead to the wear of monuments (cultural heritage) close to coastal areas [7]. Fires and deforestation are major contributory factors to the destruction of biodiversity, such as trees (natural heritage) that may be hundreds of years old, and are living testimonies of human and nature co-existence and collaborations [7].

The conservation of natural and cultural heritage involves its fruition and preservation at the same time, therefore a dilemma [6]: usage can lead to destruction. Thus, a new solution has to be discovered, to maintain their history, to show them to the public, while, at the same time, contributing to initiatives that call for their conservation. This solution may even allow the promotion of the protected cultural and natural heritage of humanity, such as fields of natural biodiversity, natural parks, forests, and indigenous areas.

Technologies have been extensively used in the presentation and preservation of Cultural Heritage [8] and its values, in particular, in the form of augmented-reality technologies guiding visitors through physical spaces, such as museums [9] and heritage sites [10]. Users can be guided through the complexities

of the information, presenting historical and artistic details of the artifacts through characters, plots, and interactive sequences of information based on audio or multimedia assets [10].

Moreover, during the last decade, several European Union (EU)-funded projects embraced this task. CHESS (2011-2016) [11] and recently MEMEX (2019-2022) [12] explored how to use technology and interactive storytelling to transform how we experience museums and heritage sites, expanding the heritage access to minorities and groups at risk of exclusion [13, 14].

Some contemporary examples include games and Transmedia Storytelling experiences [15]. For instance, "Fragments of Laura" [16] can create an impact and render curiosity to attract tourists to develop knowledge and awareness about the cultural and natural heritage of Madeira island, promoting ecotourism [17].

This dissertation explores how blockchain technologies, like NFTs, can 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. This dynamic behavior originates the perfect first challenge to create a solution that can capture and protect it. Departing from this point of view, NFTs are 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 - from a blossoming tree in spring to a forest full of snow in the winter. 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.

Given the nature of this project, where a mobile application will create a bonding between final users and the blockchain, a user-centered design methodology will be followed, defined by ISO 13407 [18]. This approach supports the development of a solution where users' needs and concerns are met. The combination of user-centered design methodology with the NFTs framework empowers users with an increased choice ability, through a unique experience - users have an application designed for them, and they can support an NFT of their preference - for example, a winter tree or a spring three, depending on what they like.

1.1   Project Structure

This section is intended to provide a clear view of how the multiple methodologies and system components were organized to absorb the two main topics of this project: NFTs combined with Cultural and Natural Heritage. Considering that a mobile application would be developed, two main components were

envisioned: the front end (system user interface) and the back end (system logic and functionality).

These two components were validated and implemented following two methodologies/frameworks: User-Centered Design (UCD) and an NFT framework. UCD provided the tools to validate both components and to design and implement the front end. The NFT framework administers the back end functionality, including how these two components communicate.

1.2 Document Structure

This dissertation document is organized as follows:

- **Chapter 2 - State of the Art**: introduces some notions related to this project and presents the research and analysis of state-of-the-art associated with the background concepts;

- **Chapter 3 - Non-Fungible Tokens**: details how the blockchain platform was chosen, the overall architecture for the smart contracts, problems, and solutions to tackle the developed temporary licensing model, smart contracts implementation, closing with the integration of the blockchain platform to Flutter, the User Interface (UI) Development Kit used for this project;

- **Chapter 4 - User Centred Design**: describes the process of planning and conducting the user research, synthesizing and processing the collected data sets, the creation of personas and scenarios, the ideation phase, the creation and evaluation of a Low-Fidelity (Lo-Fi) prototype, ending with the design of the High-Fidelity (Hi-Fi) iterating and improving the previous one;

- **Chapter 5 - Final Solution**: defines the requirements and the architecture for successfully conceiving this project, the creation of the functional prototype (final solution), finishing with the final user evaluation for this prototype;

- **Chapter 6 - Conclusion**: ends the present dissertation document by summing up what was achieved and by reflecting on future work.

2

State of the Art

Contents

The present chapter outlines existing solutions that combine the two themes tackled by this dissertation project: NFTs and Natural and Cultural Heritage. Given the novelty of NFTs [19], not much has been done in this field. The presented studies and projects are new, mostly developed in 2021 with some still in development. It was possible to identify some challenges in common with this dissertation project, namely, the digitization of physical assets or layering of heritage into the blockchain [20]. However, two particular points were found that none seems to solve: the longevity problem (keeping a revenue and promotion stream after the first purchase of the NFT) and environmental concerns (using a zero-emissions blockchain platform, with low gas fees) being the last one an important point to preserve even further current heritage [7].

2.1 Background

This section firstly explains what NFTs are, followed by an examination of the current market, closing with the importance of protecting Natural and Cultural Heritage.

2.1.1 Blockchain and NFT

NFTs stands for Non-Fungible token and can be defined as "a unit of data stored on a blockchain that certifies a digital asset to be unique and therefore not interchangeable while offering a unique digital certificate of ownership for the NFT" (Nadini et al., 2021) [19]. It identifies all the owners of an asset, transforming something digital (or physical, after being digitized) into a one-of-a-kind verifiable asset.

NFTs are an exponentially growing market and use case, departing from the original creation platform, Ethereum, to diverse implementations on other blockchain platforms [19]. One of the first categories to adopt NFTs was gaming for the trade of in-game objects [19]. Artists and digital content creators rapidly focused their attention on the platform's ability to certify a digital asset in terms of uniqueness and interchangeability, while guaranteeing ownership, via blockchain [3]. By 2022, NFTs are being applied to various contexts.

NFTs started in 2017 with CryptoKitties, a "collection of artistic images representing virtual cats (...) that allows players to purchase, collect, (...) and sell them on Ethereum" (Nadini et al., 2021) [19]. CryptoKitties completely congested the Ethereum Network due to its popularity [19]. In March 2021, the highest auction price was achieved for a living artist - Beeple - that sold an NFT of his work for $69.3 million [19].

Some ideas have emerged for smart contracts and blockchain to be used in court, reducing complex systems to enforce transactions [21]. This is supported by some blockchain characteristics, such as consensus, provenance, immutability, finality, and decentralization added to the powerful smart contracts and NFTs, further covered in Chapter 3.

Furthermore, NFTs could an excellent application for preserving cultural and natural assets. From getting funds to conserve natural resources [20, 22] to sustaining a full country patrimony [23], we can use NFTs as a helping resource. For instance, Portugal has its initiative to support social and helping institutions by transforming some of the splendid São Roque Museum art treasures into NFTs [24], while other works take advantage of what NFTs offer to protect wildlife and endemic animal species [25].

In conclusion, NFTs are a novel technology, and much ground needs to be covered.

2.1.2 Cultural and Natural Heritage

Heritage can be defined as everything that was created and left behind by our ancestors, or as the unending earth creations that are naturally transforming over time, such as the beautiful landscapes provided by forests [26]. It is perceived as an immeasurable and irreplaceable resource that can tell histories, ensuring personal and collective identity. Heritage can be found anywhere, in small things that we may have at home to lands and laws [26].

On one hand, Cultural Heritage represents the legacy of tangible or intangible, socially determined heritage assets, inherited from past generations. Regarding tangible culture, we have, for example, books, monuments, works of art, and artifacts. For intangible culture, we have, for example, traditions, language, and knowledge. On the other hand, Cultural Heritage also includes Natural Heritage. Natural heritage refers to the series of biodiversity elements, for example, fauna and flora, geological structures, and ecosystems [26].

Cultural heritage is something that needs to be protected and preserved, not only from human activity but from environmental changes. Above all, heritage induces respect, and future generations need to know what humankind has achieved so far [26]. In light of this, UNESCO manages and protects the special cultural and natural heritage of humanity. Thus, UNESCO has a document, adopted in 1972, that provides a framework for international cooperation in preserving and protecting cultural and natural areas across the world [5].

Technology is also considered an excellent ally to protect heritage. Hence, "the complement of traditional methods to cultural heritage management has been augmented with the introduction of digital or new media" (Kalay, et al., 2007) [8]. For example, storytelling is a tool to preserve and honor cultural heritage. Some recent efforts have combined digital games, and technology with storytelling to sensitize audiences to endangered natural patrimonies [27], and UNESCO-protected landscapes [16]. But the potential for blockchain technologies and NFTs in this field is still largely unexplored.

2.2 Related work

This section will cover existing projects and studies that conciliate the protection of natural and cultural heritage with technology.

2.2.1 The alliance between museums and blockchain

Technology, particularly Blockchain, can bring benefits to existing historic organizations, namely, museums. The article "Key blockchain projects to improve performance at the British Museum" [28] explores the benefits that the British Museum may achieve by adopting blockchain technology.

The authors start by noting that blockchain technology can benefit all stakeholders, including visitors and the host organization. A set of four strategic projects are presented, considering the strengths and weaknesses of the British Museum. One interesting aspect is the illustration table, provided in the article, with the detailed weakness and the blockchain solution for each project.

In short, the first project is an "Industry-Wide Loan and Provenance Tracking" that solves the lack of loan and provenance tracking by launching an industry collection database using the blockchain. Next, the second project is "Digital Art Footprint" solving the absence of digital art initiatives by promoting a digital art exhibition, featuring artwork made and exchanged on the blockchain. "Expanded Payment Methods" is the third project that solves the limited payment options in the Museum by allowing cryptocurrencies. The last project is "Accessible Market for Ownership", breaking the limitations of exclusive markets with encouragement for part-owners instead of one exclusive owner, the Museum.

To end the article, the authors present a very particular and interesting idea: "the lack of consensus to create industry standards for a volatile technology" (Gallagher et al, 2020) [28], by understating that these implementations are difficult but can bring major improvements to the museum.

2.2.2 NFT-based fundraising systems for preserving Heritage

NFTs-based systems are starting to be used to raise awareness or funding for nature conservation [25]. From artists like John Gerrard that released an NFT of his iconic "Western Flag" as a "Cryptofund" for Climate and Soil Regeneration [29], to the research-based project "Heirloom", developed by a team of students of Mugla University, in Turkey [22]. Heirloom 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 [22].

This project uses NFT technology, where the digital assets, previously assembled from the physical one, through a transformation process, are stored in an InterPlanetary File System (IPFS) [1]. Smart

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[1] A peer-to-peer hypermedia protocol

Contracts are the absolute key to the scarcity of intermediaries, making the transactions and the system completely autonomous [30].

The use case was a foundation for the development of the old olive trees in Milas, intending to simplify the resulting transactions and bureaucracy involved in traditional donation systems by promoting transparency to preserve cultural heritage and increase awareness around this area [22].

One identified issue in this work is the long-term sustainability of the technique regarding donations and the environmental impact of the used blockchain. For the first point, revenues might stagnate after purchasing the NFT. The second point concerns the usage of a zero-carbon blockchain solution as environmental impact is one of the causes of the degradation and destruction of cultural and natural assets [7].
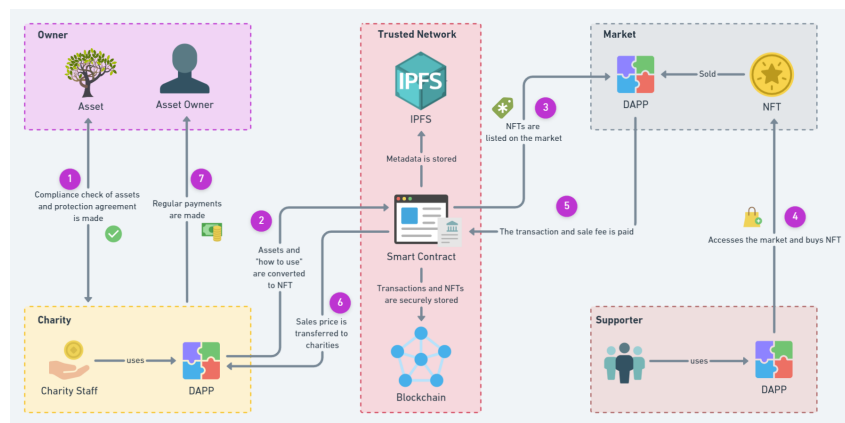
Figure 2.1: Heirloom architecture schema.

2.2.3 KHHN - Korea Heritage and History NFT

KHHN is a recent project to protect Korea's, one of the top 10 world economies [23], natural and cultural heritages through the powerful abilities of blockchain and NFTs. 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. The trade of these NFTs generates donations to preserve Korea's cultural and natural heritage [23].

Relying on NFTs, this project guarantees immutable and irreversible operations to record Korea's heritage information. This transformation, like similar projects that use NFTs, uses smart contracts. More precisely, this project uses Chainlink's decentralized oracle network, which provides "tamper-proof inputs, outputs, and computations to support advanced smart contracts on any blockchain" as referred to on Chainlink's website [31].

This project also tackles the two types of heritage that UNESCO recognizes [5]: Cultural and Natural Heritage. It was submitted to a Hackathon, "Chainlink Virtual Hackathon Spring 2021", that intends

to "build the next generation of smart contracts with Chainlink Oracle", winning one of the prizes in 2021 [23].

With deeper analysis, the team faced some challenges in common with this present dissertation project: "layering of heritage information and content chains" and "tokenization of heritage assets".

Figure 2.2: KHHN banner on their website `https://khhn.io/`, by January 10, 2022.

2.2.4 Using blockchain for Time-stamping Digital Culture Heritage

The project was one of the first approaches that used blockchain technology to save and preserve cultural heritage by time-stamping [32]. As "changing words in an article that only appeared online is relatively simple and changes can occur at any time" [32], the authors tried to develop a strategy for "securely preserving digital cultural heritage", identified by the German Society for Computer Science as a grand challenge [32].

With this, a web-based service was implemented to create "automatically trusted timestamps for any online content", as specified on their paper [32]. This system starts by autonomously downloading and archiving a web page specified by a user, similar to the "Wayback Machine"[2]. It then identifies the textual changes, creating tamper-proof, decentralized, trusted timestamps, making it impossible for changes to go unnoticed.

One weakness identified in this project, also stated by the authors, is the absence of a distributed version of the solution, to increase both solution's trustworthiness and availability.

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[2]An online service that caches multiple versions of a webpage over time

2.2.5 Art, antiquities, and blockchain: new approaches to the restitution of cultural heritage

This journal article, published on June 12th, 2020, highlights the potential of blockchain by presenting ideas on how we can save and preserve art and antiquities' history and possession [20].

It starts by giving some insights into the case of Byzantine Frescoes where the author had some trouble presenting the work as legitimate, after showing them for the first time. Blockchain, with its inherent properties, allowed these rights to be negotiated securely and immutably, giving credit and establishing concrete ownership, allowing decoupling of ownership and exhibition rights, e.g., for museums.

The authors expose four cases where it was possible to apply blockchain, namely, "splitting ownership and exhibition rights", "returning a portion of a group of artifacts" (by designing a portfolio approach), "recording of works in active archaeological digs" and "selling or donating privately held works" [20].

As stated, "these conversations build new versions of the collaborative networks intended in the original 1970 UNESCO resolution, while dignifying and respecting the autonomy of the varied source countries" [20], which is a statement that complies with creative solutions that can be powered by blockchain capabilities.

2.2.6 Future tourism trends: Utilizing non-fungible tokens to aid wildlife conservation

As the world population expands, the environmental impact of human activity is an increasing concern as the planet faces the challenges of environmental destruction and climate change [33].

Several animal species are in danger, leading to extinction. Moreover, some wildlife species, part of the planet's cultural and natural heritage, now remain only in certain parts of our planet [25]. By promoting a fundraising system supported by blockchain and NFTs, creating digital wildlife collectibles may help finance wildlife conservation [25].

The paper also explores NFT's *extensibility*, which is described as "the ability for one NFT to be another with another NFT" (Mofokeng et al., 2018) [25] allowing the creation of a new wildlife character based on a previous one, similar to CryptoKitties [34].

2.2.7 Memes and NFT trends to saving heritage performing arts

"Memes and NFTs trends can save heritage performing arts" investigates the support of NFTs and blockchain "to rejuvenate traditional art forms such as Kabuki" (Damodaran, 2021) [35] by transforming heritage artwork into so-called "memes". Kabuki is one of the three greatest Japanese classic theaters and UNESCO has branded this form of cultural celebration as an Intangible Cultural Heritage [36].

The author expresses the community's will to make this form of the culture known, especially to the younger ones, separating its multiple parts into smaller components. These components could be turned into "memes" since it is a powerful world that offers exotic possibilities [37]. Such memes could be transformed into NFTs, exposing the characteristics of the culture to a broader, digitally-native audience. This solution also serves as an initiative to boost the creativity of these organizations, given the low investment by the government and private institutions [36].

The author highlights three problems associated with the current NFT system, namely: the high costs associated with creating an NFT, the used energy, and the unfairness that exists in some markets where "the rich get richer". Finally, concerns about the heavy carbon footprint associated with the NFT minting process [3, 38].

2.2.8 Artentik - Santa Casa da Misericódia de Lisboa

Introduced at the 2021 Web Summit, Artentik is a platform curated by Santa Casa da Misericórdia de Lisboa to show the world Portugal's art treasure over the São Roque Museum. These assets are transposed to the digital world and then sold over NFTs, the profits of which are used to support social institutions. On December 1st, 2021, the first asset, one of the world's most-sacred art, was sold [24].

Since Santa Casa da Misericordia has been collecting art for over 500 years, gathering all the historic and cultural properties underlying them [24], blockchain and NFTs are perfect for securely storing these properties.

This initiative pushes even forward Portugal's technological advancements and marks an important step in preserving Portugal's cultural heritage through the use of blockchain and NFTs.
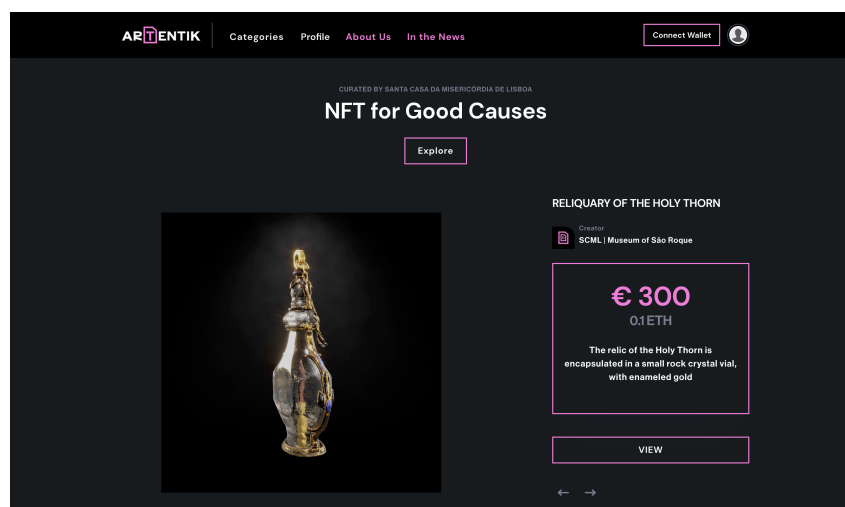
Figure 2.3: Artentik website https://www.artentik.com/ with "Reliquary of the Holy Thorn" being sold for 0.1ETH.

2.3 Discussion

After the above analysis, it was possible to see how creative and specific NFT solutions can be. NFTs are used to do good and to sustain our history and the planet, immortalizing past generations and making our heritage last for future generations to enjoy.

However, something that none of the solutions solve is the climate impact caused by some blockchain solutions [38]. Ethereum network is used in the majority of solutions, which, besides having high transaction fees, is a great energy consumer [39], which has a flow-on effect on climate change.

Another uncovered point by the solutions above is demonstrating the current state of cultural and natural heritage. For example, if someone wants to contribute by preserving a tree with great historical value, it would be interesting to show the actual changing over the seasons. Seasons have a direct impact on biodiversity, namely fauna, and flora [40].

These two details are an opportunity to innovate, the creation of temporary NFTs - a new type of token that provides a licensing model that is time-limited. This not only maintains a possible flow of donations but also contributes to the exposure and awareness of cultural and natural heritage. Given environmental concerns, a carbon-neutral platform also needs to be chosen, fulfilling the two identified gaps.

3

Non-Fungible Tokens

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This section will cover the framework used for this project - NFTs. This framework administers the backend functionality, including how it will communicate with the front end.

In the past few years, the term NFTs has gained immeasurable attention from computer enthusiasts and the public [19]. In short, NFTs are unique cryptographic tokens, saved on the blockchain, that can represent real-world tangible assets [3]. Many applications have emerged, especially in the revenue field with considerable NFT markets around [19].

However, the real potential of these tokens remains vastly unexplored, including their benefits and challenges [41]. NFTs current reputation is not promising, as they are being judged without real knowledge of their true potential, being over-explored to sell "tweets" or "memes" for large amounts of money [42].

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 [30]. This executable code "facilitates, executes, and enforces an agreement between untrusted parties without the involvement of a trusted third party" (Alharby & Moorsel, 2017) [30]. For example, it allows person "A" and person "B" (untrusted parties) to buy each others' NFTs (agreement) without a need for person "C" (trusted third party) to mediate and certify the agreement.

The following sections will cover the main blockchain platform chosen for this purpose, as well as the process of implementing and testing the Smart Contracts. This chapter ends with the creation of a bridge between the blockchain platform and Flutter (the platform chosen to implement the front end component, as will be described on Section 4.3). In other words, it will describe how the communication between the front end and the back end was implemented.

3.1 Platform

Starting by analyzing multiple existing Blockchain platforms such as Bitcoin, Ethereum, and Monero, [43], it was perceived that this popular platforms were not appropriate for this project based on their carbon footprint associated with the use Proof-of-Work (PoW) and similar consensus mechanisms. PoW is well-known for consuming large amounts of energy as it uses computer-intensive tasks to create consensus, a crucial property on the blockchain [44]. Since part of this dissertation project consists of maintaining natural and cultural patrimony, using a low-carbon blockchain such as Stellar [45], Avalance

[46], Tezos [47], Algorand [48] or NEAR Protocol [49] is a more appropriate choice. These platforms were assessed as they promote low-carbon operations, all based on Proof-of-Stake (PoS) consensus mechanism.

Table 3.1: Comparison between low-carbon blockchain platforms.

Platform	Consensus Protocol	Smart Contract support	Smart Contract Scripting Language	Documentation Type	Emissions per transaction (g CO2 eq)	Certified Carbon-Neutral
Stellar	PoS based [50]	No [51]	-	Payments oriented	0.062 [52]	No
Avalance	PoS based [53]	Yes [54]	Solidity [54]	Payments/Smart Contracts oriented	-	No
Tezos	PoS based [55]	Yes [56]	Archetype or Ligo [56]	Smart Contracts/Distributed Apps oriented	2.5 [57]	No
Algorand	Pure PoS [58]	Yes [59]	Python [59]	Smart Contracts/Distributed Apps oriented	≈ 0 [58]	No
NEAR Protocol	PoS based [60]	Yes [61]	Rust or Javascript [61]	Smart Contracts/Distributed Apps oriented	≈ 0 [62]	Yes [62]

As illustrated by Table 3.1, NEAR Protocol seemed to be the most appropriate for this project. This decision was made based on three factors. Firstly, it is a "Climate Neutral Product" certified by the South Pole in 2021 [62], which tackles the environmental impact concern. Secondly, the community and the easy-to-follow tutorials, enabling rapid development of the project. Finally, NEAR Protocol is also open-source, highly scalable, and efficient, serving "as the secure, (...) foundation for a new kind of decentralized applications" as described on NEAR Protocol's Website [63].

Specifically for NFTs, NEAR Protocol allows transactions to be processed for a negligible fee at fast speeds. Smart Contracts can be easily upgraded, even after being deployed (if the token structure was not modified) [63]. It also enables new economic features, promoting royalty-based smart contracts [61], following Open Web principles. With all these features and advantages, NEAR Protocol seems to be the most well-suited platform to build our solution with.

3.2   Smart Contracts

After choosing the platform, the initial smart contract flow was designed. The first decision comprised the scripting language. NEAR protocol allows the use of Javascript or RUST to develop the smart contract [61]. RUST was the chosen language as it is more low-level than Javascript, allowing granular control of the code. Syntactically, it is closer to C++ but was designed for performance and safety, guaranteeing memory safety, making it ideal to write smart contracts [64].

Following NEAR Protocol documentation [61], it was noticed that two smart contracts were needed. The first smart contract would be responsible, in large terms, for minting the NFT. Minting, in this context, refers to the process of converting digital data into a digital asset stored on the blockchain [65]. The second smart contract would be responsible for managing the minted NFTs, that is, to perform the NFTs transfer between the actual owner and the buyer with a set of requirements, like a sales price. In short, the two contracts would communicate via cross-contract calls, as described in Section 3.2.2

The most important contract would be the first one, responsible for incorporating the new licensing model proposed for this project. However, this created a challenge - how to keep track of time on a distributed asynchronous system? How to make sure that the NFT is flagged as expired when the expiration time is reached? The next section covers how this challenge was addressed in detail, including the implementation. Subsequently, the Marketplace Contract section covers implementation aspects.

