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Development of cryptogames with Unity on an Ethereum Blockchain Test Network: Case Study and Challenges

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Abstract: The development of software aligned with Web3 innovations is essential to stimulate discussions on the application of these technologies in the scientific realm. This study presents the development of a 'cryptogame,' a game that integrates blockchain technology to incorporate Non-Fungible Tokens (NFTs) into its functionalities. The paper explores fundamental Web3 concepts, with references to relevant literature, and details the development process, including the methodologies and models adopted. As a result, a puzzle game was created that utilizes NFTs as playable characters, allowing for the transfer of these assets between digital wallets. Furthermore, the study investigates the application of these concepts in adapting a traditional mobile game for the use of NFTs, demonstrating the necessary changes in user interface and game mechanics to support the integration with digital assets.

Keywords: Blockchain, Game Development, NFT

1 Introduction

In the last decade, a new form of payment known as cryptocurrency has emerged [Mattos *et al*., 2020]. The main characteristic of this asset is decentralization, which means there is no need to involve third parties in transactions, making national and international financial operations more efficient in terms of time and cost compared to the model used in the traditional banking sector [Abramova and Böhme, 2016]. Although the term cryptocurrency is often used synonymously with Bitcoin (BTC), the first cryptocurrency to be launched, there are currently various cryptocurrencies that extend beyond BTC.

Exploring the possibilities of Web 3 in the digital gaming market, Fantini [2020] state that blockchain has established itself as one of the most promising technologies today and can provide new perspectives for the digital gaming market. Among the expectations created for blockchain in games, the authors claim that there is the possibility of conferring property rights to digital assets within the game, making them non-fungible, exchangeable, and independent of development. This game mode is called "play-to-earn" [Giles *et al*., 2021; Fantini, 2020].

One of the concepts that guide the digital gaming market is Web 3. According to the company ConsenSys Software Inc. [2021], Web 3.0 is characterized as an internet that incorporates identity, money, and an additional social layer. This vision of an internet is built on open protocols that value transparency and innovation and seek to decentralize the power of large corporations, putting control of data in the hands of users [Oliveira *et al*., 2018; Voshmgir, 2021]. Thus, blockchain technology plays a fundamental role in this context, offering secure and transparent solutions for the digital gaming market [Giles *et al*., 2021].

Using qualitative and bibliographic research methodology, this article[1] sought to present the development of a "cryptogame" a digital game that incorporates blockchain technology using the Unity engine as a case study. The aim was to understand the process of integrating this technology in a gamified context, leveraging the concepts of Web 3.0 mentioned earlier, such as decentralization, transparency, and the ability to confer property rights to digital assets. To achieve this, we will use a test network (TestNet), exploring the benefits and challenges of applying blockchain in this scenario.

2 Theoretical Framework

2.1 Blockchain Concept

According to Belotti *et al*. [2019], blockchain is a technology that brings the concept of shared record to distributed systems for a range of application domains, from cryptocurrency to potentially any industrial system that requires a decentralized, robust, reliable system and automated decision-making in a multi-stakeholder situation. A typical example of a blockchain is illustrated in Figure 1. A blockchain consists of sets of data that are composed of a chain of data packets (blocks) where each block comprises multiple transactions. The chain of blocks is extended by each additional block and thus represents a complete record of transaction

[1]This paper is a revised and extended version of Silva *et al*. [2023].