3.2.1 Temporary NFTs Contract

The main goal of this smart contract was to create a solution, that comprised the following requirements:

1. Mint temporary NFTs by providing a timestamp that represents the date when the NFT will be flagged as expired;

2. Have enumerating functions to correctly display minted NFTs;

3. Allow NFTs transfers via cross-contract calls;

4. Have royalties support.

3.2.1.A Challenge

Since we were dealing with a decentralized system, which is a sub-type of a distributed system [66], most of the latter's problems are inherited. Concretely, for the proposed licensing model, synchronization and clocks are issues in this context [66] as the temporary NFTs need 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. A first analysis presented two solutions for this problem, however, none are trustworthy for a complex system like the proposed one:

1. **Use the user's local clock:** This solution comes with some problematic concerns. In a distributed system setting, we cannot trust a single clock. Users' clocks are not reliable as the user can exhibit byzantine behavior, producing incorrect timestamps that affect the overall trustworthiness of the solution [67]. In addition, two users in different time zones may not see the same NFT expiration state;

2. **Use a time server running a known synchronization algorithm, like Network Time Protocol (NTP):** This solution was more promising than the last one. However, there are no guarantees that the server output is correct. Moreover, it becomes a single point of failure, which breaks the main property of a decentralized system [66].

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.

With further research on NEAR Protocol's Rust Software Development Kit (SDK) [68], a public function that outputs a Unsigned 64-bit Integer (u64) with the "current block timestamp, i.e, number of non-leap-nanoseconds since January 1, 1970, 0:00:00 UTC." was identified [69]. 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 to be trusted, making it a potential candidate to solve this challenge. However, it is unknown how precise this timestamp was in terms of reliability and precision to flag NFTs as expired. To check this, a testing contract was deployed on the NEAR Protocol. This testing contract contained a function that returns the current timestamp outputted by the *block_timestamp* function present on NEAR Protocol's Rust SDK.

At this phase, most of the contract calls were done via a Command-Line Interface (CLI), so, it was decided to craft a simple benchmark script to call the contract function chained with the local system's timestamp (which was checked for correctness with a trusted NTP server - *pt.pool.ntp.org*). The benchmark script was the following:

```
near call $contractId get_current_timestamp --accountId $contractId ; perl -MTime
    ::HiRes=time -e 'printf "\%.9f\n", time'
```

Listing 3.1: Benchmark script that outputs current block timestamp and local time (*macOS* version).

This script does a near call to the *contractId* variable, the testing contract ID saved on the terminal environment. It calls the get_current_timestamp function. Then, when the NEAR Protocol output is displayed, it calls a function to retrieve the actual system timestamp in milliseconds (to comply with NEAR Protocol). The benchmark was executed six times, where both timestamps were registered for further comparison in Table 3.2. Before proceeding with the comparison analysis, it is important to mention the following:

- Since the remote call takes more time to execute as network latency was present, and internal NEAR operations take some seconds to complete before returning the output, a difference between local and remote timestamps was expected;

- To reduce this difference, a ping test was done to *https://rpc.testnet.near.org*, the URL for NEAR's testnet remote procedure calls. The average latency during the moment of execution of the benchmark was about 29.129 Milliseconds (ms). In short, it is safe to reduce ≈ 30 ms to the difference between the local and remote timestamps.

As observed from Table 3.2, by removing the average network latency, an average value of about 850 ms was the difference between NEAR Protocol's last block timestamp and the local one. With this in mind, it was decided that this "less-than-one-second" difference is acceptable for this project, which validates the potential candidate to solve our problem without using external servers or users' clocks.

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Table 3.2: Comparison between NEAR Protocol's last block timestamp with actual/local timestamp.

Call #	NEAR Block Timestamp (ms)	Actual/Local Timestamp (ms)	Difference (ms)	Difference minus latency (ms)
1	1648987979190	1648987980560	1370	1340
2	1648988002025	1648988003160	1135	1105
3	1648988060984	1648988062001	1017	987
4	1648988075285	1648988076266	981	951
5	1648988143878	1648988145111	1233	1203
6	1648988165987	1648988166045	58	28
		Total (average):	879.2857143	**849.2857143**

After solving this time-related challenge and validating the temporary NFT concept, the implementation phase of the smart contract, using RUST, took place.

3.2.1.B Implementation

The NEAR Protocol's contract skeleton was used as the basis for this project and comprises the standards used to create a correct, basic, smart contract with some core functionalities, such as [70]:

- The logic that complies with NEAR Protocol's approval and transferal management extension standards, allowing to approve or revoke a certain account to transfer a token on the owner's behalf. This is particularly useful for allowing the marketplace contract to perform a transfer from the NFT owner to the supporter;

- Enumerating functions for viewing information about NFTs, following NEAR Protocol's enumeration extension standards;

- The default metadata for the NFT metadata, which allows aggregate information to the NFT;

- NFT minting logic;

- NFT payout-related function to enable royalties support.

With this skeleton contract, which seemed very complete, the first modification was on the NFT token metadata structure to include the block timestamp parameter, which was called *expires_at*, as demonstrated by the code below.

```rust
#[derive(BorshDeserialize, BorshSerialize, Serialize, Deserialize)]
#[serde(crate = "near_sdk::serde")]
pub struct TokenMetadata {
    pub title: Option<String>,
    pub description: Option<String>, // free-form description
    pub media: Option<String>, // URL to associated media, preferably to
    decentralized, content-addressed storage
```

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```
7    pub media_hash: Option<Base64VecU8>, // Base64-encoded sha256 hash of content

     referenced by the `media` field. Required if `media` is included.

8    pub expires_at: Option<u64>, // When token expires, Unix epoch in milliseconds

9    pub reference: Option<String>, // URL to an off-chain JSON file with more info.

10   pub reference_hash: Option<Base64VecU8>, // Base64-encoded sha256 hash of JSON

     from reference field. Required if `reference` is included.

11 }
```

Listing 3.2: Definition of the token metadata structure with expires_at field.

It was decided that this parameter expects a UNIX timestamp, in milliseconds, to comply with RUST's block_timestamp function output . After preparing the NFT metadata structure to receive the *expires_at* parameter when minting, the logic to mark the NFT as expired took place.

The second modification was done on the smart contract core and internal functions to expect a timestamp to check if the NFT *expires_at* metadata field value was greater than or equal to the current NEAR Protocol's block timestamp. If it was, then the NFT was not expired, otherwise, the NFT was flagged as expired.

The third modification was related to the enumerating functions. For instance, while reading the documentation, it was noted that NEAR Protocol's Wallet UI does a call to an enumerating function to display minted NFTs, allowing users to see their minted tokens on the wallet website [70]. So, the existing enumerating functions were modified to only output the tokens that were not expired, based on a "greater than or equal" logic to compare timestamps. After this procedure, a new enumerating function was implemented to display non-expired NFTs based on the owner's wallet identification. This function was useful as many users will use this contract to mint their temporary NFTs. In other words, thinking about the final back end, this function will allow each user to retrieve their and their only non-expired NFTs. The code for this function can be found below:

```
1  pub fn nft_non_expired(
2       &self,
3       account_id: AccountId,
4  ) -> Vec<JsonToken> {
5       let now = Some(env::block_timestamp() / 1_000_000);
6       log!(
7           "now: {}",
8           now.unwrap_or(0)
9       );
```

```
10        //get the set of tokens for the passed-in owner
11        let tokens_for_owner_set = self.tokens_per_owner.get(&account_id);
12        //if there is some set of tokens, we'll return the length as a U128
13        if let Some(tokens_for_owner_set) = tokens_for_owner_set {
14            //we'll map the token IDs which are strings into Json Tokens
15            tokens_for_owner_set.iter()
16                //we'll get the metadata for each token
17                .map(|token_id| self.nft_token(token_id.clone()).unwrap())
18                //we'll filter out the tokens that aren't expired
19                .filter(|token| token.metadata.expires_at > now)
20                //we'll collect the tokens into a vector
21                .collect()
22        } else {
23            //if there isn't a set of tokens for the passed-in account ID, we'll
    return an empty vector
24            vec![]
25        }
26    }
27 }
```

Listing 3.3: Definition of nft_non_expired function to return non expired NFT based on the token owner account_id.

The fourth and final modification was to enforce and complete minting, transfer, and royalties functions to expect the new NFT metadata structure. Especially, the transfer functions to block transferals of expired NFT.

With these modifications, the contract was working as expected. For example, while minting an NFT using NEAR Protocol's CLI package, it was possible to create a new NFT passing the required metadata information, including the *expires_at* parameter. After minting the NFT with an expiration time of 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' (organizations, in the context of this project) 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.

3.2.2 Marketplace 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 NFTs Smart Contract, including the expired ones for visualization purposes on the Front end;

2. Transfer non-expired tokens between the owner and the supporter.

3.2.2.A Implementation

This smart contract had no relevant challenge, as the relevant logic regarding temporary NFTs was already defined in the previous smart contract. With this, the skeleton for this smart contract was also based on NEAR Protocol's "Zero to Hero" tutorial [70], focusing on Marketplaces. This skeleton comprises all the functionality inherent to a NFTs marketplace. However, it is important to illustrate how this contract works, namely regarding the cross-contract calls done with the temporary NFTs contract. Figure 3.1 illustrates an interaction diagram that 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).
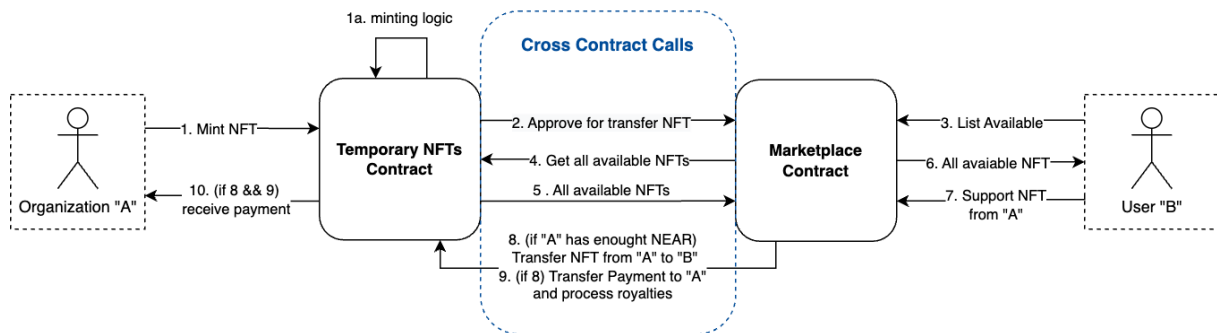
Figure 3.1: Interaction flow diagram illustrating cross-contract calls.

As observed (Figure 3.1), 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 NFTs does a cross-contract call after minting the NFT to approve the Marketplace contract to display and transfer NFTs (further detailed on Section 3.3).

Concerning skeleton modifications, it was necessary to change the Sale structure (responsible for creating sales) to return the NFT with the *expires_at* parameter and to change internal functions to prevent supporting expired NFTs. The first modification was straightforward, as it was only necessary to modify two pieces of code: one where the Sale structure is declared, informing that a new parameter *expires_at* will be present, and the second in the structure constructor, to inform the contract where to get the *expires_at* parameter.

The second modification took place on the offer function responsible for "selling the NFT". To assure that the sale could not proceed in case the NFT was expired, the following lines were added:

```rust
1  //get the sale object from the unique sale ID. If the sale doesn't exist, panic.
2  let sale = self.sales.get(&contract_and_token_id).expect("No sale");
3
4  //get the expires_at parameter from the sale object
5  let expires_at = sale.expires_at;
6
7  //if the sale has an expiration date, make sure it hasn't expired yet
8  if let Some(expires_at) = expires_at {
9      assert!(
10         env::block_timestamp() < expires_at,
11         "Sale has expired"
12     );
13 }
```

Listing 3.4: Verification added to the offer function to prevent sales of expired NFTs.

Before concluding, it was important to note that the storage management model was inherited from the skeleton of this contract. The process of minting the NFT would need to have attached a certain amount of NEAR to cover the costs of storing the data on the contract, as it was with the NFT contract [70]. By design, cross-contract calls would be transparent to the end-user, as non-technical users would use the final solution too (as will be discussed in Section 4.3.4). With this, from the moment when "Create NFT" button is pressed, all the transactions from minting to approve are done in a batch and the final result presented to the user is the NFT itself. This means that, to the NFT price defined by the organization, an insignificant amount would be added to cover storage costs on both contracts.

As both contracts were concluded, the next challenge was related to the communication between NEAR Protocol and the Flutter. To advance, Flutter was the main development platform used to create the prototypes since the Hi-Fi one, as will be discussed in Section 4.3.4. In short, the communication between the back end and the front end. The challenge here concerns the lack of libraries to connect Dart (the language behind Flutter) to NEAR Protocol, which means the bridge between these two components was implemented from scratch. Section 3.3 will cover how this challenge was tackled.

3.3 Communication with Flutter

As described above, 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 NFTs from the final solution UI.

After reading NEAR Protocol's documentation, it was noticed that they offer an Application Programming Interface (API) for doing Remote Procedure Calls (RPC) [71]. However, this is a solution to perform view calls (any call used to query the contract). Function calls, used to modify the blockchain, could not be performed directly from the NEAR Protocol's RPC as they needed to be signed with the caller's NEAR Wallet private key, and the documented way for creating a signed transaction from scratch seemed virtually impossible. A possible candidate to overcome this issue was to use NEAR Protocol's JavaScript APIs, running on a node.js Representational State Transfer (REST) server. With further research, it was found that a NEAR Platform's REST server exists, based on their JavaScript APIs, simplifying how these transactions were created [72]. Nonetheless, one of the problems remained - these transactions needed to be signed with a private key, so, how to obtain the NEAR Wallet private key from the user using the final solution? This problem will be discussed in the next section.

3.3.1 Getting users' NEAR Protocol Wallet Private Keys

The first approach to this problem was to analyze the login's communication flow inside NEAR Protocol's Wallet website *https://wallet.testnet.near.org/*. It was done by opening Chrome's DevTools and searching for possible tips within the exchanged network packets. In this process, it was perceived that NEAR Wallet saved a cookie containing the private key associated with the users' wallets. 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 Plaftform'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 noted to be implemented in the prototype that would be created. If the application detects a user without a Wallet, a "Connect your NEAR Wallet" button shows up. 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, given the fact that private keys were being manipulated, a way to securely save their value needed to be found. In fact, this application was targeted to run on iOS and Android, and both provide secure ways to store sensitive information. For instance, iOS has "Keychain

Services" that allow to "securely store small chunks of data on behalf of the user", as described on the Apple Developer website [73]. After a quick research through Flutter packages, *flutter_secure_storage* was found. This package allowed the interaction with iOS Keychain and Android Keystore, saving encrypted information locally [74].

Putting pieces together, this in-app browser solution with secure storage allows users to do a quick login inside the application to be able to create (if the user belongs to an organization) or support NFTs. A little snippet of code can be found below:

Listing 3.5: Listening for the cookie with the private key and saving it securely.

```
1  controller.webStorage.localStorage.getItem(key: '_4:wallet:accounts_v2').then((value)
      {
2      if (value != null) {
3          walletValue = value;
4      }
5      var t = value != null ? walletValue.keys.toList() : [];
6      var accountName = t.isNotEmpty ? t[0].split('.')[0] : "";
7      controller.webStorage.localStorage.getItem(key: 'nearlib:keystore:$accountName.
      testnet:default').then((value) async {
8          if (value.toString().isNotEmpty && value != null) {
9              print(value);
10             Navigator.pop(context);
11             ProfilePageController profilePageController = Get.find<
      ProfilePageController>();
12             await saveKeysOnStorage('near_private_key', value);
13             await saveKeysOnStorage('near_account_id', accountName + "." + widget.
      initialUrl.split('.')[1]);
14             profilePageController.userHasWallet(true);
15             profilePageController.onNearLogin();
16             Get.back();
17         }
18     });
19  });
```

3.3.2 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 an RPC and REST servers, all requests need to be send using HyperText Transfer Protocol (HTTP) through Secure Sockets Layer (SSL), for extra security. For this, inside the Flutter project, all the endpoints were defined in a constants file and a class was made to handle the HTTP communication. This allowed the creation of simple JavaScript Object Notation (JSON) requests, signed with the respective private key, to be sent and processed by the remote servers. For example, the code below exemplifies one of the phases in the process of supporting an NFT from the application.

Listing 3.6: First phase function to process a purchase on NEAR Protocol.

```
1  Future<bool> phaseOneNEARSaleProcess(String price, String tokenId) async {
2      print('1/2 --------------- REGISTER PURCHASE ON NEAR ---------------');
3      var privateKey = (await FlutterSecureStorage().read(key: 'near_private_key')).
       toString().split(':')[1];
4      var account = await (FlutterSecureStorage().read(key: 'near_account_id'));
5      var body = {
6        "account_id": account,
7        "private_key": privateKey,
8        "contract": kMarketPlaceAddress,
9        "method": "offer",
10       "params": {"nft_contract_id": kContractAddress, "token_id": tokenId},
11       "attached_gas": calculateRequiredGAS(),
12       "attached_tokens": nearToYocto(price)
13     };
14     Response r = (await HTTPProvider().post(kNearRestAPI_CALL, jsonEncode(body)));
15     if (r.body.toString().contains('panic') || r.body.toString().contains('
       KeyNotFound') || r.body.toString().contains('error')) {
16       Get.back();
17       showErrorSnackbar('supporting_problem'.tr, 'supporting_problem_desc'.tr);
18       waiting.value = false;
19       return false;
20     } else {
21       print(
```

```
22        '1/2 DONE --------------- REGISTER PURCHASE ON NEAR --------------- DONE');
23     return true;
24    }
25  }
```

This chapter concludes the description of the framework used for this project, creating a cohesive back end and empowering the front end with the communication tools to talk with NEAR Platform's blockchain. The upcoming chapter will cover the main methodology used for this project, UCD. This methodology was used the validate the idea behind the back end (the marketplace with temporary NFTs) and to envision, design and develop the front end, resulting in a Hi-Fi prototype that will originate the final Functional Prototype (FP) for this project.

4

User-Centered Design

Contents

This section will cover the primary methodology used for this project. UCD is an interactive design process, defined by ISO 13407 [18], 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.

In fact, on projects where costs are an important factor, a good user study with usability in mind can increase revenue, saving time and effort. The previous statement ranges from short-term to long-term interest by saving on development, maintenance, and user support, leading to better end-user engagement [75].

Herewith, users will play a vital and active role during the development and evaluation of this project. Sketches and prototypes are at the core of User-Centered Design as they are present over all iterations by simulating multiple design alternatives and testing functionalities. Testing is another core activity to confirm that we have achieved our goals [75].

In this sense, UCD influenced the two main components of this project. The front end was directly impacted as it was the main target of this approach. For the back end, developed on Chapter 3, it did not have a direct impact, but rather a validation of the concept.

This section will start by covering the initial user research, including all the planning, interviews, personas, scenarios, and ideation phases, followed by the Low/Mid-Fidelity Prototype, ending with the High-Fidelity prototype, which will be very close to the final solution.

4.1 User Research

To start with a user-centered design approach, we need to define the users we may be working with, in other words, the population. For UCD projects, the multidisciplinary framework [76], ISO 13407 [18] defines the following four human-centered design activities:

- Understand and specify the context of use;

- Specify user and organizational requirements;

- Produce more than one candidate design solution;

- Evaluate designs against requirements.

4.1.1 Planning

In connection with the previous activities, the planning phase comprised the first two. For this, a quick brainstorming session on a whiteboard was conducted to define some aspects, namely, the context, the population, and how the population would be studied.

4.1.1.A Usage Context

Given the nature of NFTs and how widely spread they are nowadays, it was decided to first evaluate the devices used in this context. After quick reasoning combined with a web search through NFT markets, such as OpenSea [77], Magic Eden [78], and others, the following conclusions arose:

1. Some NFT markets are available on websites. They can be used on any computer or mobile touch-enabled devices, like smartphones;

2. Some NFT markets are available in App Stores to be used as mobile applications.

The final solution for this project could either be a website or a mobile application. However, a mobile application was chosen for multiple reasons. The first reason comprises studies from mobile applications versus websites [79]. Statistics to support these studies could be found, mainly published by hosting and internet providers and Web Analysts, showing that more than half of web traffic is from mobile device applications [80]. The second reason is that existing NFT Marketplaces, such as the ones described above, can be compared with content-driven applications like *Instagram* or *Tiktok*. These apps are mostly used on mobile devices as they are readily available, at a touch distance. The third and most important reason is that touch-enabled mobile devices use a natural pointing device, our fingers. Gokturk & Sibert, for instance, support this idea by saying that our "index finger is significantly better as a direct pointing device than as an indirect pointing device using an isometric finger-controlled joystick" (2019) [81].

To summarize, the usage context of our application is a mobile application running on a touch-enabled mobile device, controlled by touch gestures. As natural heritage plays a vital role in this project, this application can be used anywhere - indoors and outdoors, from day to night.

4.1.1.B Population

Using NFT Marketplaces as a reference, two main user groups can be identified: the clients, which can buy NFTs, and the creators, which can create and publicize their NFTs. Consequently, it made sense to define two groups for this project: the clients (who can support the NFTs) and the organizations (a client, but with the ability to create NFTs inside the application). By segregating duties, we are preventing regular clients from creating NFTs to receive undue profits - only approved organizations can create and promote their NFTs.

For the clients, three subgroups were defined: users without NFTs experience, users with some experience, and experienced users. This decision allows the creation of an application for all, where even the users that don't know what NFTs are, can use the application.

For the organizations, it was decided to have a real company as a use case. Turismo de Portugal was the perfect fit for this context. They are responsible for "the promotion, enhancement, and sustainability

of the tourist activity" (Turismo de Portugal, 2022). After reaching Turismo de Portugal for the first time, they accepted to be part of this user study as NFTs are of their interest too.

4.1.1.C Population study

Given that most users were doing remote work due to the recent COVID-19 pandemic [82], semi-structured interviews were elected as the primary data collection method. General interviews enable us to talk to people to find out about their experiences, and how they think and feel about something. However, the semi-structured ones depart from a set of questions where the interviewer has a good idea of the topics that will be covered but the conversation is free to vary and create other paths different from the predetermined list of questions. In fact, "at one extreme, the questions are very simple and the order of question easily adhered to. On the other, the questions can be very open, and the conversation can take many directions before all the areas you want to address are covered" (Miles & Gilbert, 2005) [83]. After reaching Turismo de Portugal, it was agreed that a form will take place instead of an interview, so they can fully organize themselves.

Following the choice of techniques, a literature review took place to find out and evaluate previous work. This could help to identify possible problems and gaps with solutions and also to find out what the best questions are. With this, the main questions were prepared. Open questions had a preference over closed ones, as they are great for finding out "why" rather than "how many/much", opening the spectrum of possible tips to find more about the users [83].

For the interview guide/plot, these questions were divided into four sections. The first section was the introduction, where the interviewer does their introduction, followed by a quick introduction to the project, how the interviewee will help, assuring that the interviewee knows that they have the opportunity for up-front questions during the interview. Finally, an appreciation is transmitted to the interviewee, showing gratitude for the help. The second section questions perform a context acquisition about the interviewees, gathering data like age, job, hobbies, and familiarity with NFTs and mobile platforms. The third section explores user interaction and opinions, with positive and negative aspects, for the following themes: online shopping, protection of natural and cultural resources using technology, and NFTs platforms usage. The fourth and final section of this guide is an "outro" where the interviewee can ask more questions or clarify doubts and where they give their consent to continue the study. A full copy of the semi-structured interview guide can be found in Appendix A.

For the form, it was decided to better understand the Turismo de Portugal as an organization, their opinion about NFTs, and current needs and use cases.

4.1.1.D Interviews

After defining the previous planning aspects, it was time to conduct the interviews with users and apply the form to organizations. Starting by the form, it was sent via email and answered by two collaborators of Turismo de Portugal. As their answers were very complete, exposing current concerns and opinions, no questions were asked afterward.

The interviews were conducted individually, via a remote conference application, with a heterogeneous group of 9 people, from ages 20 to 48 years. This population was dived into the subgroups defined during the planning phase. Each interview took about 30 to 40 minutes, depending on the interviewee's available time.

A code was attributed to each participant, for both form and interviews, to better distinguish them and to help with the anonymization phase.

Table 4.1: Codes applied to participants and the participants' count number for each category.

Category (Expertise)	Code	Description	# Participants
None (Beginner)	CN	No experience with NFTs	3
Some (Performer)	CS	Knows NFTs and some applications	4
Expert (Expert)	CE	Uses/Buys NFTs	2
Organization	ORG	Employees be able to create NFTs	2

4.1.2 Synthesizing User Research and User Validation

After collecting all the necessary aspects, an analysis and a treatment needed to be done to organize all the data in the best way possible.

The first step consisted of doing the interviews' transcription and anonymization. Although any sensible data was collected, some of the users' opinions and context can quickly identify them if put together. This issue was solved by anonymization with the codes defined during the interviews phase to comply with European Union General Data Protection Regulation (GDPR) principles [84]. This anonymization was done by removing all names and replacing them with the corresponding codes, found in Table 4.1. For example, the first user without experience that was interviewed had the code "CN1" in place of their name.

The second step comprised the creation of a "Map of Ideas". This map was done on a spreadsheet where each page represented a user category. On each page, all the information from the interviews that belonged to the same topic was grouped. The main topics stem from the main sections of the interview plot:

1. Introduction (with user profiling and NFT background knowledge);

2. Online shopping (with current issues, what is good, what can be improved);

3. Protection of natural and cultural resources (importance, use of technology, use of NFTs, concerns);

4. Other opinions (that naturally emanated from semi-structured interviews).

The exception for the previous structure targets organizations. As the form had 6 questions, the organization's section, on the map, was divided into those 6 questions, being:

1. In what contexts had Turismo de Portugal used NFTs?

2. As an organization, what is your opinion about NFTs? What are the strengths and weaknesses?

3. As an individual, have you ever used NFTs? If yes, how?

4. What is your opinion about NFTs promoting and protecting natural and cultural resources?

5. What is important to you when promoting Portugal's natural and cultural resources?

6. Other opinions/concerns.

This allowed the creation of a defined panorama of opinions and concerns. An example of a page from this map of ideas, illustrating clients with no experience (CN), can be found in Appendix B. From this process, the following aspects were extracted, by user group/category.

4.1.2.A   Users with no experience on NFTs (code CN)

Introduction: participants with ages ranging from 22 to 48 years. All of them are studying, from law to finances. As hobbies, all love to read books, do online shopping, watch television, go for walks with friends, and travel. One of the interviewees referred to their taste for arts and paintings. They were born in different locations and different contexts. From an emotional point of view, they are very extroverted. They all love to be with friends and family, talk about all sorts of things and investigate new themes and trends. All the participants identified that NFTs are related to blockchain, but none know what they exactly are and their purpose. However, some manifested their interest in learning more, although they did not know what or where to search for. After explaining the concept to them, they found it very interesting due to its properties. They also referred that what they heard about NFTs, before hearing the explanation, gave them a bad impression of the technology. One of the participants even suggested an idea to use NFTs - a trading card book. After stating that those NFTs are temporary, they got even more interested: "this would be extremely useful for zoos like when you are the godfather of some animal, you pay for it, you support the animal for a certain amount of time" - as stated on Appendix B. This validated the idea of having this new licensing model for NFTs.

Online shopping: the first things they noted when asked about what makes a product appealing were the image, a good description, and the shopping interface. Most of the interviewees from this group

also stated that they do not like buying out of necessity. Some told that they prefer products with a large reviews number (or "likes"). When asked about what makes a good shopping experience, the ease of payment, the organization, and the speed were the most relevant factors. Interviewees trust apps where they don't need to put their banking information and can select and pay quickly, authenticating with their biometric identification. Regarding problems and improvements, users stated that some applications are not interactive or well cataloged, and have usability problems and bugs. They referred again to the difficulty of doing payments on some. Finally, their opinions contrast when asked about digital content shopping. Some love the ability to receive digital content right on the email, while others don't, as someone with access to their email can easily "hijack" the content.

Protection of natural and cultural resources: all the participants recognize the urge to protect natural resources, as "we only have our planet, we don't have a planet B, at least until now". A general agreement about using new technologies to protect natural resources was also made. Some told that the proposed solution for this project is very well thought out and that it would be great to check the history of a certain asset from an application that they know they can trust. The idea was, once again, validated by the users. However, two participants showed some concerns about using NFTs to do so, as they never bought an NFT before and don't know the technology capabilities or problems. They mention that everything must be clear to avoid corruption. To the question "what would be important when creating this platform?", a participant pointed out good usability, and safety from a point of view of data protection and being good at picturing the assets. A requested feature was language translation.

Other opinions: a personalized, non-invasive, experience was requested in a way that new NFTs can be suggested to users based on their likes. Besides this feature, a form of "instruction manual" was requested by the oldest participant in the study, referring that they love it when they are setting up a new iPhone and all the tutorials appear to show users what is new and how to use certain functionalities.

Results: Based on what is described above, the first conclusion was that 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. This conclusion was based on the contrast between the manifested emotions, before and after the interviewer explained what NFTs were and how they might be used but was also an explicitly requested feature. This decision might expand the spectrum of users that will use the application (the ones that don't know about the concept but want to learn). The second decision was to implement a quick way of proceeding with the NFT payments, using biometric authentication features. Finally, interviewees referred that they like applications with personalized experiences and that are intuitive, with good usability. Consequently, the third decision was created - doing a personalized solution that reacts to users' likes.

4.1.2.B Users with some experience on NFTs (code CS)

Introduction: participants with ages between 22 and 30 years. One of the interviewees is studying Computer Engineering and the other two are currently working, one as a programmer and the other as a cybersecurity specialist. From this first part of the introduction, it was expected that the participants had some knowledge about NFTs and blockchain. Their hobbies are all related to technology, with some referring the like for sports, photography, going to the gym, seeing animals and insects, and traveling. From an emotional point, they are extroverted but sometimes they close themselves up, being more introverted. When asked about what NFTs are, they all explained well, however, they never used the technology or bought one. One of the participants mentioned that NFTs and blockchain have a tremendous impact and potential, however, most of the current solutions give them a bad reputation. After the interviewer explained the idea behind the project, they all agreed that it was one of the best applications that they heard about NFTs - this statement, once again, validates the idea for the framework of this dissertation project.

Online shopping: for the online shopping section, the answers were very similar to the previous group when asked about what makes a product appealing. In short, primacy was given to the image, product description, and user evaluations. When asked about what makes a good shopping experience, they all mentioned the visual part of the website or application and its organization. Some interviewees referred that they don't like to see ads and campaigns, almost forcing clients to buy products they don't want (or don't have an initial will to buy). In line with the previous group, easy and secure payment options are a must. For the question "what problems or improvements would you suggest to online shopping platforms?", an interviewee talked about aging visual interfaces, stock showing problems, and delivery times. Finally, the interviewees showed their opinion about buying digital content with mixed opinions. While some love to buy digital things as "they are readily available for you to use", others prefer physical things as "if the platform where you have the keys disappears, you lose all of your purchases".

Protection of natural and cultural resources: in tune with the previous group, as expected, all the participants recognize the urge to protect natural resources - "I can say that I'm selfish, if we don't do good to nature, we don't do good to ourselves (...) most people don't think long term, but the question is, money resulting from bad behaviors will give us nothing if we're all dead", said one participant. When asked about the role of new technologies to protect resources, all the participants agreed that new technologies have a fundamental role in this field as "they make everything more efficient, cutting costs and problems if used correctly". Concerning the use of NFTs, especially temporary ones, to protect these resources, all the participants demonstrated excitement about it - "it was a great use case that I never thought until 10 minutes ago". They referred that, the popularity of technology is a great ally for promoting natural and cultural resources and if we're able to save them at the same time, then it is a must. Once again, the initial concept of this dissertation got validated by users. However, it is important

to note that one of the participants told that the final solution must not have the word "buy" NFT, as it is for solidarity - "a solidarity NFT", and instead, use the word "support". About possible concerns, all interviewees noted that the technology is secure and well documented, however, damage can be done if the idea "(...) falls into the wrong hands, however, the potential is larger than the risk", said one participant.

Other opinions: a consensus was observed between all the participants on two features, requested by all: showing who supported the NFT and maintaining an active history of the NFTs that each user supported on their profile.

Results: Based on what is described above, we can see a tendency where users prefer applications with easy and secure payment methods like Google Pay and Apple Pay. Analyzing these two forms of payment and after asking users why they love them so much, it was observed that they love to click on the "payment" button and authenticate with their biometrics features. In tune with the previous group, this is a feature that will be implemented in the final solution. 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. Finally, a feature requested by this group was the possibility to show the history of supported NFTs.

4.1.2.C   Users with experience on NFTs (code CE)

Introduction: participants with ages around 23 years. Both participants took a course on Computer Engineering at the same university. Both are working, one as a C# developer and the other as a full-stack developer. For hobbies, they love to play video games, learn new technologies, and also play team games like basketball. From an emotional point, they are very balanced, not showing signs of being introverts or extroverts. Both interviewees had profound knowledge about NFTs and blockchain as both bought them before. After presenting the project, they noted that it might be the first time they heard about a good NFT use case, being very impressed with the temporal feature of NFTs.

Online shopping: In parity with the previous two groups, opinions did not diverge and tended to be related to the image as the main aspect of a good online shopping experience. Also, a good and intuitive interface was mentioned, and low prices. Another angle that does not relate to this project is the urge to follow the order status, from the moment it is purchased, until the moment it is delivered. Both participants prefer to buy digital rather than physical as "it is an extremely fast experience. I click on the buy button, do the payment, a timer appears, and then, before the timer ends, I receive the code via email".

Protection of natural and cultural resources: in symphony with previous groups, all the interviewees agreed that natural and cultural resources need to be protected and that new technologies can

play a fundamental role in this area. Concerning the use of NFTs to do so, both interviewees showed excitement for the idea, as "if it is to help, not just to make money like the current NFTs solutions are, then it is super nice". However, one of the participants demonstrated some concerns about corruption and implementation, suggesting that companies should not be able to use the application right after registration, passing through an approval process first. This approval process verifies if the organization's details are correct and confirm with the organization what they want to do. This will prevent anyone, including actors that might create fake company accounts, to make money on others' behalf. Given the sensitivity of this matter, this idea was flagged as a high priority for implementation.

Other opinions: a request made by one of the interviewees was to create a sort of medals and trophies to motivate the users to buy more and to create a "healthy competition".

Results: 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.

4.1.2.D Organization (code ORG)

Two total answers were given to the form, from Turismo de Portugal employees, ages between 27 and 46 years old. One of the participants took a course on Digital Marketing.

In what contexts had Turismo de Portugal used NFTs: based on the given answers, the organization did not use NFTs. However, it was mentioned that they are a very relevant topic to connect territory to a digital value, "created creatively, without the need to negatively impact the local in terms of sustainability", said one of the participants.

As an organization, what is your opinion about NFTs? What are the strengths and weaknesses: as NFTs were a topic of interest, the following topics were mentioned: the lack of good knowledge about what NFTs are and how they could be used - "additionally, and giving the fact that the sustainability theme is crucial, this is one of the main concerns when looking for a solution to apply the technology". And, speculation about how someone could create value from NFTs, as "what matters to us is the creation of digital value connected to emotions, moments, places and experiences", said one participant.

As an individual, have you ever used NFTs? If yes, how: one of the participants already bought some NFTs, and the other one showed interest in the technology, stating that it was a theme in the study, especially about how the negotiation of exclusive digital assets could be profitable.

What is your opinion about NFTs to promote and protect natural and cultural resources: both

participants agreed that NFTs are a technology that can be used to promote and protect these resources as "all technologies are a mean and not an end and their goodness will depend on how humanity creates and uses them", stated one of the participants. One of the participants also mentioned that NFTs have the potential to generate fair revenue for organizations like museums, making the patrimony accessible to anyone and allowing it to be repaired and maintained. "In conclusion, NFTs present a hybrid landscape where the public can explore, collect and influence our shared cultural heritage, giving museums opportunities to build loyal communities and develop digital revenue streams", expressed one of the participants, commenting on the urge for these matters to be explored.

What is important to you when promoting Portugal's natural and cultural resources: both participants established that promoting patrimony is a complex and multidimensional task as it should not be interpreted as just a building or a painting, but also as the emotions, history, and experiences of the humans who preceded us. Another problem is the environmental impact of some blockchain solutions, like Bitcoin [85]. One of the participants demonstrated some concerns regarding authorship, as agreements need to be done between organizations and malicious projects.

Other opinions/concerns: as referred before, one of the participants commented on the urgency for better information about NFTs, as well as training in the area, such as tutorials, and clarification sessions, as it is "extremely new, inducing doubts and concerns to programmers, curators and clients" that can postpone both the evolution of NFTs and the solution itself.

Results: Although these answers were given within a form, they provided insightful information about how patrimony needs to be pictured, besides the physical aspect. With this, one feature that could be implemented is: during the minting process, give the possibility to organizations to add descriptions, and hyperlinks to videos and web pages. 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.

After creating and organizing the map of ideas with the interviews and forms data, the next step was to create Personas. 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 [86]. To add, "a persona represents an aggregate of target users who share common behavioral characteristics" (Miaskiewicz & Kozar, 2011) [86]. In contrast with actors, personas are much more detailed, highlighting software development needs and engineering requirements, and, consequently, actors can be derived from personas [87]. The more detailed the persona is, the more the design/developer will understand them, creating a sort of emotional connection with it, and allowing their desires to flow from the paper to the final product [86]. The next topic will cover how these personas were created.

4.1.3 Personas

Three personas were created to match the initial user study (interviews and forms) in terms of emotions, occupation, needs, and concerns, with the help of the Map of Ideas (that aggregated interviewees' ideas). For instance, regarding NFTs experience, 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. All three personas have a detailed profile, to broaden the developer spectrum while developing the app, including:

- Name and Birthday;

- Small description and quote;

- Detailed description of the persona, including hobbies, studies, and interests;

- Current wants/needs;

- Life goals;

- Frustrations.

The full personas description can be found in Appendix C, as a sort of detailed identity card that helped to visualize them throughout the rest of the process. However, a description of each one is present in the following excerpts, including the group code they represent.

4.1.3.A First Persona - Emily Alves Sousa (group: CN)

Emily is 24 years old and was born in Portugal. She recently started an internship in a law office as she just finished her solicitor/law degree. What Emily wants to start her own office as she is passionate about what she does. In her free time, Emily loves to investigate all sorts of things. She regularly goes to the gym and loves to go to the beach with friends and family. Sometimes, Emily does online shopping but and recently became interested in digital art after seeing the spread of NFTs all over the news, more specifically on physical assets that are transformed into digital ones. She has been trying to seek more information about NFTs, but nothing seems to clarify her ideas. As Emily states "I think NFTs are a promising technology, but it is a new unknown reality to me as I don't see how they can be applied". In short, Emily's wants/needs are:

- Learn more about NFTs and how they can be good to invest;

- Having a place where Emily can see curiosities that motivate her to invest in NFTs;

- Used a good NFT marketplace where makes sense to invest money. Emily loves personalized experiences, like Instagram, where they recommend posts she might like.

4.1.3.B   Second Persona - Laura Castro de Azevedo (group: CS and Organization)

Laura is 39 years old and was born in Portugal. She loves to travel, so recently Laura is thinking about moving to someplace in Costa Vicentina. Laura took a Design and Marketing degree some years ago and, after working for other companies, she settled as the Marketing Team Leader of one of Portugal's top Tourism organizations. As creativity is part of her daily basis, she investigated NFTs because they are a current trend and is trying to use them to promote and protect assets without affecting them. As Laura said "technology is a mean and not an end, so, the NFTs concept that we seek to work is the one that adds value to the territory where the biggest patrimony is cultural and natural. I truly believe that NFTs will add value to these points". Of course, this complies with her company's goal to diversify revenues and to make natural and cultural patrimony accessible to everyone. In short, Laura's wants/needs are:

- Use NFTs to make patrimony accessible to everyone without compromising sustainability or the assets themselves;

- Generate revenue with NFTs to finance the conservation and restoration of assets. Also, to diversify her company revenues;

- Invest in NFTs formation to end all misinformation and a bad reputation.

4.1.3.C   Third Persona - Archie Buckley (group: CE)

Archie is 25 years old. He was born in England but came to Portugal with his parents when he was a kid. Currently, he is working as a C# Software Developer. Archie is more of an introvert who likes to learn new programming languages, play online games with friends, and also basketball. Sometimes, Archie does capture the flag or casual walking and stops by some cultural or natural assets to see it closer. One thing that gets him very excited is when he earns medals on his Apple Watch when he completes an exercise, or even medals at games after achieving something. As his company worked with blockchain before, he has lots of experience with it and recently with NFT, diving deep down on NFTs specifications and workflows. He thinks that current NFT use cases are a mess and there are none used for a good cause. In short, Archie's wants/needs are:

- A good cause to invest on with NFTs, as current use cases do not get his attention, with a well-designed UI and location-awareness;

- Be able to see a personal purchasing history;

- Gain medals when supporting NFTs;

- A place where people get well informed about NFTs;

- A new NFT licensing model;

Following the creation of these personas, the next step was to create user scenarios based on the personas' needs. The word scenario can be widely used inside the design community as there are multiple kinds and types of scenarios [88]. The chosen ones for this study were activity or usability scenarios, also known as use cases (Gonçalves et al., 2017) [89]. Activity scenarios show users doing tasks using described ideas and functionalities [89]. The creation of scenarios allows the designer to move from the problem space to the solution space [90]. In short, and following Gonçalves et al. methodology [89], activity scenarios should answer the following questions (2017):

1. **Who is the user?** Can be answered by looking at the persona;

2. **Why is the user using the application?** What is the persona's motivation to use the application, including the usage context?

3. **What are their goals?** What the persona intends to achieve;

4. **How do they do it?** What are the steps taken to achieve their goals? What are the actions, and goals?

As a visual representation of the interface had not yet been conceived at this point, this description of the scenarios should not include a reference to it, and when included, it should be simple [89]. The next section will show and describe the created scenarios for each persona.

4.1.4 Scenarios

The scenarios described below were created based on the persona's needs and suggested functionalities during the interviews and addressed during the synthesizing user research phase. From which:

1. Tutorial explaining what NFTs are and how they will be used;

2. Feed with recommendations;

3. Company registration with approval;

4. Creating the first NFT within the application;

5. Nearby NFTs;

6. Medals after receiving NFTs.

From these scenarios, the first two belong to Emily, the next two to Laura, and the last two to Archie. In the end, we should have a representation of the behavior of the final users within the application.

4.1.4.A Emily installs the NFT app

Emily is in her bedroom, searching through the App Store on her mobile phone, and sees the new NFTs application. As she is curious about NFTs, she decides to install the application. Emily clicks on the

install button and the application appears on her smartphone. She opens the application. After opening, she is greeted by a welcome screen with two buttons: "Learn More" and "Dive In". As Emily knows just a little about NFTs, she decides to press "Learn More". The app displays interactive pages explaining what NFTs are and how are they used in the context of promoting and preserving natural and cultural heritage. Emily smiles and gets excited, saying: "oh, now I know what NFTs are" and "this is a good use case". Emily finishes the tutorial and enters the application, exploring what it has to offer.
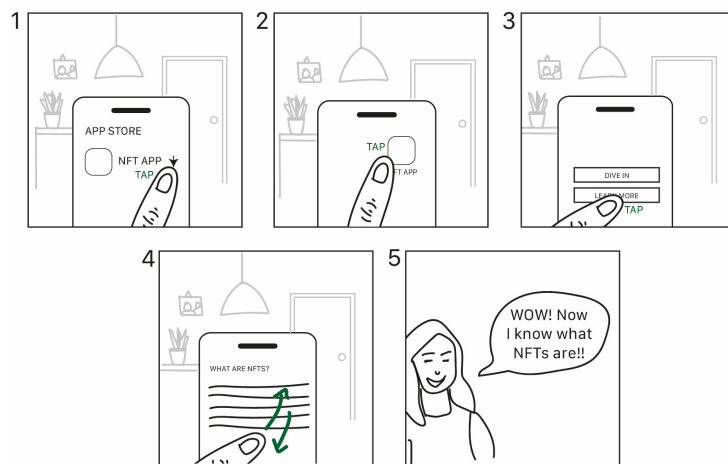
Figure 4.1: Emily scenario where she installs the NFT App.

4.1.4.B   Emily scrolls through the main feed and sees some recommendations

Emily is on the train on her way to her internship. She decides to explore what NFTs are available for her to support at that moment, so she opens the application. After opening the application, she is presented with the main feed. While on the main feed, she is presented with some recommendations based on organizations that she follows and based on what she added before to her favorites. Emily clicks on one of the recommendations and observes the NFT. She zooms on the picture of a landscape and checks its history. A smile comes to his face when she notices that the landscape is located at one of her favorite places, near Sintra. Emily is thinking about supporting that NFT, so he can help one of her with the preservation of one of his favorite places.
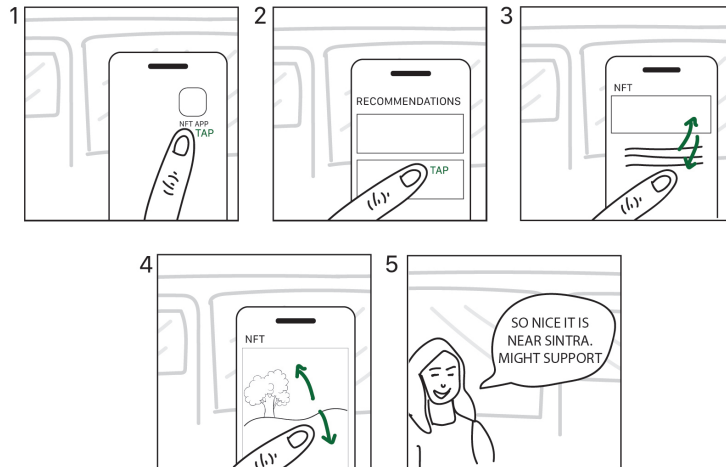
Figure 4.2: Emily scenario where she sees recommendations.

4.1.4.C Laura registers her company on the platform

Laura is happy, she introduced the idea to her company and the board approved the new digital marketing plan. She decides to try this new NFT application and goes through the application to register a new company, selecting this option. After selecting this option, she carefully fills all the form data, After filling it, she submits the new company request with all the necessary documents. After submission, the request goes for approval by the application administration entity. After a few hours, she receives a confirmation email from his company email saying that the company is approved to create a new NFTs using the email that she used to register. Happy with that, Emily reads the instructions and notices a new section on his application where she can create a new NFT for her company.
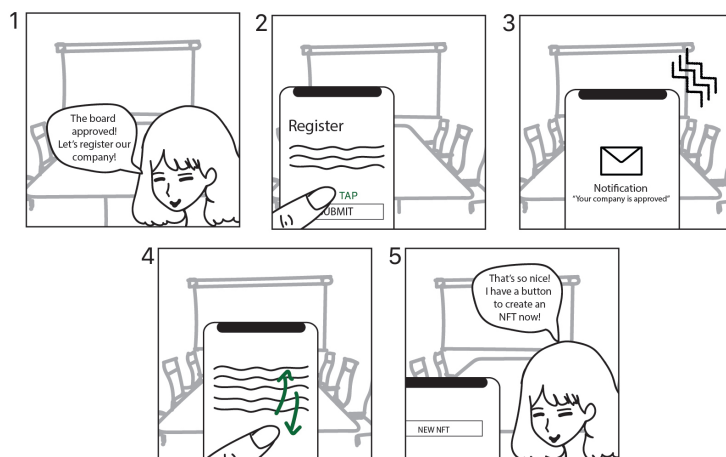
Figure 4.3: Laura scenario where she registers a company.

4.1.4.D Laura creates her first NFT on the platform

Laura is exploring one of her company's lands and notices a beautiful tree. Laura talks to the land keeper and he tells her that the tree is over 10 million years old and belongs to some ancient and important family. Laura collects as many details as she can as she saw a great opportunity to create a new flow of revenue for the company by promoting that tree while using some donations to preserve it. Laura gets her smartphone from his pocket and opens the NFT app. She clicks on the new button that appeared when the company was approved: "Create an NFT". Laura uses the in-app feature to take an artistic picture of the tree and fills in all the information, including how the donation will be used. As the tree will be different next month because summer is about to start, she decides to set an expiration date for 1 month, being NFT valid until the end of spring. Happy with the result, Laura decides to publish the tree NFT and the NFT gets added to her company's collection.
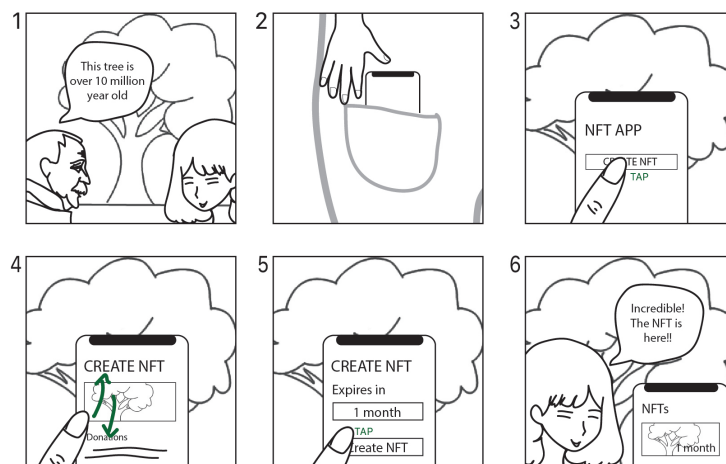
Figure 4.4: Laura scenario where she creates an NFT.

4.1.4.E Archie sees the "Nearby" NFTs

Archie goes for a walk with some of his friends. He was having a lot of fun and then remembered that he has the NFTs application. So he decides to open the application. He sees that on the first screen, there is a section with NFTs created from nearby assets. He gets stunned when he sees a tree that is right in front of him and his friends. Archie touches the tree NFTs and gets even more surprised by reading the tree's history. He tells his friends that the tree is over 10 million years old and they get surprised by this fact. Archie sees that he can help the tree by supporting the NFT but notices one particularity: the NFT will be valid for one month. He is super curious as this is a new NFT licensing model, different from the others that he is used to. He gets even more surprised by seeing that this one month is the time left to end the Spring season. Archie saves this NFT for later so that when we get home, he can think about it. Archie and his friends added that spot to their favorite ones to visit, due to the history of the tree.
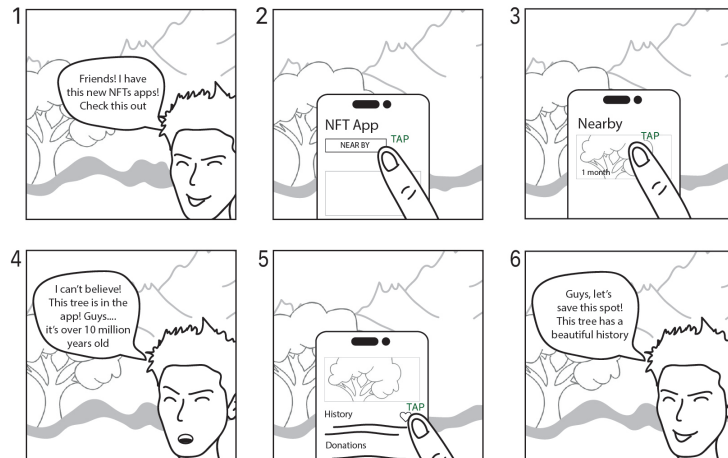
Figure 4.5: Archie scenario where he sees Nearby NFTs.

4.1.4.F   Archie supports an NFT and receives a medal

Archie gets home after a long walk with his friends and sits on his couch. He takes his smartphone from his pocket and decides to check the NFT that he saved before. Archie opens the NFT application and clicks on the favorite button. After clicking on it, he sees the beautiful tree he had seen in person before and clicks. Archie carefully analyses all the information about the NFT, including the tree history and where the crypto that he might spend goes to. After reading everything carefully, Archie gets excited and wants to support the NFT. He checks if the amount of NEAR that he has in the wallet is enough to support the NFT and gets happy to see that it is. Archie returns to the tree NFT and clicks on the "Support" button. Archie confirms the transaction and receives the temporary NFT in his wallet. Archie is super surprised. Suddenly, his phone vibrates and a new medal appears on the screen. Archie's excitement is even bigger as he loves to win medals. This medal congratulates Archie for supporting the first NFT and for doing something good with nature. Archie is now very excited about this and gained the motivation to support more!
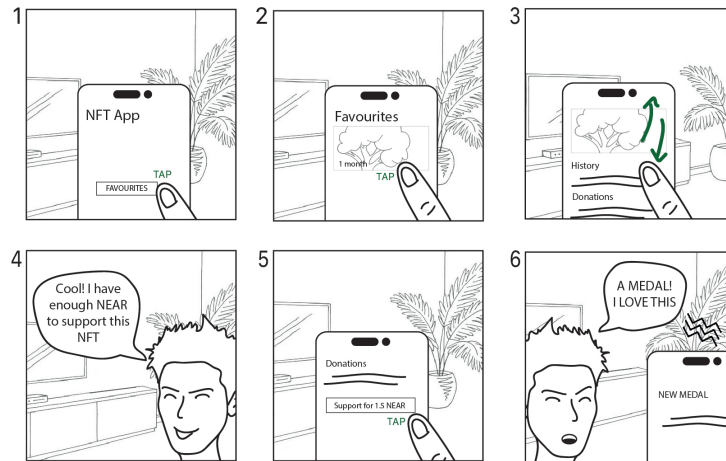
Figure 4.6: Archie scenario where he supports an NFT.

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) [90]. 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) [90], being quick to make and provided when needed. The ideation phase is described in the next section.

4.1.5 Ideation

Following the principles described above, ideation took a very quick pace to represent some possibilities of the main UI elements. As shown in the final iteration of this process, represented in Figure 4.7, these elements include the "Main App Navigation Bar", envisioned to be a single floating app bar that is present across all screens, changing its behavior depending on the page, and some other UI elements, including "Navigation/Tab Buttons" and "NFTs Box". The first bar appears on the main screen, and the second and third ones appear on the secondary screens. As the idealized navigation bars have 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, including rule number one, "strive for consistency" [91] and Norman's Design Principles, namely consistency, defining that using similar operations to achieve similar tasks is a critical principle for learning as it helps users to recognize and apply patterns when new situations appear [92].
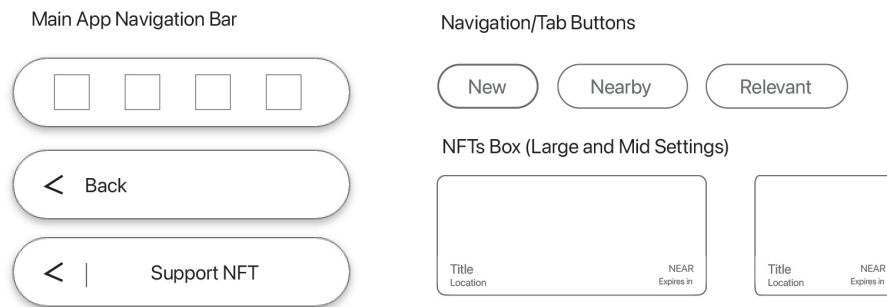
Figure 4.7: Final iteration of ideation phase.

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, it is time to start prototyping.

As described by Gonçalves et al., prototyping can be seen as a concrete, but a partial representation of the system we want to develop, allowing users to interact and validate the concept and functionalities (2017) [93]. The main goal of prototyping is to gain information about the design of the interactive system at a fast pace, allowing designers to study and fix usability problems and design new features to reach the best solution [93, 94]. When used in an organizational environment, prototyping, combined with user studying, can save costs and development time, allowing problems to be found in a very early stage of development [93].

The following topic will cover one type of prototyping: the Low-Fidelity one. Fidelity, in the scope of prototypes, refers to the proximity of the visuals to the final solution in terms of fonts, sizes, messages, colors, and other aspects [93]. Usually, low-fidelity prototypes are represented by sketches that omit lots of details to focus users, when testing, on the functionality rather than visuals [93]. In comparison with high-fidelity prototypes, low-fidelity ones are super flexible, with almost no cost to apply changes [94].

However, nowadays, we have some applications that allow designers and developers to quickly build prototypes with some functionality and basic visuals, maintaining the aspects of flexibility and ease-of-change of low-fidelity prototypes. Examples of these applications include Adobe XD [95], Figma [96], and Sketch [97]. Knowing these applications exist, given the time frame for this project and the situation where most prefer to do remote working [98], it was decided to do a prototype using Adobe XD. 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 [95]. As Adobe XD allows some interaction without increasing development costs and times and combined with some visuals created during the ideation process, the Low-Fidelity prototype easily becomes a Mid-Fidelity prototype, without losing inheriting properties from the Low-Fidelity ones.

The next section will cover how the low/mid-fidelity prototype was created and how it was tested,

showing, in the end, the main conclusions from the user testing.

4.2 Low-Fidelity Prototype

As mentioned above, the Lo-Fi was developed using Adobe XD. All the designed screens and function-alities needed to be coherent with the previous problem space, following users/personas' needs, taking into account scenarios and the ideation phase. It was decided that the application would have three main screen/page types:

- **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, sec-ondary pages will represent NFT details and organization details.

First, it was defined the number of screens and the possible interaction/flow between them, respect-ing main and splash pages, as demonstrated in the diagram below.
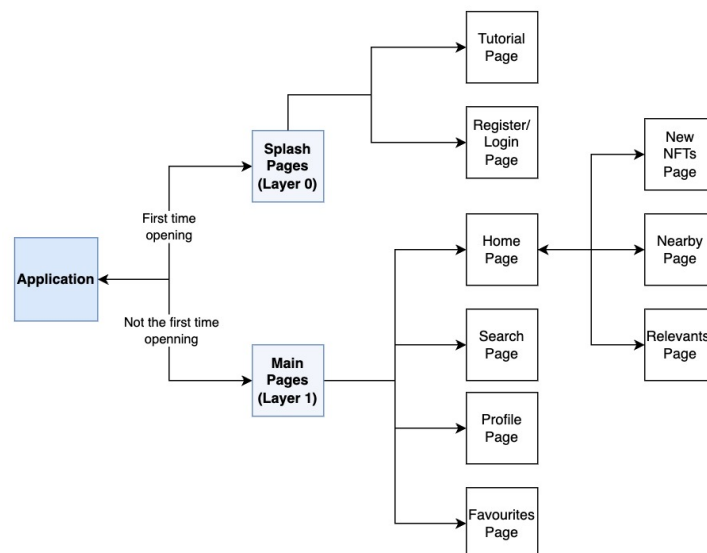
Figure 4.8: Screen flow diagram.

After this definition, the creative process began. This creative process was highly influenced by some Interaction Design principles, like Shneiderman's "Eight Golden Rules" for designing User Interfaces [91], Norman's Design Principles [92], and Nielsen's heuristics [99]. The overlapping of some rules, like Consistency, helped to simplify the requirements and goals mapping. In the end, the standard was to

create a nice-looking UI, with a good user experience (UX), following users' requirements and requested functionalities.

The first created components, as they would be used across the application, were the navigation ones, inspired by the ideation process. After creating them in Adobe XD, the main pages came to life. The aspect of these pages can be seen in Figure 4.9, however, it is important to note that the Profile Page has two variants - the normal client profile page and the organization profile page.
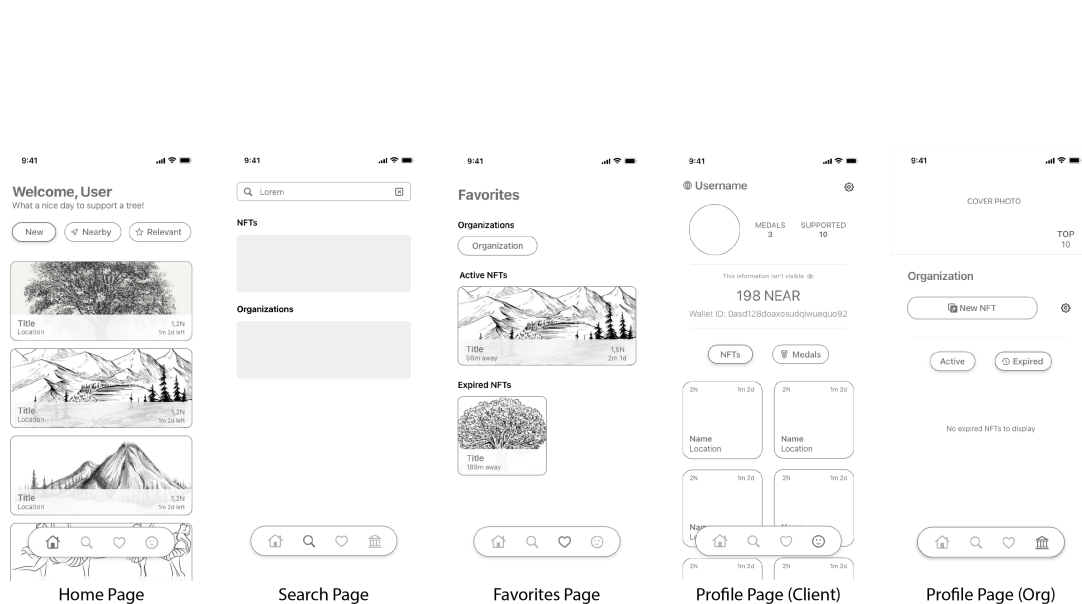
Figure 4.9: Main Pages on Lo-Fi Prototype.

After the main pages, the secondary pages were created. The secondary pages have two types: the NFTs Details Page and the Organization Details Page, as shown in Figure 4.10. The NFTs details page can be accessed by the Main Pages and the Organization Details Page can be accessed by the Search Page (from the Main Pages) and from the NFTs Details Page. From the point of view of NFT Details, considering the collected information during the interviews, the image is the most important aspect. As mentioned by one of the organizational interviewees, cultural and natural assets are complex and much more than an image. So, it is important to tell the history behind the NFT and its location, as well as have some resources namely links to videos, storytelling experiences like Transmedia Stories [15], or simple websites. One of the interviewees' concerns during interviews was corruption. To make things as clear as possible, we decided that it was important to have a section where the NFT royalties are well portrayed, including the percentage, and blockchain wallet as well as a description stating why that wallet is receiving that percentage.
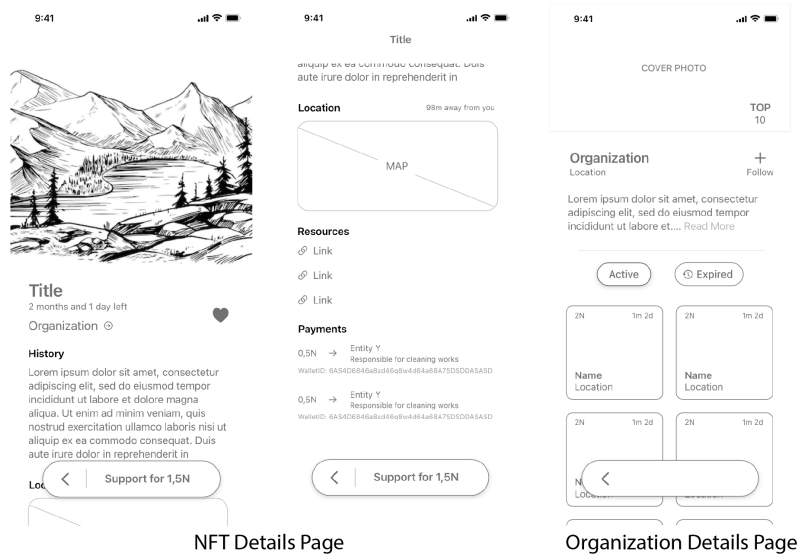
Figure 4.10: Secondary Pages on Lo-Fi Prototype.

Then, the splash pages were designed. These pages include a requested feature which was a tutorial explaining some aspects of the NFTs, a section to register or login, and a company registration form. The figure underneath illustrates some of these screens.
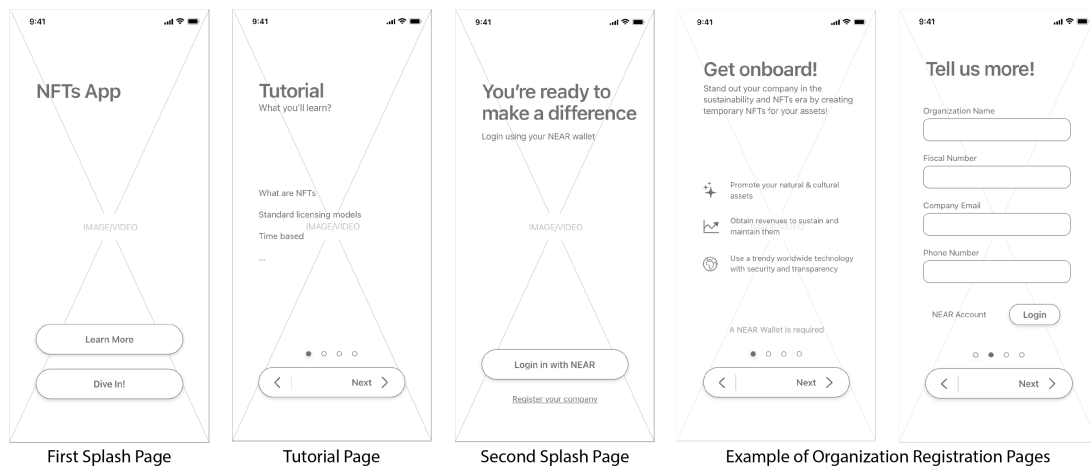
Figure 4.11: Splash Pages on Lo-Fi Prototype.

Before adding the interaction between pages, an overlapping page to Create an NFT, within the Organizational Profile variant, was designed. A medal-winning notification and a payment pop-up that uses biometric features were projected, as requested by the users.

Medal notification

NFT Details Page | Payment Pop-up
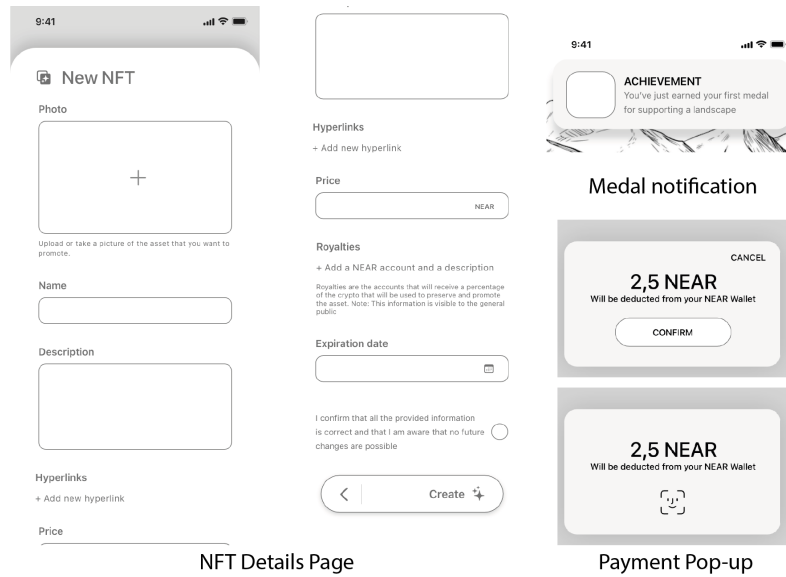
Figure 4.12: Create NFT Overlapping Page, Medal Notification, and Payment Pop-up on Lo-Fi Prototype.

After concluding the Lo-Fi design, it was time to implement the interaction flow. Adobe XD allows a simple "drag and drop" between pages to create animated transitions, so this process took almost no time. Finally, Adobe XD generates a simple link that assembles a working prototype that can be easily tested by users. Changes are also very simple to apply. In total, from the ideation process to the generated test link, it took one day to do the prototype, reassembling the low-fidelity prototype properties.

From this, it was time to test the prototype with users. When the designer/developer wants to evaluate a system in terms of usability, they want to know how effective it is in terms of learning facility, memorization, and other aspects [100]. It also allows perceiving if users' requirements are met, in terms of functionalities, reading through their emotions, and listening to what they say during the testing [100]. In short, and following ISO 9241-11:2018, user testing empowers designers and developers with powerful metrics in terms of usability, effectiveness, efficiency, and satisfaction [101]. It allows this iterative process to continue, applying improvements and recommendations given by users, while testing, the next iteration of the prototype. The next topic will cover how the Lo-Fi prototype was tested regarding its methodologies and results.

4.2.1 User Testing

Before actually starting with the user testing, it is recommended to prepare an experimental plan to conduct the testing. According to Gonçalves et al., an experimental plan is created and used before the testing sessions, avoiding *a posteriori* problems. A good experimental plan should describe, among others, the following aspects (2017) [100]:

- **What is the goal?**

- **Where?**

- **Duration.**

- **Users/Population.**

- **Tasks.**

- **Testing Methodology.**

Starting with the first question, the main goal was to evaluate the performance in terms of the usability of the prototypes and to evaluate possible problems and concerns that users might face. For the second and third questions, it was decided that the tests will take place online, via an online-conference platform, given the flexibility of the generated prototype link, and that it should take no more than 40 minutes.

Answering to the users/population aspect, the initial users from the user studying were summoned to perform the test, and they all accepted to proceed with the study. However, due to several reasons, only 5 users wanted to perform the test. As studied by Nielsen and Landauer, a mathematic model was defined to relate the number of tested users with the percentage of problems identified (1993). Their conclusions were that 1 participant will be able to identify about 85% of usability problems [102]. Although a population of 5 participants was small and given that at least two prototypes would be produced, then the testing proceeded with the available population.

Then, it was decided that the tasks to apply will be based on the scenarios created for the personas. As stated by Gonçalves et al., scenario tasks should identify the main goal of each task and how users can achieve them. Scenario task context also motivates users to accomplish the proposed task, as they have a goal to be accomplished. The description of the task should be enough to promote users' autonomy without explaining, in detail, how they will accomplish the goal (2017) [89]. With this, each task had two main sections: a scenario and the task description.

For the testing methodology, given that the tasks would be performed remotely, a form would be provided to the users with the activities and respective questions, combined. While users are performing the tasks, they will be asked to "think aloud", combined with direct observation of what they are doing. Think-aloud is a user-testing technique developed by Newell and Simon (1972), which has its roots in cognitive psychology. It provides a detailed observation of what the user is doing while performing tasks [103], incorporating verbalized ideas, doubts, ideas, and facts. It was then introduced in user interface research by Lewis in 1982, being successfully applied since then [104]. The form includes, for each question, a scale question "from 1 (very difficult) to 5 (very easy), how easy it was to do this task" and some open questions related to felt emotions, and opinions. While the user was doing the tasks, some usability measures were registered, such as: the time needed to complete the task, the number of clicks, the number of errors, and the number of times when help was needed.

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 would be asked to describe, top to bottom, what they see

on the main screen [105]. The second one was based on a standard usability test, specifically, System Usability Scale (SUS). SUS is a ten-item questionnaire where each question has a Likert scale from 1 to 5, where 1 means completely disagree and 5 means completely agree [106]. It intends to evaluate a system's effectiveness, efficiency, and satisfaction through a single number (score) representing the overall usability of the system benign studied. This score ranges from 0 to 100 and is calculated based on the following criteria: "For items 1, 3, 5, 7, and 9 the score contribution is the scale position minus 1. For items 2, 4, 6, 8, and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SU" (Brooke, 1986).

The experimental plan was concluded and a full example of the application form can be found in Appendix D. From it, the user testing took place with the chosen population. The results, divided by tasks and methodologies are demonstrated below.

4.2.1.A   Results

The following table shows the collected metrics during the user testing. As described above, a comparison was made between the time users needed to complete a task and the time that an expert needed. The same applies to click numbers. Errors on each task are also present.

Table 4.2: Collected metrics during Lo-Fi prototype user testing.

Task	Average Time (Users)(s)	Time (Expert)(s)	Time difference	Average of clicks number (User)	Clicks number (Expert)	Clicks difference	Errors
1	31.5	22	9.5	6	6	0	0
2	55.75	42	13.75	4	4	0	0
3	42.25	24	18.25	5	5	0	0
4	76.75	40	36.75	8	9	1	1
5	76.25	57	19.25	5.5	5	0.5	0
6	62.25	54	8.25	4	4	0	0

From the table, task 4 was highlighted as users took too long to complete the task, with an increased click number and an error. Task 4 asks participants to perform the following tasks:

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 did not like the current profile icon with a smile";

- "I have no idea where I can check how much crypto I have".

From the Lo-Fi prototype, users had to go to their profile to check the amount of crypto they had. This originates a break in the flow of the application as the user needs to exit the NFT Details Page to check if they have enough crypto to support the NFT. A suggestion was given by one of the users - display the amount of crypto in the confirmation pop-up, which was a good idea to apply in the next iteration of the prototype.

As what concerns tasks 1 to 3, and 5 to 6, the results were the following:

- **Task 1:** participants completed the task with success, stating that it was simple and direct with "I think that the interface looks great and clean, which facilitates the execution of each task". One of the users mentioned that the interface is too rounded: "it looks very nice, however, I would reduce the corner radius". For the scale question, all users answered 5 (very easy);

- **Task 2:** the task was completed by all participants. One of them stated that the provided information for the NFT was essential and very well portrayed and another one pointed out that it was not immediate to find the organization button, as it should be more "highlighted". Regarding the scale question, 4 users answered 5 (very easy) and 1 user answered 4 (easy);

- **Task 3:** participants were very satisfied with the result, stating, for example, "I liked the nearby feature, very interesting" and "nothing bad to point out, it was a basic functionality very well implemented". To the scale question, all participants answered 5 (very easy);

- **Task 5:** all participants stated that the process of registering the organization was easy and well-organized, however, two users stated that the button to login into the wallet should be changed and not part of the registration process. For the scale question, all users answered 5 (very easy);

- **Task 6:** participants pointed out the following aspects regarding the process of creating the NFT: "the button should be visible elsewhere and not inside the organization profile screen" and "the option to add hyperlinks should have a less technical name rather than hyperlinks". Regarding the scale question, all participants answered 5 (very easy).

As a result of these tasks, and adding to the suggestion to put currently available crypto inside the payment pop-up (task 4), the following improvements were noted:

1. Highlight the organization button inside NFT Details Page;

2. Remove the button to login into NEAR Wallet from the Registration/Login Screen and change it to the profile screen. With this change, the application could be used by anonymous users without the need to connect a wallet right away. However, this change stops the possibility of supporting/creating NFT until a wallet is present;

3. Change the Create NFT button from the Organization Profile Page to the Main Navigation Bar. With this, when the application detects that the logged-in account belongs to an organization, an extra button to create the NFT will appear on the Main Navigation Bar;

4. Change the text of the hyperlink inside the Create NFT overlapping page to "References";

5. Change the overall corner radius for the UI elements. One of the participants stated this suggestion and a small iteration was performed. In fact, reducing the corner radius improves some aspects of the application, from sizes to look and feel.

It was also possible to point out user satisfaction while using the Lo-Fi prototype. All participants, when faced with the prototype for the first time, reacted by saying that it was looking very nice, with clean visuals. Some noted that the floating Navigation Bar was something that not many applications were using, so it adds some "freshness". The NFT's information was also validated, which means that the asset was well portrayed in the solution. In short, both the UI and User Experience (UX) were validated, very positively, during these methodologies.

There is still one last methodology to be evaluated, the SUS. The scores for each participant are represented in the table below:

Table 4.3: System Usability Scale question scores for each participant.

Question/Participant	1	2	3	4	5
1 - I think that I would like to use this system frequently	5	5	4	4	5
2 - I found the system unnecessarily complex	1	1	1	1	1
3 - I thought the system was easy to use	5	5	5	5	5
4 - I think that I would need the support of a technical person to be able to use this system	1	1	1	1	1
5 - I found the various functions in this system were well integrated	5	5	5	5	5
6 - I thought there was too much inconsistency in this system	1	1	1	1	1
7 - I would imagine that most people would learn to use this system very quickly	5	5	5	4	5
8 - I found the system very cumbersome to use	1	1	1	1	1
9 - I felt very confident using the system	5	5	5	4	5
10 - I needed to learn a lot of things before I could get going with this system	1	1	1	1	1
SUS Calculation for each participant	**100**	**100**	**97,5**	**92,5**	**100**

In concordance with the previous testing methodologies, SUS represents a very favorable score in terms of usability. The average value for SUS is 68, obtained from the results of 500 usability studies with more than 5000 users [100]. In conclusion, participants were very satisfied with the Lo-Fi prototype,

which means that the final solution might receive a similar acceptance. The next step would be to implement the suggested improvements and tweak functionalities. As there were no drastic changes and usability seemed good, it was decided to construct the Hi-Fi. In contrast to Lo-Fi prototypes, Hi-Fi prototypes are very close to the final solution, embracing aspects like font, font size, colors, images, sizes, and graphical design aspects [93]. They are left to the final development phase as they have a little more cost to apply possible changes, and are expected to be close to what the user wants, fixing all the issues with the Lo-Fi prototype [93]. The next topic will cover the main aspects of the Hi-Fi prototype.

4.3 High-Fidelity Prototype

To start with the Hi-Fi prototype development, the first thing that was considered was the development platform. Since Adobe XD is a prototyping/design tool, the Hi-Fi prototype was prepared to receive all the back end functionality (blockchain/NFTs functionality described on Chapter 3). With this in mind, Flutter [107] was the chosen platform for developing the Hi-Fi prototype.

As stated on the Flutter website, "Flutter is an open source framework by Google for building beautiful, natively compiled, multi-platform applications from a single codebase" (October 2022). It has some great properties that allow developers to quickly build applications that adapt to any screen and operating system [107]. Applications built using flutter have a near-native performance and are super flexible, allowing developers to control every pixel to create customized, adaptive designs [107]. But the two main factors that directly affect the choice of Flutter were: the ability to quickly apply and visualize design changes (reducing development time and costs) and the fact that it combines both development (back end) and design (front end) in a single package [107]. Another advantage is that Flutter is extremely scalable - it was decided that the final solution would work on Android and iOS, but a small change in the code allow it to run on web browsers and desktops.

Before the development phase of the Hi-Fi prototype using Flutter, some visual aspects need to be defined. These aspects required an initial study (like Graphical Design Principles and Rules) and others derived from the opinions given during the Lo-Fi prototype test (like color palettes).

4.3.1 Graphical Design Principles and Rules

In research from Gonçalves et al., a well-designed screen correlate two aspects: aesthetics and functionalities, clearly displaying information and helping users to understand how to interact with it. All elements displayed on the final screen should have a purpose and a meaning (2017) [108]. Derived from psychological and physiological factors, some design principles were created to create a coherent and aesthetically pleasing UI [91, 92]. A known example of these principles is Norman's Design principles [92]. These principles can be combined with usability ones, like Shneiderman's "Eight Golden

Rules [91]. Although some were used during the Lo-Fi prototype designing stage, a set of them was left as details were not present on the prototype.

The following list details the relevant design aspects, according to Gonçalves et al. [108], that were decided to be relevant during the Hi-Fi prototype planning phase. Some of which are mapped to usability rules.

- **Proximity:** make sure that similar elements are grouped. This principle was already applied on the Lo-Fi prototype, where Navigation/Tab buttons are together, as well as NFTs boxes;

- **Alignment:** make sure that related elements are properly aligned. This creates a sense of organization, which is pleasing, improving ease of use. This principle was applied to the Lo-Fi prototype, but requires reinforcement during the creation of the Hi-Fi prototype as this must be explicitly declared while coding;

- **Text:** make sure that the text is aligned to the left. This principle is aligned with the users' culture. As Portuguese users are the main focus of this application, it is common for occidental societies to read from left to right, top to bottom. Like the previous one, this also needs to be reinforced;

- **Repetition (maps with coherence/consistency principle):** make sure that elements are repeated across the design solution, this includes spaces, fonts, colors, and other UI elements. This principle was also applied to the Lo-Fi prototype, not only on texts but also on elements like NFTs boxes and buttons;

- **Contrast (maps with Visibility principle):** this principle contradicts the previous one, as it defends that "if something is going to be different, then it should notoriously be". As the Lo-Fi prototype did not have colors, it was decided to be a concern during the development of the Hi-Fi prototype. For example, creating a good amount of contrast between the background and text. During the interviews, users also requested a Dark/Light mode-sensitive application, which fortifies the idea of having this principle as a priority.

Taking into account the usability principles mapped above, the following directly impact the design process:

- **Return:** make sure that all users receive information about a performed action [92]. This is more of a usability principle but it directly influences the design phase, as alerts and dialogs need to be present;

- **Affordance:** make sure that a UI element autonomously suggests its purpose, without the need to explain [92]. This is another usability principle that needed to be improved from the [92] prototype, for example, for the organization button inside the NFTs Details Page, as some users complained that they did not know it was a button.

4.3.2 Colors

Colors are as important as design principles. If they are not correctly chosen and applied, they could break some of the principles [108]. Colors have a direct impact on user emotions [109], so, their first contribution is to aesthetics. However, colors can also be used to convey and highlight information but also state (for example, a red blinking LED informing that an error occurred) [108]. Each color also has a meaning [109], for example, blue colors "represent both the sky and the sea and is associated with open spaces, freedom, intuition, imagination, inspiration, and sensitivity" (Bell, 2021). However, it is important to be aware of the users' context that was studied during the research phase. During the user study and the Lo-Fi prototype testing, some participants mentioned that they would love to have a Dark/Light theme within the app, with preferences for blue colors.

With this consideration in mind, it was chosen to create a color palette that resembles the blue color, taking into consideration the dark and light mode settings and complementary/adjacent colors. Figure 4.13 shows the final iteration of the color palette with blue colors at its core. In fact, both background and secondary colors are variants of the blue color. For each square representing the color, it is possible to see the setting (light or dark mode), at the top, followed by a color tag and the respective hexadecimal value. It is believed that this color palette conveys confidence, freedom, and inspiration [110], combined with a sense of futurism brought by the combination of the darker/lighter colors with the accent ones.
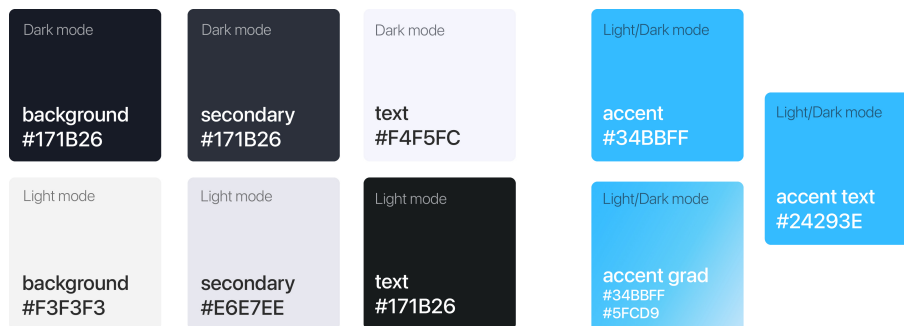
Figure 4.13: Final iteration of the used color palette.

4.3.3 Typography

For the typography, it was recommended by Gonçalves et al., to use fonts without Serifs as the interface will be displayed on computer/mobile screens [108]. This recommendation was done as Serif-based fonts have small and thin lines that require devices with complex resolution settings to be reproduced in the best way possible [108]. Concerning font sizes, spacing, and weights, it was decided to follow well-defined User Interface Guidelines, for example, Apple's "Human Interface Guidelines" which define and explain a set of typography rules with best practices [111].

After defining these aspects, the design/development process of the Hi-Fi prototype began. Since Flutter uses the concept of encapsulated Widgets, where each UI element is a Widget [107], it was settled that a bottom-up approach would be followed, starting with small widgets (like the Main App Navigation Bar, Navigation/Tab Buttons, NFT Boxes) and ending with complete pages, like the Main Page, that would consist on an agglomerate of small 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. As Chapter 5 will present more details of the final user interface, the following topic will rather focus on the improvements. In short, the next topic will present a map between the Lo-Fi prototype and the Hi-Fi prototype for the 6 improvement points, defined in the Lo-Fi prototype user testing results. Two other requirements suggested during the user research interviews were attached: the dark/light mode and the app localization (both in Portuguese and English).

4.3.4 High-Fidelity Prototype

First improvement: change the way that the available crypto is shown. In other words, on the Lo-Fi prototype, the only way that the user had to check their available crypto was to exit the screen where the user was and go to the profile. This breaks the interaction flow, as the user needs to stop a task (like supporting an NFT), to check their crypto. The change was to move the available crypto to the payment pop-up but also let the available crypto appear on the main screen.

Lo-Fi Prototype   Hi-Fi Prototype
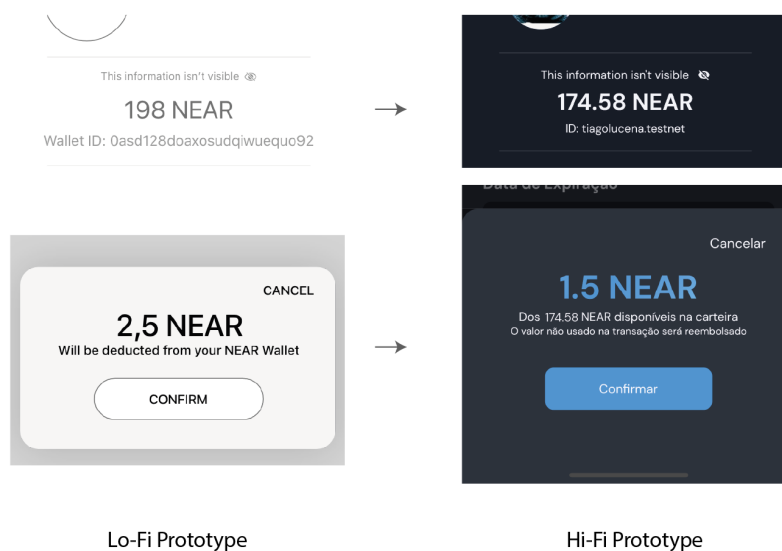
Figure 4.14: First improvement: adding the wallet balance to the payment pop-up.

Second improvement: highlight the organization button inside the NFT Details Page, as some Lo-Fi testing participants did not notice, at first, that a button was present. This reinforces the coherence/consistency as buttons have the same aspect across the application, which was not verified on the Lo-Fi prototype.

Lo-Fi Prototype   Hi-Fi Prototype

Figure 4.15: Second improvement: changing the organization button to the default to maintain consistency.

Third improvement: remove the button to log in to the crypto wallet from the registration screen and move it to the profile section. This improvement will allow users without a wallet to check the available NFTs but not to support them, increasing the promotion and the visibility of the asset. It also creates consistency between organizational and "normal" client accounts.

Lo-Fi Prototype   Hi-Fi Prototype

Figure 4.16: Third improvement: moving the connect wallet button from the registration/login flow to the main profile.

Fourth improvement: change the "Create NFT" button from the Profile Page (for organizational accounts), moving it to the Main Navigation Bar. With this, the application detects when the logged-in account belongs to an organization, and an extra button to create the NFT will be displayed. This improves usability as it resembles other applications like *TikTok*, where the "new post" button is on the main screen, without the need to go to the Profile Page.

Lo-Fi Prototype   Hi-Fi Prototype
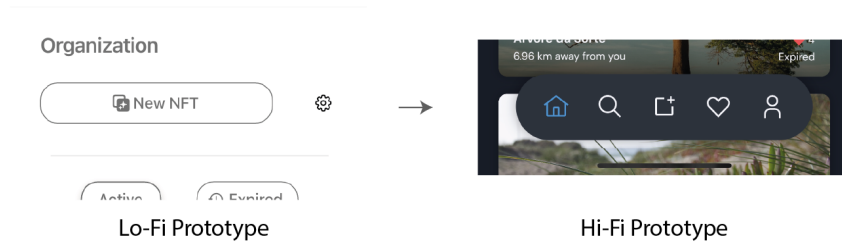
Figure 4.17: Fourth improvement: moving the "Create NFT" button from the profile page to the Main Navigation Bar.

Fifth improvement: change the text of the hyperlink inside the Create NFT Overlapping Page to "Resources", with an option to "Add Link". This way, non-technical language is better to improve users' readability and usability, enlarging the spectrum of users (from non-technical to technical users).

Lo-Fi Prototype   Hi-Fi Prototype
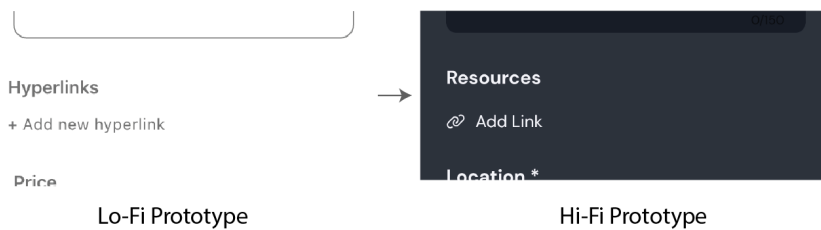
Figure 4.18: Fifth improvement: changing Hyperlink to Resources, to remove technical language.

Sixth improvement: change the overall corner radius for the UI elements. One of the participants stated this suggestion and a small iteration was performed. In fact, reducing the corner radius improves some aspects of the application, from sizes to look and feel.

Lo-Fi Prototype   Hi-Fi Prototype
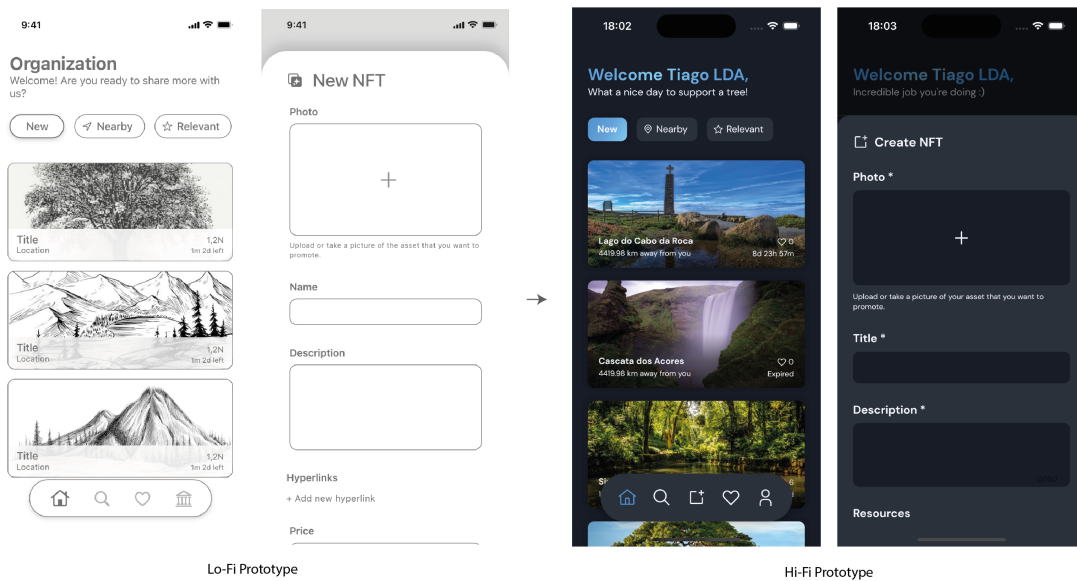
Figure 4.19: Sixth improvement: changing corner radius from the Lo-Fi prototype.

Light/Dark mode with App Localization: these were two of the most requested features during the user research (where users stated that they like shopping apps with dark mode) and Lo-Fi prototype testing. The Light and Dark Mode was implemented following the defined color palette and app localization was done in Portuguese and English. Both configurations react to the phone settings. For example, if the user uses their phone in Portuguese, the app will be in Portuguese. If the user has an automatic dark/light mode based on the time of the day, the app will react accordingly.

Dark Mode / English Version   Light Mode / Portuguese Version
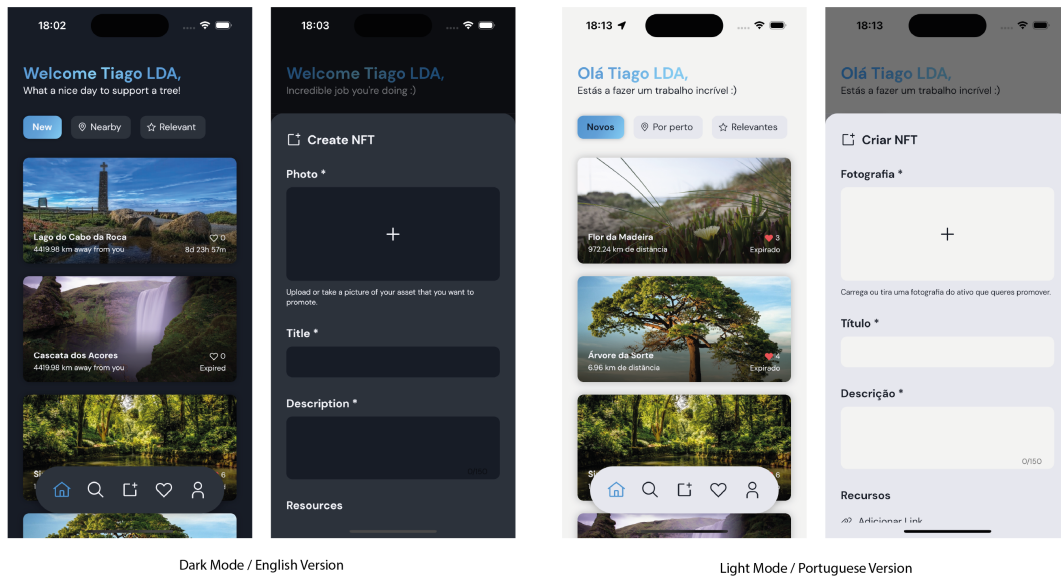
Figure 4.20: Dark Mode with English on left and Light Mode with Portuguese on the right.

Since the back end was left to be integrated in the prototype, it was decided that the User Testing for the Hi-Fi prototype would be made with the final FP. The next chapter will cover the final solution for this project, which comprises the FP that will aggregate the two components of this project, the back end (developed on Chapter 3 and validated in the present chapter) and the front end (validated, envisioned and developed in this chapter).

5

Final Solution

Contents

To understand how a complete solution could be created, initial user research was fundamental. For instance, to cover the requirements and the overall architecture of the final solution in terms of users' needs and desires, the datasets collected on Chapter 4 provided a good sense for these aspects. Concerning engineering requirements and architecture to code the final solution, Chapter 3 provided insightful aspects and solved some concerns that could have hampered the final solution (for example, the creation of the new, temporary, NFT licensing model or even the problem of making the front end and back end talk to each other).

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 NFTs directly from a mobile application using a carbon-neutral blockchain platform;

- create a new use-case for NFTs, trying to demonstrate a part of their true potential.

With this, in this section, the main requirements and the architecture of the final solution are explained, resulting from an overview of the collected data since the beginning of this project. To finalize, a complete overhaul of the crafted solution is shown and described, in the Functional Prototype section, ending with its evaluation and discussion.

5.1 Requirements

It is expected for a new NFT Marketplace platform to emerge, incorporating this new concept of temporary NFTs used to promote, secure, and preserve Portugal's natural and cultural patrimony, with the following requirements:

- 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 and log in with an approved account prior to their first login;

- Display existing NFTs in an intuitive way, showing the right information about the asset, 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

As mentioned in Chapter 1, the solution integrates the two components, the front end, and the back end. These two components were designed taking into consideration two main methodologies/technologies: UCD and NFTs. For instance, the front end was directly influenced by the UCD studies performed on Chapter 4 and the back end was validated in the very same chapter but had its technical challenges and implementation covered on Chapter 3.

From an architectural point of view, this solution was crafted following a layered "Three-Tier Architecture". This architecture is well-established in software development as it allows local changes on individual tiers given the low dependency between them (the upper depends on the immediate below) [112], separating logic from data and views. Dependency between multiple tiers creates a very fertile field to use UCD methodology given the nature of its iterative process. From a development point of view, and to comply with this layered architecture, Model-View-Controller (MVC) pattern was chosen. This pattern promotes even more flexibility, reducing code dependability and making components easily modifiable [113].

Before proceeding with architectural details, the first step taken was to reason about the possible models for this solution and to create an entity-relationship model to better conceptualize and plan each solution and the inherent architecture. This model was represented in a diagram, illustrated in Figure 5.1

In the following subsections, the three solutions tiers are presented and explained in greater detail, starting with the Data Tier, followed by the Logic tier, and ending with the Presentation Tier.

5.2.1 Data Tier

This first tier is responsible for accessing, processing, and storing all the information that is needed for the application to present information successfully, according to users' requests [114]. Following the entity-relationship model, represented on Figure 5.1, it was possible to reason about the nature and multiplicity of the data. The system comprises two data sources:

- A NoSQL, document-oriented database, using Google's Cloud FireStore (for storing data) and FireAuth (for storing authentication features, securely);

- NEAR Protocol's blockchain, to consult the information about NFTs, process their expiration state, payments, and minting procedures. For: consulting and minting NFTs.

Starting with the first point, Google Cloud FireStore is a NoSQL database in the cloud. Given its NoSQL nature, meaning that no structure or extensive code is needed when storing data, features like scalability, availability, low latency, and high performance are present, which is ideal for object-oriented programming [115]. FireAuth is another feature that allows a system to securely save users' identities
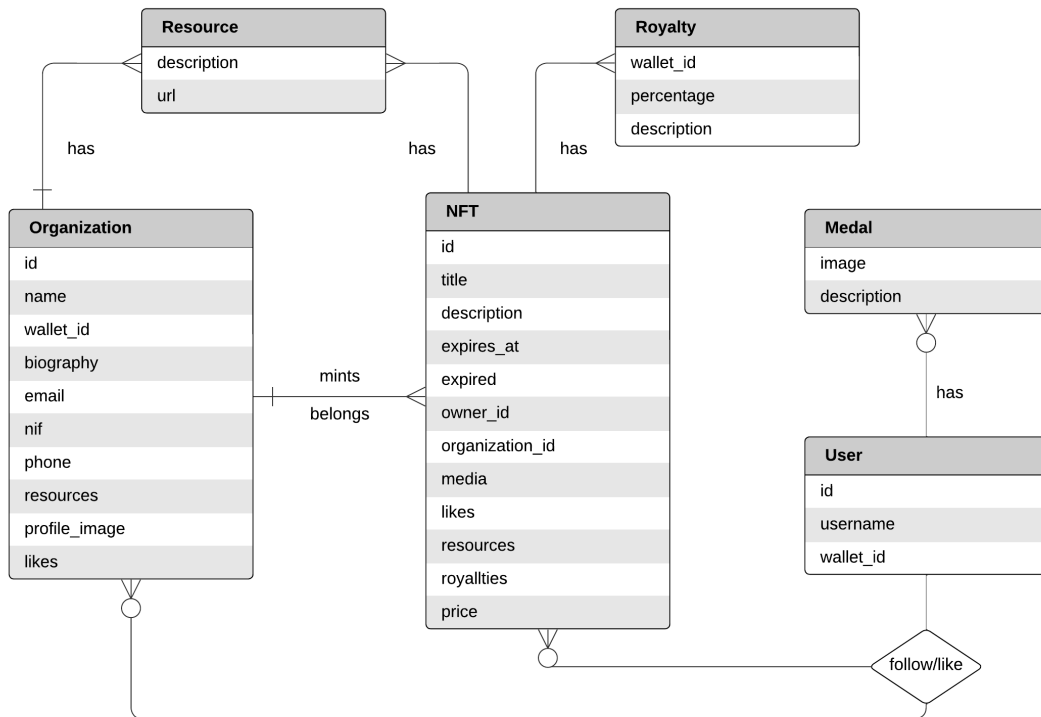
Figure 5.1: Entity-Relationship diagram representing the interaction between the multiple entities.

and information. FireStore and FireAuth were the chosen solutions given their benefits, learning curve, and integration with Flutter/Dart, as they provide a complete SDK for Dart with an automatized setup.

The second point was a mandatory choice as the NFTs are stored on the blockchain. To keep the system reliable, tracking updated information while maintaining data integrity, queries to NEAR Protocol via its RESTs services are mandatory [114].

To comply with MVC pattern, Models were created to represent the data that is extracted or sent to data sources.

5.2.2 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.

The implemented logic in the system ensures 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 and described in Section 3.3.

As Firebase and Fireauth were used, some of this logic relied on Google's Firebase business logic

features. Firebase consists of a Mobile Backend as a Service (MBaaS) which empowers app developers with tools to link their applications to cloud storage and cloud solutions provided by Google [115]. For instance, Firebase allowed the implementation of multiple login providers, like Google, Twitter and Facebook.

To comply with MVC, controllers and providers were created. Controllers are in the middle of models (representing data) and views (representing layer) enabling communication between these two. Providers talk to controllers to provide the data they need to create the models.

5.2.3 Presentation Tier

This final tier is responsible for hiding 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.

In this context, the UI runs on a mobile device with iOS or Android. However, as described on Hi-Fi prototype Section 4.3, the solution was created using Flutter. This means that, with small changes, the UI could easily be expanded to Web Browsers and Desktop applications.

To comply with MVC, views were created for each Page. These views talk with the controllers to present all the necessary data to the UI.

The definition of the UI and UX, in the created views, was based on the users' requirements and desires collected during the user study, and on design and usability principles, explained on Section 4.3.

5.3 Functional Prototype

Based on the Hi-Fi prototype presented in Section 4.3, the third and final prototype was created. This prototype joins the two main components of this project - the back end (defined on the Non-Fungible Tokens, Chapter 3) and the front end (defined on User-Centered Design, Chapter 4). The following subsections will cover the main functionalities of this prototype.

5.3.1 Splash Pages - Login/Register, Tutorial and Organization Login

The primary interaction, as demonstrated on Figure 5.2(a) is a welcoming screen where users can choose to proceed with the login or learn more about NFTs. By proceeding, they are presented with four login options, illustrated on Figure 5.2(b), one of which is to "Enter as Guest", allowing users to use the application (with restricted functionalities such as Favourites and Supporting NFTs). As exemplified on Figure 5.2(c), "Login with Google" was chosen. After the login, users are redirected to the Main Page where their permission is asked to use location, exemplified on Figure 5.2(d).
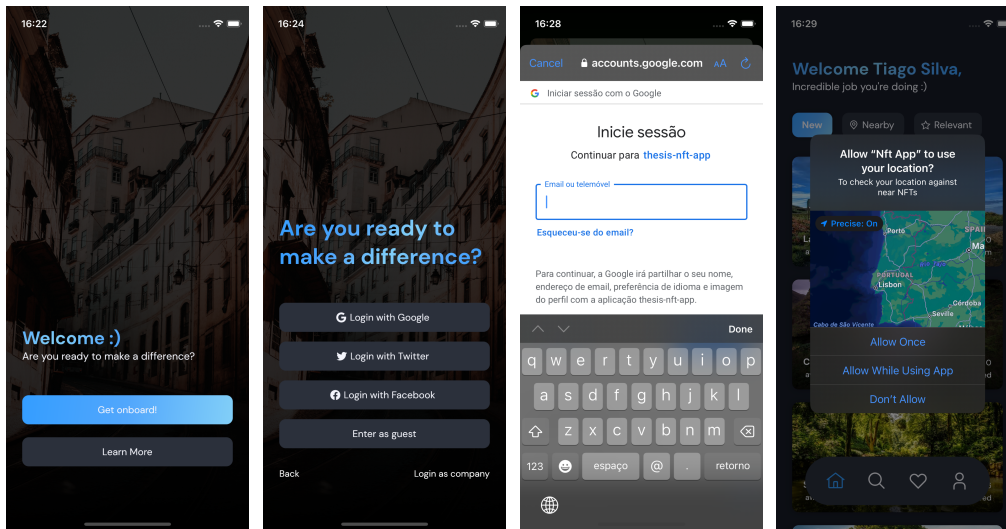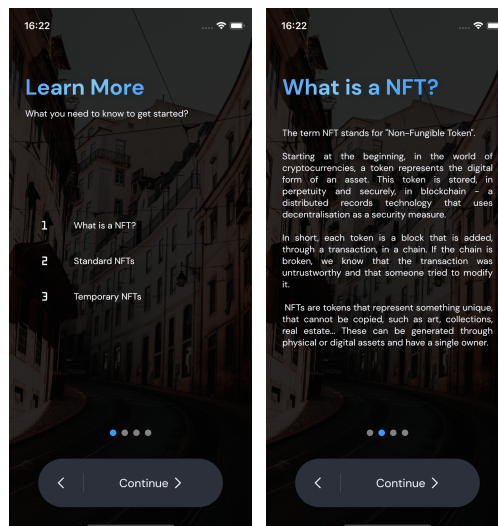
Figure 5.2: Users Login/Registration flow.

If the user opts to "Learn More" a set of four pages are presented, explaining what NFTs are, what are their standard licensing model, and ending with the new licensing model developed for this solution. This tutorial is exemplified on figures Figure 5.2(e) and Figure 5.2(f).

5.3.1.A   Organizational Registration

In the case of an organization that wants to create NFTs, a specialized login and registration flow was created. To access this flow, an organizational user needs to press the "Login as company" button as

shown on Figure 5.2(b). Then, they can proceed with the login or registration process. For registering, they need to provide some information, as exemplified in Figure 5.3(a), Figure 5.3(b), and Figure 5.3(c).

After submitting the request, the account goes for approval. If the account is approved, they receive an email with a password reset link. After this, they can proceed with the login, as exemplified on Figure 5.3(d)

(a)   (b)   (c)   (d)
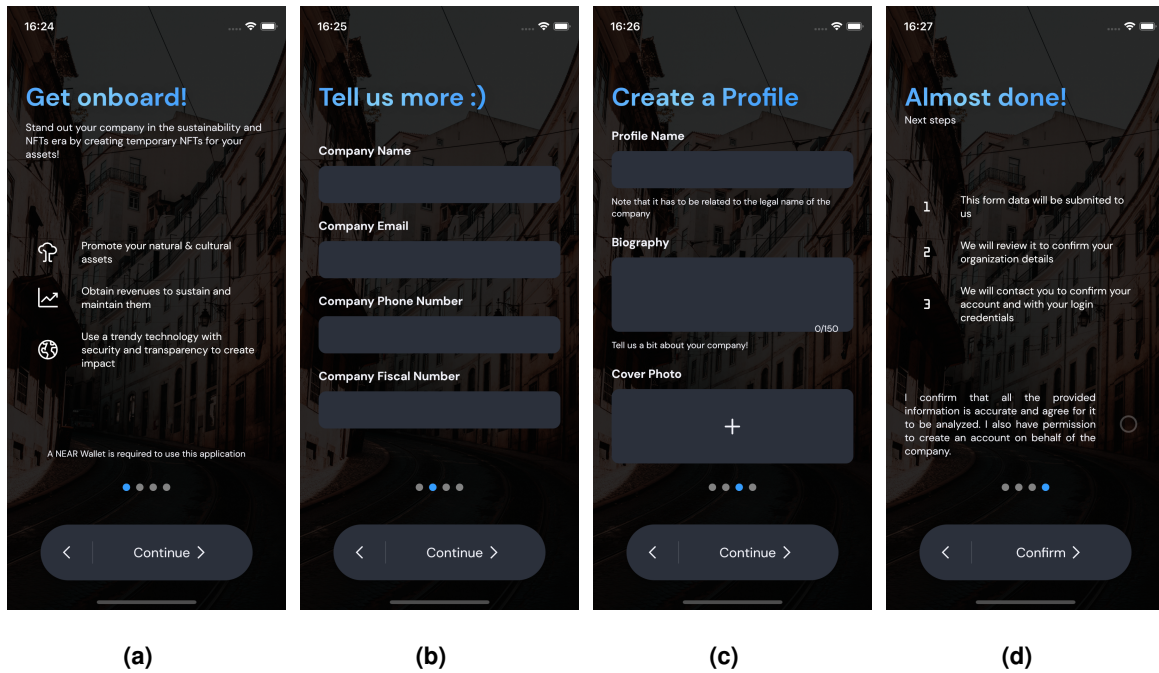
Figure 5.3: Organization Login/Registration flow.

5.3.2 Main Pages - Home, Search, Favourites, and Profile

After the Splash Pages, users are presented with the Main Pages. These pages include the Home Page (Figure 5.4(a)) which shows a welcoming message from a set of pre-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 (Figure 5.4(b)) allows users to search for NFTs and organizations by their name or location. Then, the Favourites Page (Figure 5.4(c)) that displays organizations and NFTs that users add to their favorites. Finally, the Profile Page (Figure 5.4(d)) where users could see their information, supported NFTs, and medals, in case they have a connected wallet.

(a)   (b)   (c)   (d)
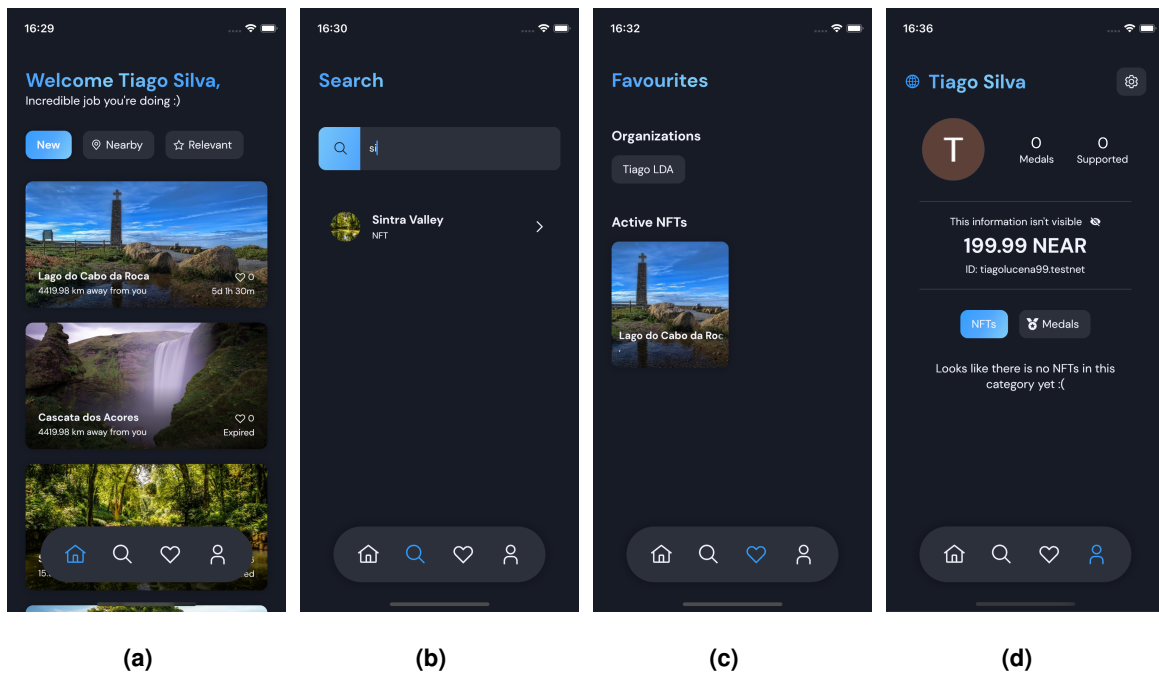
Figure 5.4: Main Pages.

5.3.3   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 till expiration. Then, it shows the history, location (Figure 5.5(a)), available resources, and how the funds will be used (Figure 5.5(b)).

Concerning organizations, it displays useful links to their website, email, and phone, their description, statistics, and active/expired NFTs. As described on the Hi-Fi Section 4.3, 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.

(a)   (b)   (c)
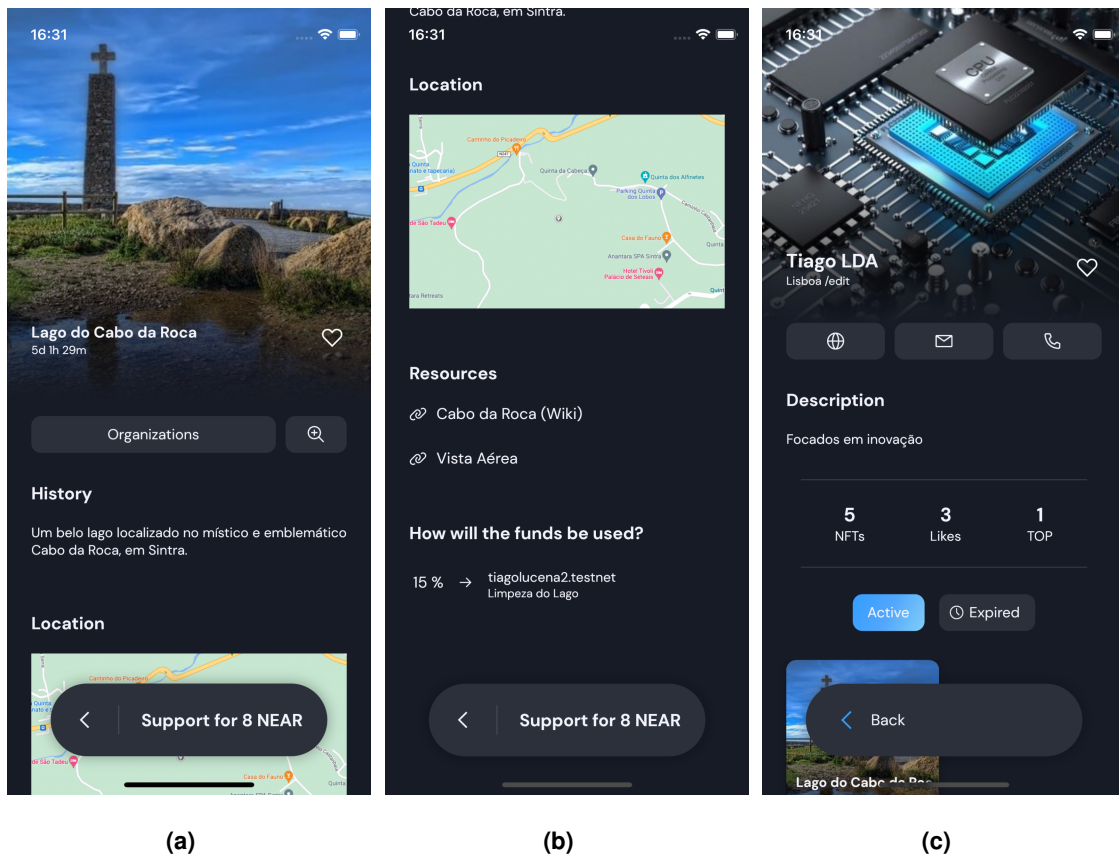
Figure 5.5: Secondary Pages - Details about NFTs and Organizations.

5.3.4 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 (as observed from Figure 5.6(d). From Figure 5.6(a), Figure 5.6(b), and Figure 5.6(c), it is possible to see the requested fields to create a new NFT, namely: 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.

(a)　　　　　　(b)　　　　　　(c)　　　　　　(d)
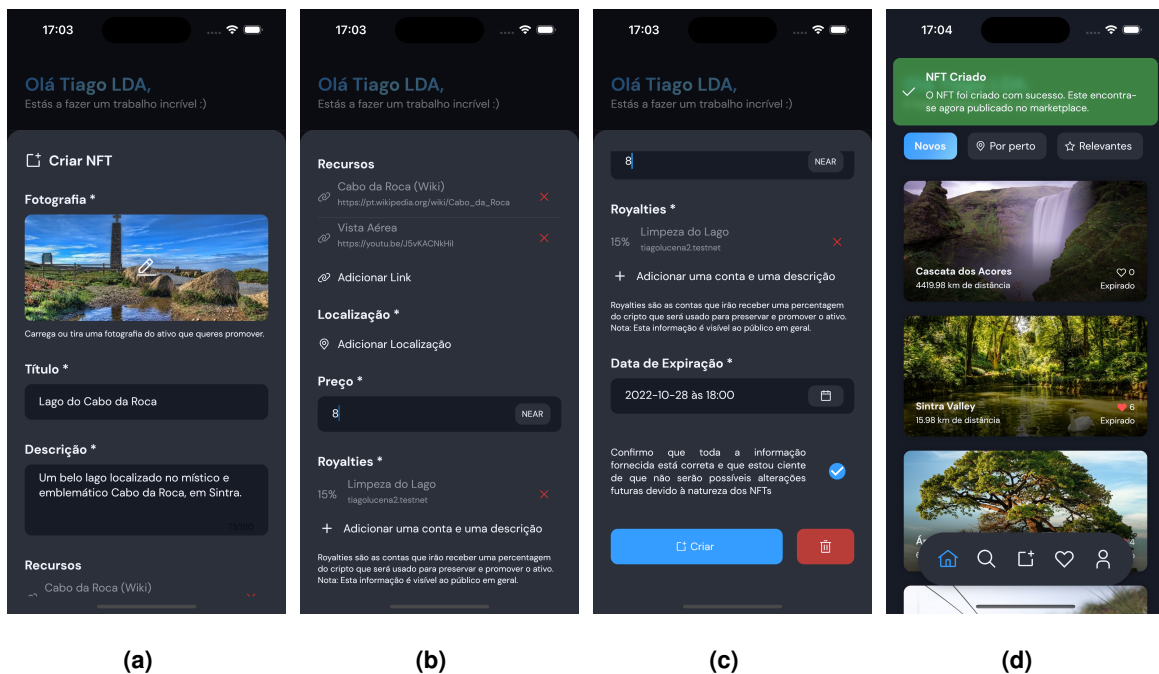
Figure 5.6: Creating a new NFT.

5.3.5 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 supporting value, users are prompted with the Confirmation overlapping page (Figure 5.7(a)) 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), as illustrated in Figure 5.7(b).

If the supporting process is completed successfully, users receive a medal depending on their actual context (number of supported NFTs, for example). Figure 5.7(c) illustrates a user receiving a medal for supporting their first NFT. Besides the notification, the application plays a sound to congratulate the user, making the phone vibrate too. Users are able to check their supported NFTs and Medals on the profile page (Figure 5.7(d)).

| (a) | (b) | (c) | (d) |
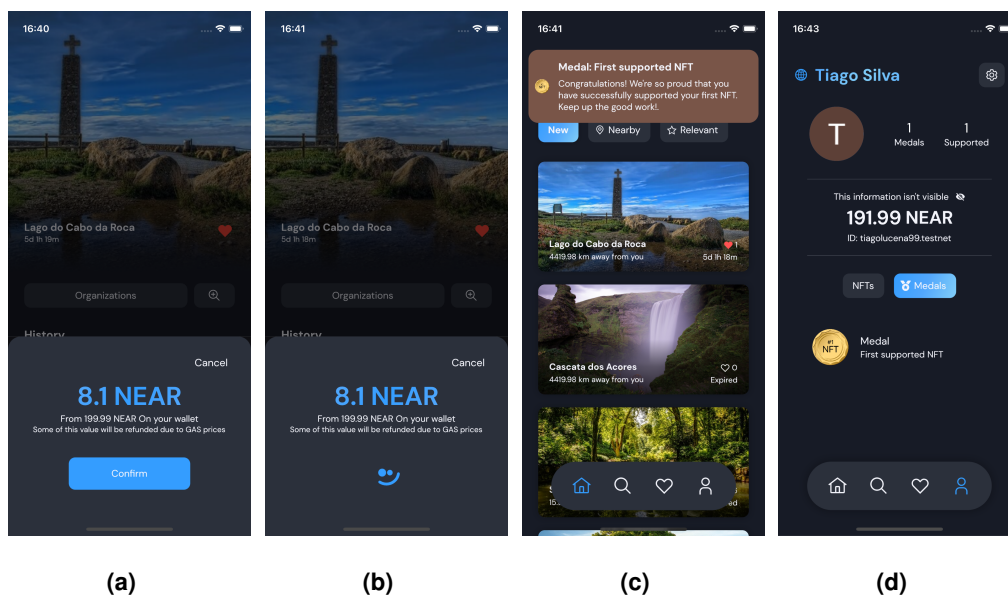
Figure 5.7: Supporting a NFT.

The only functions that were not covered here, as they were covered in the Hi-Fi Section 4.3 are the Light/Dark mode support and language translation to Portuguese and English, depending on the mobile device settings. The next section will proceed with the user testing and evaluation of this functional prototype, which is close to the final solution.

5.4 Evaluation

To evaluate the FP, the experimental plan was based on the Lo-Fi. However, it was less rigid, as usability and interaction flow were 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 participants to complete a set of tasks using the think-aloud technique. After completing the tasks, participants were left 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.

5.4.1 Tasks

A set of three tasks were prepared for this prototype:

- Take the tutorial, login into the application, and add two NFTs to your favorites;

- Log out, log back in using an organizational account provided by the interviewer, add a wallet provided by the interviewer, and create an NFT;

- Log out, log in using a Google account provided by the interviewer, add a wallet provided by the interviewer, choose an NFT, check the NFT information, and support the NFT.

The following data was collected after the three users accomplished the tasks:

- **Task 1:** all participants completed the task with success, without asking for help, and without errors. The overall feedback was very positive, with comments like "it looks super nice", "I like that you changed the corner radius for the buttons" and "with was great that you added several login options and a detailed tutorial for those who don't understand what NFTs are";

- **Task 2:** at the beginning of the task, users were provided with an organization account, approved in the system, and a NEAR Wallet seed that allowed them to log in to a test wallet for minting purposes. All three participants completed the task with success, without asking for help and without errors. The overall feedback was very positive, with comments like "the option to pick or take a photo was very clever", "I love the UI of the application" and "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";

- **Task 3:** users were, provided with a Google account to test the "Login with Google" functionality, and a NEAR Wallet seed that allowed them to log in to a test wallet for supporting an NFT. All

three participants completed the task with success, without asking for help and without errors. The overall feedback was, once again, very positive, with comments like "the fact that I could log in with multiple providers is fantastic and easy", "I loved the experience of supporting the NFT", "The medal after buying the NFT is a very personal touch that fits extremely when in the context, motivating application users' to support more".

5.4.2 User Experience Questionnaire (UEQ)

UEQ technique was chosen because it is a fast and reliable questionnaire that measures the user experience of the interactive product [116]. It has a set of 26 characteristics that are evaluated from 1 to 7. In the end, results were introduced in the UEQ Data Analysis Tool, an Excel file provided by UEQ Website [117], and the overall experience was calculated. table 5.1 represents the evaluation that each participant gave to the 26 characteristics, from 1 to 7. On the "Characteristics (1/7)" column, the leftmost work represents the number 1 and the rightmost the number 7.

After introducing the data in the provided Excel file, the results were positive. First of all, UEQ Data Analysis Tool produces two graphs, the first graph Figure 5.8(a) illustrates the attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty of the system. The second graph Figure 5.8(b) groups the previous aspects into three groups: attractiveness, pragmatic quality (perspicuity, efficiency, and dependability), describing tasks-related quality aspects, and hedonic quality (stimulation and originality), describing non-tasks related quality aspects [117]. For both graphs, the default scale ranges from -2 to 3. For reference, values higher than 0.8 represent a positive evaluation.

Observing the graphs, all values are above 2, which is 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 results achieved were validated by the UI/UX expert, which also participated in the previous tests.

(a)   (b)
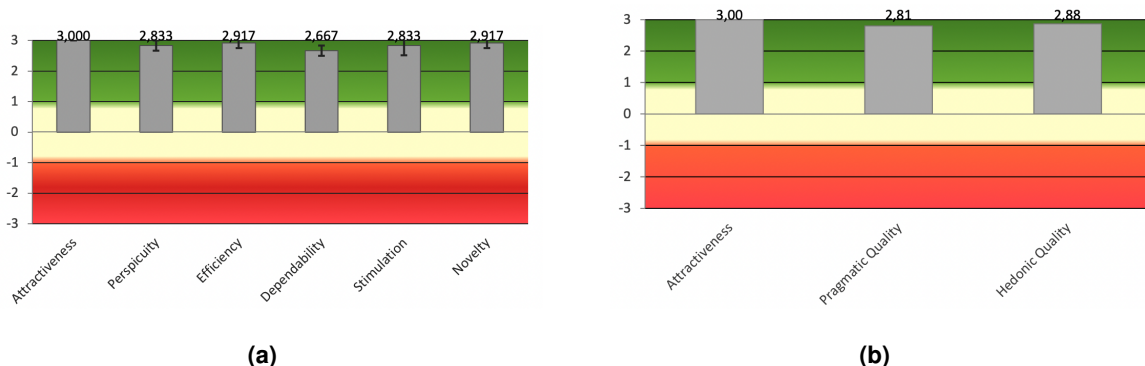
Figure 5.8: UEQ Results Graphs.

Table 5.1: UEQ scores given by the test population.

Characteristic (1/7)	User 1	User 2	User 3
annoying/enjoyable	7	7	7
not understandable/understandable	7	7	7
creative/dull	1	1	1
easy to learn/difficult to learn	1	1	1
valuable/inferior	1	1	1
boring/exciting	7	7	7
not interesting/interesting	7	6	7
unpredictable/predictable	5	6	6
fast/slow	1	1	1
inventive/conventional	1	1	1
obstructive/supportive	7	7	7
good/bad	1	1	1
complicated/easy	7	6	6
unlikable/pleasing	7	7	7
usual/leading edge	7	7	6
unpleasant/pleasant	7	7	7
secure/not secure	1	1	1
motivating/demotivating	1	2	1
meets expectations/does not meet	1	1	1
inefficient/efficient	7	7	7
clear/confusing	1	1	1
impractical/practical	7	7	6
organized/cluttered	1	1	1
attractive/unattractive	1	1	1
friendly/unfriendly	1	1	1
conservative/innovative	7	7	7

5.4.3   General opinions

While users were autonomously using the functional prototype, not following any tasks or directions, some opinions were given. Since the population used to test the Function Prototype was not large, and since the Lo-Fi/Mid fidelity prototype had some elements that resemble the final interface, with some functionality in terms of interaction, a word cloud was formed to describe the final solution. This word

cloud, illustrated in Figure 5.9 was composed of a total of 54 words collected from the users. From a first analysis, in concordance with the user evaluation, no negative words were used and most users found the solution to be innovative, easy-to-use, and mainly instructive and educational, given the explanation of the NFTs concept, broadening the spectrum of users that can successfully use the application (from users without experience on NFTs to expert users). Expert users also mentioned that the idea behind this solution was one of the best use cases that they ever heard for NFTs.

Figure 5.9: Word Cloud from the most used words during user studying and evaluation.

5.4.4 Discussion

Taking into consideration the complete user study and testing, it was possible to conclude that UCD was a fundamental tool to understand users, their concerns, and their needs. Since the beginning, the general idea for this dissertation project was well received and approved, with all concerns noted to find the best solution to find them. Both in the Lo-Fi and more on the Hi-Fi prototypes, some design and usability rules were taken into consideration.

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

- UCD was confirmed to be an excellent approach to conceive, design, and develop solutions that met users' needs. All advantages [86, 88, 94] 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, some 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.

6

Conclusion

Contents

As a consequence of the twin Nature and climate change crises, several problems are emerging, threatening our heritage, where human action, environmental issues, and forgetfulness (and consequent lack of maintenance) are causing some cultural and natural patrimony to be on the brink of destruction. This problem has led reputable organizations to create initiatives and recognize cultural and natural heritage as extremely important, as with UNESCO. It is imperative for our society to preserve our heritage, as it can define us, impose respect, and transmit our characteristics and achievements to future generations.

With the tremendous evolution of technology, many solutions have emerged to tackle this issue by promoting the magnificent cultural and natural heritages coexisting on our planet. This consequence allows us to solve this problem, from solutions that tell our story to permanent and accurate markings of landmarks on the blockchain. The hope of conserving these heritages grows with this evolution and over time. Recent solutions employ the robust capabilities of NFTs to promote culture and create a source of donations to preserve it. However, some characteristics needed to be solved: the little concern for using solutions with a low environmental impact and the incredible dynamism of our biodiversity, which is constantly changing.

After analyzing the concepts and previous works, it was possible to identify that NFTs are left to be explored in the area of cultural and natural heritage preservation and conservation. Bearing this in mind, the proposed solution for this project intended to create a new NFTs licensing model, whose NFTs would be temporary in order to highlight the promotion and protection of heritage. This temporary licensing model, combined with a carbon-free certified blockchain platform, provided the foundation to create a mobile-based NFTs marketplace application.

To create functionality and communication with blockchain, NFTs framework provided the infrastructure to develop and create a cohesive back end. The creation of the back end started by choosing a blockchain platform that is carbon-neutral, *in casu*, NEAR Protocol. This platform enabled the creation of two smart contracts: the first one concerning the creation of temporary NFTs which presented some challenges related to clocks and distributed systems synchronization and the second concerning marketplace operations, so the created NFT could be supported from users. To end up the development of this framework, the connection between NEAR Protocol with Flutter needed to be implemented. This connection was totally made from scratch, as no stable Flutter/Dart APIs existed to do this connection with NEAR Protocol.

To validate both concepts (the new licensing model and the mobile-based marketplace), a User-Centered Design methodology provided the tools needed to carefully listen to users' needs and context, gathering important data to design a solution that met their needs, concerns, and desires. After validating these concepts, the design process was started. This process took into account the data and context collected from the user study and some known design and usability principles and rules. From the

middle of this project, the first Lo-Fi/Mid-Fidelity prototype was materialized, impacted by heavy user testing to understand how usable it was and what were the first user opinions. Then, the Hi-Fi prototype was developed, incorporating all the suggestions and improvements collected from the Lo-Fi prototype user-testing. An extra effort was made to prepare this prototype, made using Flutter, to embrace the NFTs solution. This concluded the design process and the front end component of the project was successfully created.

Ultimately, the FP, 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, since the Lo-Fi prototype, presented very positive feedback and user receptivity, demonstrating that UCD is an excellent framework to envision and create solutions "from humans to humans".

6.1 Future Work

Given what was conceived for this project, and taking into consideration its current state and the results from the conducted studies and investigations, the following topics might be the subject of future improvements to this dissertation project:

- Integrating the application with new blockchain platforms with carbon-neutral certification. This empowers final users with more possibilities of choice for supporting NFTs without the need to have a NEAR Protocol's Wallet;

- Improve the social features of the applications, allowing users to talk to each other and to trade NFTs, following, for example, the concept of *Cryptokitties* [34] or Wildlife Collectibles [25];

- Create a web UI, outside of Google's Firebase, to approve organizational accounts by an approved and specified team, in case of the application of this project to a business setting;

- Expanding the solution accessibility concerns, allowing people with disabilities to use the application with full functionality;

- Use Flutter capabilities to expand the spectrum of supported devices and users, by enabling the final solution to run directly from a web browser. Small modifications would be needed, but the integration should be very straightforward.

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A

Semi-Structured Interview Guide

Description: This appendix contains the semi-structured interview guide applied to the participants during the initial user research.

Introduction [3 to 5 minutes]

1. Interviewee presentation, greeting, and a quick introduction to the project.
2. Convey value and appreciation for taking the time to do the interview.
3. Assure confidentiality and present the documentation methods. Ask for agreement.
4. Show the opportunity for up-front questions during the interview.

Context acquisition [3 to 5 min]

1. Tell me more about yourself (age, job, education, hobbies).
2. How familiar are you with mobile platforms?
3. Can you explain to me what are NFTs?
4. Are you familiar with NFTs? If yes, what is your opinion regarding this technology?
5. In what context did you see/use/bought NFTs?

Research main topics [10 to 15 min]

1. Let's focus on the context when you use the internet or your mobile device for shopping.

   (a) What makes a product engaging for you? What details make you buy a certain product?
   (b) In your opinion, what makes a good shopping experience?
   (c) Besides purchasing physical items, how has been your experience purchasing digital items?
   (d) What problems do you think online shopping platforms have?
   (e) Can you tell me some apps/websites that, somehow, motivated you to buy from them again?

2. Let's talk about protecting natural and cultural resources.

   (a) Why do you think that our planet's resources need to be protected?
   (b) Where might new technologies enter to save these resources?
   (c) What is your opinion about using NFTs to protect these resources?
   (d) Do you think that NFTs will increase awareness of these resources?
   (e) What are your main concerns about using NFTs for this purpose?
   (f) What do you think can be important when creating such a marketplace?
   (g) If these NFTs are temporary, will it increase your excitement for supporting one?

Outro [less than 3 min]

1. Before we conclude, do you have anything else to add, any comments, or questions?
2. This study will take about 3 months. Would you be interested in participating in the rest of the study? This includes other processes and interviews to analyze the future prototypes and it is expected to have a weekly or two-in-two weeks small meeting.

B

Example of the Map of Ideas

CN - Client with no Experience	
Introdução	
Introdução / Uso de Plataformas Digitais	
22 anos, vivo em Lisboa, estudo Solicitadoria no ISCAL. Tenho como hobbies estudar, leio bastante, no fundo. Gosto de fazer compras online, ver televisão, ir ao cinema, pronto, fazer planos com amigos e com o namorado e estas coisas.	CN1
22 anos, estou a terminar o mestrado e vou começar agora a trabalhar, hmm, em Setembro. Tenho estado mais focado na parte de data science, então vou começar a trabalhar nessa parte, hmmm, vim de Beja, e agora estou a morar em Lisboa há 2 anos e agora vou continuar lá.	CN2
48 anos, sou mãe, acabei agora uma licenciatura em direito, a já tinha um curso de gestão hoteleira. sou uma pessoa sem grandes conflitos, Sou calma, necessidade de grandes agitações para ser feliz.	CN3
Hobbies	
Gosto de consultar a base jurídica digital da Almedina. Também faço alguma leitura online, revistas de advogados, revistas de cariz mais técnico, também faço assim alguma leitura online.Gosto de tirar fotografias, fazer pesquisas na internet, tipo onde vamos comer, esse tipo de coisas. Utilizo o telefone para várias coisas, como todos nós nos dias de hoje, para ver produtos, compras, entretenimento.	CN1
Gosto de fazer desporto, vou ao ginásio, gosto de ir à praia, gosto de ir passear e viajar.	CN2
Pratiquei desporto federado a durante 20 anos ou mais… Adoro estar no meio dos amigos. Não sou grande discotecas, mas gosto do social e gosto de conversar. Gosto de estar com a família. Interesso-me por peças artísticas, arte em geral.	CN3
O que são NFTs?	
Já ouvi falar de Bitcoin, e do tema de tokens não fungíveis. Pronto, são umas chaves seguras ou coisas únicas, não se pode dizer únicas, quer dizer, pode dizer-se coisas mas são coisas não corpóreas, hmmm, portanto, em si, no meu mundo, serão apenas direitos sobre determinadas entidades, pronto. Nunca usei NFTs.	CN1
Sinceramente, eu não percebo muito disso. Sem que tem que ver com blockchain, mas não sei detalhes.	CN2
Ai, não sei, não sei explicar.	CN3
Opinião sobre NFTs (antes de explicar)	
É assim, para mim é uma realidade nova e desconhecida, mas penso que seja uma tecnologia pormissora, mas não entendo qual a vantagem em usar essa tecnologia. Qual a vantagem de fazer transações sobre essas determinadas coisas? É tudo um meio digital, tiramos uma fotografia ou um print, o objeto já se encontra em nossa posse, isso não acaba com o conceito? A única vantagem que vejo em que essa transação seja efetivamente efetuada é a transferência da titularidade da coisa, de um para outro. Mas não entendo qual a vantagem....	CN1
Opinião sobre NFTs (depois de explicar)	
Nos NFTs existe esse registo de transações? Se sim, isso é extremamente interessante. O facto de todas as transações serem visiveis, elimina fatores como a corrupção, a falta de honestidade. E o criador, recebe sempre créditos, monetários ou não, sobre cada venda, por exemplo, muito interessante.	CN1
Parece-me uma tecnologia extremamente interessante e com imenso potencial. Eu realmente tenho ouvido umas coisas sobre isso mas tudo associado a uma má reputação. Ou seja, está é a ser mal utilizado.	CN3
Possiveis uso para NFTs	
Por exemplo, as cardenetas de cromos, a malta faz essas coleções. Se calhar também seria interessante fazê-las pela forma em que não fisica ou de uma forma assim mais desmaterializada, através dos NFTs.	CN1
Opinião sobre o fator temporário	
Uma espécie de um aluger? Isso até seria interessante no domínio dos jardins zoológicos, se calhar podiam comprar imagens dos animaizinhos, lá está, de um certo montante, para a aquisição de doações para tratar deles e comprar materiais. Usando essa tua ideia, isso melhora visivelmente a promoção desses animais, porque, pelo que percebi, nos NFTs normais tu podes comprar e podes não fazer mais nada com eles. No teu projeto, vai haver sempre um novo que reflete o animal ou a coisa no seu estado atual.	CN1
Sim, acho que aumentava a vontade de apadrinhar, porque parece que não estamos a comprar por comprar.	CN2
Compras online	
O que evidencia mais um produto	
Vai depender do produto, mas, para já, eu não ando propriamente naquilo a que eu chamo lojas do chinês online, como a shein, à procura de como gastar o meu dinheiro. Eu gasto consoante a minha necessidade. Por exemplo, se quiser comprar um aspirador, vou indagar online qual o melhor aspirador, as características que eu quero, etc. E depois de uma pesquisa exaustiva é que eu procedo à compra. Pronto, a questão é? Vejo primeira funcionalidade e dentro do que é funcional vejo que é bonito. A imagem, o preço, e, por exemplo avaliações do produto, do género, 5 estrelas avaliado em 200 pessoas.	CN1
Então, tem de ser adequado para o que procuro… Geralmente comparo em mais que um sitio e vejo o que compensa mais. Depois, o site, se é fiável ou não. O feedback que as pessoas têm de lá, às vezes reparo nisso. E depois depende muito do produto. A imagem é o que sobressai mais, tem que ter uma imagem com qualidade e que não parece uma cópia de outras. E depois a descrição, tem que ser completa.	CN2
A imagem. Sem dúvida que cativa. A descrição acho importante. Acho muito importante a descrição do produto. Não tem que ser uma descrição muito extensa, mas há coisas, coisas básicas, por exemplo, se o produto, é à prova de água, senão à prova de água. Se estás a perceber, não tem, não tem perceber a capacidade do produto em si na totalidade, não é? Mas aquelas coisas assim Informação importante, sem dúvida.	CN3
O que é uma boa experiência de compras	
A facilidade de pagamento ou celeridade da entrega, essencialmente é isto. Eu gosto muito de websites que apresentem as formas de pagamento mais seguras como o PayPal o MBwAY, Apple Pay. Ou seja, o facto de eles terem isto tudo muito claro no site deles e de usarem estas fontes de pagamento seguras são logo um factor que me fazem querer fazer compras nesse nessa aplicação ou nesse website. Os sites que pedem apenas cartão de crédito tende sempre a evitar. Tento sempre também ver se os sites têm acordos com certas entidades, que tenham certificado a algum tipo de certificados, que tenham uma boa avaliação. Boa reputação e certificação. São duas características que me fazem aumentar a probabilidade de comprar num certo website.	CN1
Se é rápido, se não tenho que perder muito tempo a preencher as coisas. Basicamente é a rapidez, facilidade de pagamento e uso.	CN2
O meio de pagamento influencia muito, se é algo rápido e fácil, tipo como usar MBWay em que se recebe uma mensagem e já está, super fácil e rápido. Normalmente, aquele que tens de meter dados de cartão, não gosto tanto. Outra coisa é a garantia que a encomenda ficou bem feita. Há sites em quer recebes logo um email, outras em que não, e nessas em que recebes o email, acho mais próximas das lojas fisicas em que recebes um talão.	CN3
O que uma boa loja de compras online tem que ter/ser	
Obviamente tem que ser intuitivo e não me pode dar problemas. Há uma coisa que, pronto, puxando a brasa à minha sardinha, toda a gente tem o direito a fazer devoluções em lojas online, aos tais 14 dias. Se eu vou comprar algo numa plataforma, encomendo, e depois por inspecionar o produto vejo que de facto não gosto, se eu tentar devolver isso e a plataforma não me aceitar, então é meio caminho andado, para já, para darmos inicio a uma reclamção, e depois para nunca mais lá votlar a comprar, hmmm, mas tirando isto… Segurança, e claro, toda a parte visual.	CN1
Problemas/melhorias nas plataformas de compra online	
Grande parte das minhas experiências corre bem, não estou a ver nada negativo para já, no entanto, gostava de melhorar a entrega do produto, o tracking e tudo isso, mas não está muito relacionado com o teu projeto dado que é uma compra digital.	CN1
Problemas de usabilidade ou bugs são os que mais vejo, por exemplo, websites de compra que são muito bonitos mas nada funcionais, como às vezes o da Zara. Eles estão sempre a mudar de layout. Para além disto, os campos e as coisas têm que estar bem organizados, se não tem um texto gigante ali para ler, e, se não for muito demoroso.	CN2
O problema de alguns sites não terem formas de pagamento rápidas e de não se receber algo imediato a dizer que a encomenda está feita. Quer dizer, se te derem uma nota d eencomenda numa aplicação, está tudo bem, mas se não, tanto podes abrir a aplicação e estar lá o contrato, como pode já não estar.	CN3
Compra de conteúdos digitais	
Não acho muito seguro. Por exemplo. À pouco tempo comprei para um primo meu, um miudo de 10 anos, um daqueles códigos de Robux, para o Roblox, e eu acabei por receber um email com o código único, assim, pronto, do nada, no email. Não foi nada assim, algo, único, não sei se me faço entender. Foi só aquele código e mais nada. gostava que transmitissem aquele número único de forma mais segura, depois acabei por tirar um print e enviei ao meu primo, quer dizer, aquela questão de ser único acaba por não ser único. Com esta questão toda dos ciberataques, se um hacker roubasse a minha conta naquele justo momento, ficava eu sem o meu email e sem os meus 10 euros que investi no raio daquele cartão.	CN1
Adoro! Eu odeio estar a comprar coisas no meio da confusão. Ao comprar online, seja o que for, é muito melhor.	CN3

Proteção de recursos naturais/culturais	
Importância da proteção destes recursos	
Desde logo pela questão única que é o nosso planeta, nós só temos esse planeta, não temos um planeta B, pelo menos até agora, não saiu nada nas noticias sobre o assunto, pronto. Temos que os proteger.	CN1
Porque muitos são finitos, e cabe a todos nós termos cuidado com isso e preocupação	CN2
Porque precisam de ser protegidas, então podemos temos de ter um mundo. Temos que deixar ao mundo para os para. Temos de deixar um mundo para o futuro, não é? E só protegendo. Agora conseguimos amenizar as consequências de no futuro, não é? Se fizermos um uso regrado das dos recursos. Pode ser que ele até consiga aguentar mais um pouquinho.	CN3
Uso de novas tencologias para proteção de recursos	
Olha, por exemplo, a ideia que me apresentaste da tua tese. É uma forma diferente de solucionar este problema, através da preservação e conservação do patrimónío. Por exemplo, vendendo fotografias do geres durante as várias fazes do ano, podemos angariar fundos para a manutenção das florestas ou mesmo dessas paisagens, seria uma ótima iniciativa. E ter tudo transparente, tipo aqueles sites com estatísticas em tempo real, em que se consegue ver tudo, do género, compramos X e investimos Y, investido deste modo, produzindo estes resultados.	CN1
Depende, se for oceanos, já há coisas relacionadas para isso, mais, água, há já sistemas para ver qualidade da água, seca, controlar despesas . Por exemplo, há programas que reconhecem com fotos do rio e vêm a profundidade e sabem se está em perigo de seca ou não. São um bom meio para proteger recursos e acho que cada vez mais vai ser assim.	CN2
Acho que há aspectos negativos. O pouco contacto com a natureza direta, ou seja, não é porque o pessoal passa muito tempo agarrado aos telefones e às TVs que vai conhecer seja o que for. Acaba por não usufruir nem conhecer. Uma coisa é tu estares lá e conhecer, por exemplo, saberes que aquela planta era usada pelos indios para fazer curativos há milhares de anos vendo a planta é completamente diferente do que ver. No entanto, as novas tecnologias dão-nos imensa informação quando queremos, não é preciso ir a livros e procurar horas por uma coisa. Perdemos menos tempo para atingir um objetivo. No entanto, tem que haver um incentivo muito grande para desviar os jovens do jogos e das redes sociais.	CN3
Uso de NFTs para proteção e divulgação de recursos	
Penso que sim. Agora não se houve falar noutra coisa, os NFTs tem uma grande visibilidade, portanto, aquilo que promovem também irá ter. Por exemplo, se calhar há muito boa gente que nunca viu o Gerês e, talvez, através desses NFTs, desejam investir nesse ativo para salvar o planeta. Imagina, vão procurar, como posso salvar o planeta. Claro, depois querem investir. Quero preservar esta paisagem, quero ajudar, quero apadrinhar a Serra do Gerês.	CN1
Sim, sem dúvida, depois interessa também se é conhecido ou não, mas sim claro, se for um site em que as pessoas tenham confiança, então sim, é uma mais valia.	CN2
Acho uma ótima ideia, imagina que tens umas ruinas de uma civilização que esteve cá há milhares de anos atrás. Obviamente, é importante proteger fisicamente essa infraestrutura. Se consegures contar a sua história, teres uma imagem e angariares doações para a proteger, então sim, óbviamente que é uma ótima ideia.	CN3
Uso de NFTs temporários para proteção de recursos	
Completamente, quer dizer, uma pessoa pensa sempre, haaa isto durante umas horas é meu, portanto, penso que sim. Posso dizer que já fui padrinho do Gerês durante 2 horas e 33 minutos.	CN1
Sim, como não sei muitos detalhes, mas penso que sim, em termos de aplicação para proteger árvores, por exemplo, ou outros patrimónios, então sim, até porque é um assunto muito falado e seria bom para proteger, seria uma alavanca para promover. Pelo menos nunca tinha percebido tanto nessa perspetiva de proteção de recursos, mas sim, acho que é importante e uma mais valia.	CN2
Possiveis Problemas	
Tem que ser tudo claro, para evitar a corrupção. No entanto, eu nunca comprei NFTs, portanto não sei possiveis problemas, é algo que ainda irei averiguar no futuro, ate quando lançares esta app. Como receios, talvez mais no sentido, quer dizer, como é que são feitos esses pagamentos, essas transações, se é fácil de usar, se as plataformas de pagamento são seguras. Não faço ideia. Isto se todos os fatores de segurança estivessem assegurados. Se fosse tudo intuitivo, fácil de utilizar, tudo bem explicado, com linguagem clara e objetiva, sem letras pequenas e claro, com regras, por assim dizer, em que se veja o que o dinheiro será efetivamente usado para o bem e não para pagar a chulos.	CN1
Confesso que não tenho grandes problemas no uso de tecnologias para esta proteção. Tudo gasta energia, essa não é uma preocupação para mim e acho que quase ninguém se preocupa.	CN3
O que é importante ao criar esta plataforma?	
Intuitivo, ter tudo discriminado, ser seguro, ser interativo, os recursos estarem bem retratados. No entanto, há uma coisa que gostava de ver retratada, a questão da linguagem. Eu acho que o facto de ter várias linguagens na plataforma, é um fator potenciador. O inglês não é o meu forte, portanto, caso a aplicação fosse em inglês e dada a sensibilidade do assunto, não usava a aplicação e não comprava nada. Mesmo que não fosse um assunto sensível, não ia meter o meu dinheiro em algo que não percebia. A parte visual é muito importante, o recurso precisa de estar bem retratado. Tutoriais também seria algo interessante, a ensinar e explicar os conceitos. Tudo o resto trata-se de uma questão de layout e assim, nada muito importante.	CN1
Outros	
Experiência personalizada - Sim e não. Não quero algo que invada a minha privacidade ou que impinge algo, e não queria que, o facto de clicar num produto sem querer, que sugira coisas que não gosto por erro. Se eu clicasse no produto da Dora a Exploradora, por erro, eu não queria que todas as minhas sugestões fossem da Dora a Exploradora, porque eu não gosto da Dora a Exploradora. Mas se tiver uma boa base de aprendizagem, então sim, com boas sugestões, algo que não fosse demasiado assustador e que me levasse a querer que estava a ser espiado. Podia haver a opção de perguntar se a pessoa queria sugestões ou não.	CN1
Idade vs. Conhecimento sobre tecnologia - conforme a nossa idade, nós há coisas que não deixam de NOS interessar e como não NOS interessa, nós não vamos a pesquisar e ver e fixar que aquelas determinadas funcionalidades de uma aplicação percebes? EE, portanto, eu vejo que no, por exemplo, no WhatsApp, uma coisa assim, mais um é mais básica. Há opções que Eu Não que que Eu Não uso. Eu vejo a miúda utilizar ou não insta há coisas que que ele permite que Eu Não. Eu Não, não sei se quer fazer e eu vejo que a CN3_3 que tem o Instagram a há 1 mês para aí que tem dúzia, tem 13 anosacabou de fazer 13 anos. Ela sabe fazer aquela coisa toda e Eu Não sei nada e eu já tenho Instagram há muito mais tempo que ela é, porque Eu Não tenho necessidade, percebes? E acho que ISTO é com a idade de uma pessoa. Como não tem necessidade, até pode ter a curiosidade AO que é que giro aquilo faz. Mas como não é uma coisa tão é tão essencial na nossa, na nossa vida, porque eu acho que a pessoa com conforme a idade vai tentando descomplicar a vida.	CN3
O que faria ganhar interesse numa nova app? - O que seria importante para ganhar interesse numa aplicação nova - Eu acho que a. Eu acho que que não, não se perdia nada. Antigamente é engraçado porque antigamente, quando vinha ou. Quando não só comprava antes de haver as Internet, não é antes de haver os grandes computadores, etc. Quando aparecia o comprámos uma máquina nova. Antigamente nós íamos ler os livros de instruções. Até chegámos a um ponto em que deixámos de ler. Ninguém ligava às instruções, porque aquilo era tão friendly user, mas já saio on off, não sei quê play, não estás a ver e então já ninguém ligava essas instruções e, portanto, até deixou de existir as instruções, se quiseres vais à Internet, EE, buscas e etc mas eu acho que Houve uma altura que NOS conta como Se Eu comprava o computador, tinhas as instruções e tinhas as instruções rápidas. E essas instruções Rápidas e eu acho que no numa numa aplicação nova, acho que faz faz algum sentido tipo o básico, estás a ver assim ou algumas curiosidades? Tipo, tipo um bocado com uma, eu sei que Apple faz ISTO, não é quando, quando lança os os novos sistemas operativos, sim, sim, depois ativas bem, o que é que há de novo?	CN3

C

Personas

Emily Alves Sousa

"I love to study and to invest in what I don't know yet as the unknown can be wonderful"

Ocupation	Student
Age	24
Course	Solicitor
Education level	Graduation

Emily is passionate about art, but recently digital art is in her art. She loves to see physical assets transformed into digital ones and recently gained interest in NFTS, although experience is lacking.

Personality

Emily is 24 years old and was born in Portugal. She's living near Cascais and recently started an internship in a law office as she just finished her solicitor/law degree at ISCAL. What Emily wants is to start her own office as she is passionate about what she does. In her free time, Emily loves to investigate all sorts of things as the "sky is our only limit". Emily became interested in digital art after seeing the spread of NFTs all over the news.

Introvert	● ● ● ● ●	Extrovert
Analytical	● ● ● ● ●	Creative
Sports	● ● ● ● ●	Home Time
Technology	● ● ● ● ●	Traditional
Proactive	● ● ● ● ●	Reactive

Interests

- Gym
- Healthy food
- Laws and books
- Family and Friends
- Study and Reserach
- Online Shopping

Goals

Start her own law office. Write her law books. Have a healthy and balanced life with lots of friends and family. Dive into the unknown and research what wonderful are there to come.

Current Wants/Needs

Learn more about NFTs and how they can be good to invest in. Having a place where Emily can see curiosities that motivate her to invest in NFTs. Used a good NFT marketplace where makes sense to invest money. Emily loves personalized experiences, like Instagram, where they recommend posts she might like.

Frustrations

- Lack of reviews on some product buying websites
- How people don't protect the environment and waste food/water.
- Lack of good explanations about NFTs

Top Brands/Apps

Apple, Pinterest, Amazon, Almedina, SHEIN

Laura Castro de Azevedo

"Technology is a mean and not an end, so we must try to take advantage of the good things it provides"

Ocupation	Marketing Leader
Age	39
Course	Design & Marketing
Education level	Master

Laura is the Marketing Team Leader at the top Tourism Company in Portugal. She's trying to take advantage of the visibility of NFTs to promote and protect assets and to connect Portuguese territory to a digital value that is creatively created without impacting sustainability.

Personality

Laura is 39 years old and was born in Portugal. Currently, she is living in Santa Cruz but loves (and her job allows) to travel a lot, Laura took a Design and Marketing degree some years ago and, after working on other companies, she settled as the Marketing Team Leader of one of top Portugal's Tourism organization. She investigated NFTs as they are a current trend and is trying to use them to promote and protect assets without affecting them.

Introvert	● ● ● ● ●	Extrovert
Analytical	● ● ● ● ●	Creative
Sports	● ● ● ● ●	Home Time
Technology	● ● ● ● ●	Traditional
Proactive	● ● ● ● ●	Reactive

Interests

- UI / UX
- Marketing
- Photography
- Travelling
- Gastronomy
- Social Media

Goals

Use new technologies to achieve things. Develop a digital strategy to establish digital partnerships that align with her company's values. Protect and promote sustainability. Travel the world and discover new places.

Current Wants/Needs

Using NFTs to make patrimony accessible to everyone, adding value, without compromising sustainability or the assets themselves. Generate revenue with NFTs to be able to finance the conservation and restoration of assets. Also, to diversify her company revenues. Invest in NFTs formation, especially to end all misinformation and a bad reputation.

Frustrations

- The misinformation and the lack of information about NFTs.
- Latency and wasted time with badly designed services and applications.
- Global warming and pollution.

Top Brands/Apps

Marketeer, Twitter, Adobe, Mailchimp, TripAdvisor

Archie Buckley

"I prefer to learn new things and to focus on myself, but sometimes I love to hang out and do sports with my friends"

Ocupation	Developer
Age	25
Course	Computer Science
Education level	Gratuated

Archie is an expert regarding blockchain and NFTs as she took a course on it. He is passionate about investing in NFTs to show off to his friends and to support causes.

Personality

Archie is 25 years old. He was born in England but came to Portugal with his parents when he was a kid. Currently, he is working as a C# Software Developer in a good company but wants to work with the Flutter framework as he got amazed with the things we can do with it. As his company worked with blockchain before, he has lots of experience with it and recently with NFT, diving deep down on NFTs specifications and workflows, and also invested in some.

Introvert	● ● ● ● ●	Extrovert
Analytical	● ● ● ● ●	Creative
Sports	● ● ● ● ●	Home Time
Technology	● ● ● ● ●	Traditional
Proactive	● ● ● ● ●	Reactive

Interests

- Technology
- Blockchain/NFTs
- Basketball
- Video Games
- Paddle
- Music

Goals

Learn the top programming languages and frameworks. Be always updated about new technologies and games. Get a defined body and good health. vTravel to Korea and Japan

Current Wants/Needs

A good cause to invest on with NFTs, as current use cases don't get his attention, with a well-designed UI. Be able to see a personal purchasing history. Gain medals when supporting NFTs. A place where people get well-informed about NFTs. A new NFT licensing model. Location-aware applications.

Frustrations

- Losing in online video games.
- Current NFTs use cases and lack of good causes regarding this technology.
- Slow gym progress.

Top Brands/Apps

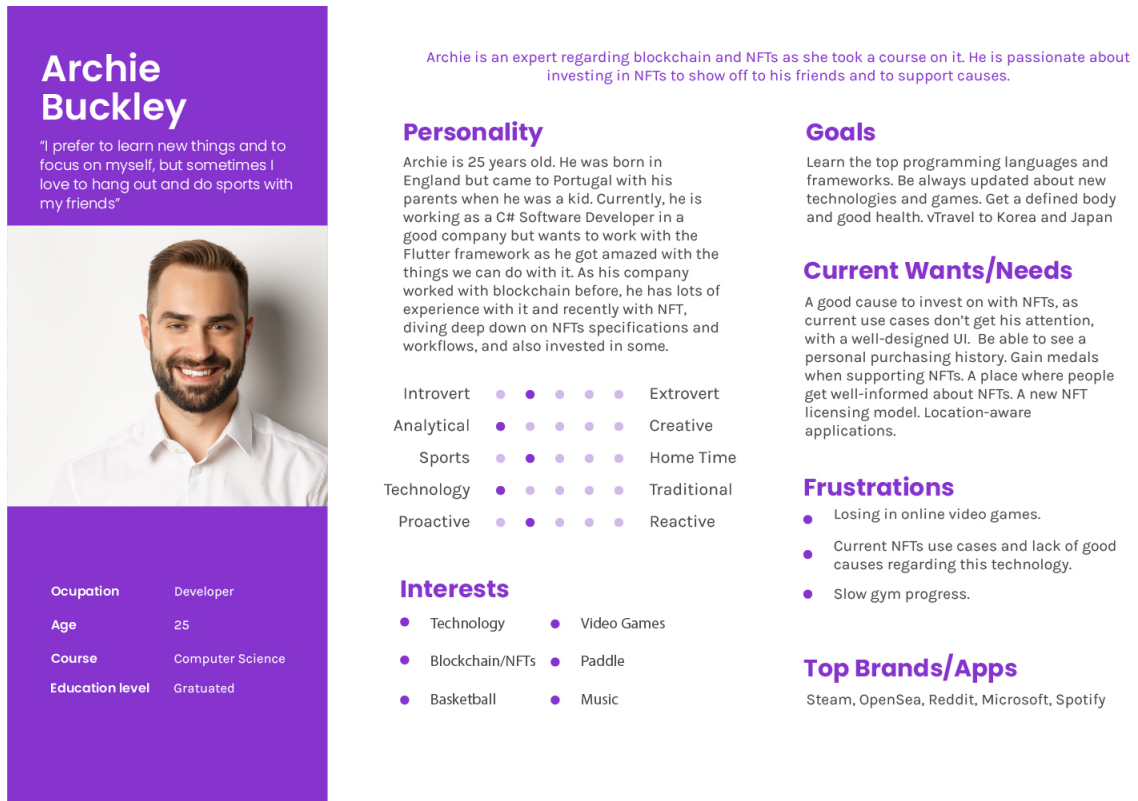Steam, OpenSea, Reddit, Microsoft, Spotify

Figure C.1: The created personas based on user research.

D

Experimental Plan for the Lo-Fi Prototype Usability Test

Tarefas de teste de usabilidade

Este formulário tem um conjunto de 6 tarefas que atestam a usabilidade do protótipo em questão e que aferem a opinião dos participantes.

Pré-requisitos:
 - É necessário ter um ID de participante;
 - É necessário mostrar o ecrã do dispositivo onde testa (por exemplo: "baixar" a câmara do computador para se ver o telefone/tablet ou partilhar o ecrã do mesmo);
 - As tarefas usam a metodologia "Think Aloud". Com isto, pede-se que "pense em voz alta" enquanto realiza as tarefas.
 - **Caso esteja a realizar o teste sem supervisão:** pede-se que grave o ecrã em cada tarefa, em conjunto com a sua voz para o "think aloud" ("pensar em voz alta" enquanto realiza a tarefa"). No caso da pré-tarefa "Wizard of Oz", basta gravar o áudio.

Nota: no main screen, o único "NFT" que é clickable é o que se encontra abaixo (segunda posição no main screen). Na aba dos favoritos ambos são clickable.

O link para o protótipo é disponibilizado em cada tarefa. Pede-se que feche o protótipo no fim de cada tarefa e que volte a abrir novamente com o link disponivel na tarefa seguinte.

Grato pela sua ajuda :)

* Required
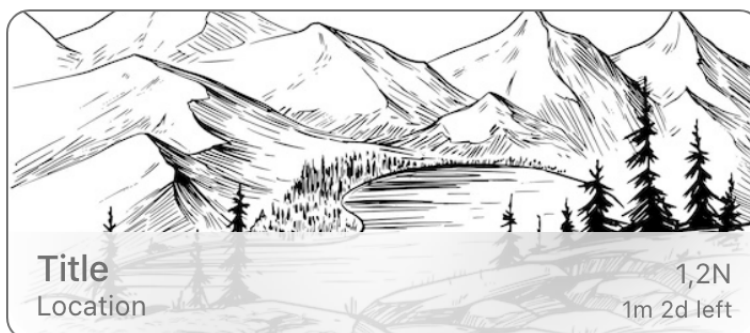
Introduza o seu ID de participante *

Your answer

Wizard of Oz

Antes de começar, a metodologia "**Wizard of Oz**" será aplicada ao ecrã principal que se encontra abaixo.

Esta metodologia consiste em descrever, de cima para baixo, da esquerda para a direta, todos os elementos visíveis no ecrã (tirando a barra de estado - bateria, horas...). Por exemplo: "vejo um botão, este botão parece que faz x".

Se estiver a realizar a tarefa sem supervisão, basta gravar um áudio.

106

Ecrã principal

9:41

Welcome, User
What a nice day to support a tree!

(New)   (◁ Nearby)   (☆ Relevant)

Title   1,2N
Location   1m 2d left

Title   1,2N
Location   1m 2d left

Title   1,2N
Location   1m 2d left

🏠   🔍   ♡   ☺
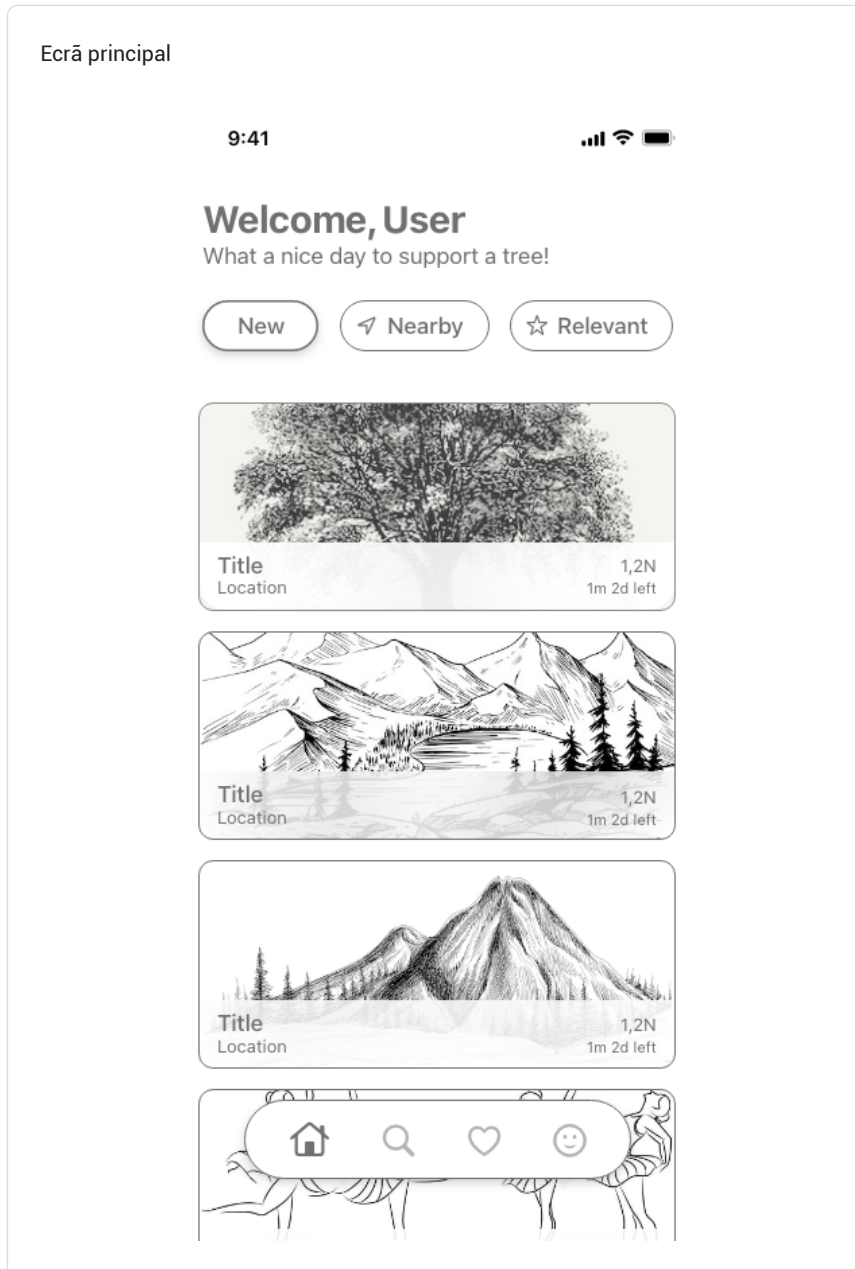
Tarefa 1

Cenário: Está interessado conceito de NFTs e esta aplicação desperta o seu interesse, especialmente por ter o fator temporal associado aos NFTs.

Tarefa:

1. Siga o tutorial de aprendizagem;
2. Faça login com a sua conta NEAR (não precisa de introduzir credenciais, apenas de clicar no botão para login).
3. Conclui a tarefa quando chegar ao ecrã principal da aplicação.

Protótipo: https://xd.adobe.com/view/952b53ea-9d39-4c2d-a910-8ba8d1734ea6-c078/?fullscreen&hints=off

Precisou de ajuda para realizar a tarefa? *

○ Sim

○ Não

Numa escala de 1 a 5, o quão fácil foi realizar a tarefa? *

	1	2	3	4	5	
Muito difícil	○	○	○	○	○	Muito fácil

Descreva sucintamente as emoções que teve ao realizar a tarefa. *

Your answer

Qual a sua opinião sobre a interface apresentada na tarefa? Pode sugerir   *
alterações/mudanças.

Your answer

Tarefa 2

Cenário: Está interessado em observar o património existente bem como a sua informação, incluindo a informação da organização.

Tarefa:

1. No ecrã principal, selecione o NFT da paisagem;
2. Observe a informação do NFT;
3. Observe a informação da organização que publicou esse NFT;

Protótipo: https://xd.adobe.com/view/41d3058b-49f2-4cfb-a970-07bc0b93dff6-1480/?fullscreen

Precisou de ajuda para realizar a tarefa? *

○ Sim

○ Não

Numa escala de 1 a 5, o quão fácil foi realizar a tarefa? *

	1	2	3	4	5	
Muito difícil	○	○	○	○	○	Muito fácil

Descreva sucintamente as emoções que teve ao realizar a tarefa. *

Your answer

O que achou sobre a informação disponibilizada sobre o NFT e sobre a organização? (Em termos de tópicos e não do conteudo genérico em si) *

Your answer

Qual a sua opinião sobre a interface apresentada na tarefa? Pode sugerir alterações/mudanças. *

Your answer

Tarefa 3

Cenário: Está a fazer uma caminhada e vê uma paisagem. Decide ver os NFTs que se encontram por perto para ver se a paisagem se encontra na aplicação.

Tarefa:

1. Veja os NFTs que se encontram perto.
2. Selecione o que se encontra mais perto.
3. Adicione-o aos favoritos.
4. Verifique se o NFT se encontra nos favoritos.
5. Conclui a tarefa se o NFT se encontrar nos favoritos

Protótipo: https://xd.adobe.com/view/41d3058b-49f2-4cfb-a970-07bc0b93dff6-1480/?fullscreen

Precisou de ajuda para realizar a tarefa? *

○ Sim

○ Não

Numa escala de 1 a 5, o quão fácil foi realizar a tarefa? *

	1	2	3	4	5	
Muito difícil	○	○	○	○	○	Muito fácil

Descreva sucintamente as emoções que teve ao realizar a tarefa. *

Your answer

Qual a sua opinião sobre a interface apresentada na tarefa? Pode sugerir alterações/mudanças. *

Your answer

Tarefa 4

Cenário: Chegou a casa, depois da caminhada, e decide suportar o seu primeiro NFT (o que adicionou aos favoritos durante a caminhada).

Tarefa:

1. Veja o preço do NFT que adicionou aos favoritos.
2. Verifique se tem criptomoeda NEAR suficiente para suportar o NFT.
3. Suporte ("compre") o NFT que adicionou aos favoritos.
4. Conclui a tarefa quando receber um achievement em forma de notificação. Observe a medalha que ganhou através da notificação.

Protótipo: https://xd.adobe.com/view/41d3058b-49f2-4cfb-a970-07bc0b93dff6-1480/?fullscreen

Precisou de ajuda para realizar a tarefa? *

○ Sim

○ Não

Numa escala de 1 a 5, o quão fácil foi realizar a tarefa? *

	1	2	3	4	5	
Muito difícil	○	○	○	○	○	Muito fácil

Descreva sucintamente as emoções que teve ao realizar a tarefa. *

Your answer

O que achou do processo de "apadrinhamento" do NFT? *

Your answer

O que sentiu quando ganhou o "achievement" (medalha)? E qual a sua opinião *
sobre este recurso?

Your answer

Qual a sua opinião sobre a interface apresentada na tarefa? Pode sugerir *
alterações/mudanças.

Your answer

Tarefa 5

Cenário: A sua empresa procura novas formas de obter receita através da divulgação do
seu património natural e cultural. Como os NFTs são um assunto corrente, como
funcionário, sugere a utilização desta aplicação à empresa. A empresa aceita. Procede
então ao registo da empresa.

Tarefa:

1. Registe a sua empresa na plataforma (nota: não precisa de preencher os campos de
   texto - não são editáveis).
2. Conclui a tarefa após chegar ao ecrã principal da aplicação e esta apresentar um
   símbolo de uma "organização" no menu de navegação.

Protótipo: https://xd.adobe.com/view/952b53ea-9d39-4c2d-a910-8ba8d1734ea6-c078/?
fullscreen&hints=off

Precisou de ajuda para realizar a tarefa? *

○ Sim

○ Não

Numa escala de 1 a 5, o quão fácil foi realizar a tarefa? *

	1	2	3	4	5	
Muito difícil	◯	◯	◯	◯	◯	Muito fácil

Descreva sucintamente as emoções que teve ao realizar a tarefa. *

Your answer

O que achou do processo de registo de empresa? *

Your answer

Qual a sua opinião sobre a interface apresentada na tarefa? Pode sugerir alterações/mudanças. *

Your answer

Tarefa 6

Cenário: Após registar a sua empresa (tarefa 5) e receber o email de confirmação do registo, decide criar o primeiro NFT da sua empresa.

Tarefa:

1. Crie um NFT para a sua empresa. Nota: não precisa de preencher os campos.
2. Conclui a tarefa após criar o NFT e ser reencaminhado para o perfil de empresa.

Protótipo: https://xd.adobe.com/view/9f675dfb-e198-4d83-93e0-2d63fc55c159-ca34/?fullscreen&hints=off

Precisou de ajuda para realizar a tarefa? *

◯ Sim

◯ Não

Numa escala de 1 a 5, o quão fácil foi realizar a tarefa? *

	1	2	3	4	5	
Muito difícil	○	○	○	○	○	Muito fácil

Descreva sucintamente as emoções que teve ao realizar a tarefa. *

Your answer

O que achou do processo de criação do NFT? *

Your answer

Qual a sua opinião sobre a localização do botão para criar NFTs? Se não for positiva, indique uma sugestão. *

Your answer

Qual a sua opinião sobre a interface apresentada na tarefa? Pode sugerir alterações/mudanças. *

Your answer

Questionário Final

O presente questionário baseia-se no princípio "SUS" - System Usability Scale ou Escala de Usabilidade de Sistema. Baseia-se num conjunto de 10 perguntas classificadas com uma escala de 1 - Discordo Completamente a 5 - Concordo Completamente.

O SUS pretende avaliar:
 - Efetividade;
 - Eficiência;
 - Satisfação

1. Eu acho que gostaria de usar este sistema com frequência *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

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2. Eu acho este sistema desnecessariamente complexo. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

3. Eu achei o sistema fácil de usar. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

4. Eu acho que precisaria do suporte de um técnico para poder usar o sistema. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

5. Eu acho que as várias funções do sistema estão bem integradas. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

6. Eu acho que o sistema apresenta muitas inconsistências. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

7. Eu imagino que as pessoas aprenderão a usar este sistema rapidamente. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

8. Eu achei que o sistema era complicado de usar. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

9. Eu senti-me confiante a utilizar o sistema. *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

10. Eu irei necessitar de aprender muitas coisas novas para utilizar o sistema *

	1	2	3	4	5	
Discordo Completamente	○	○	○	○	○	Concordo Completamente

Google Forms

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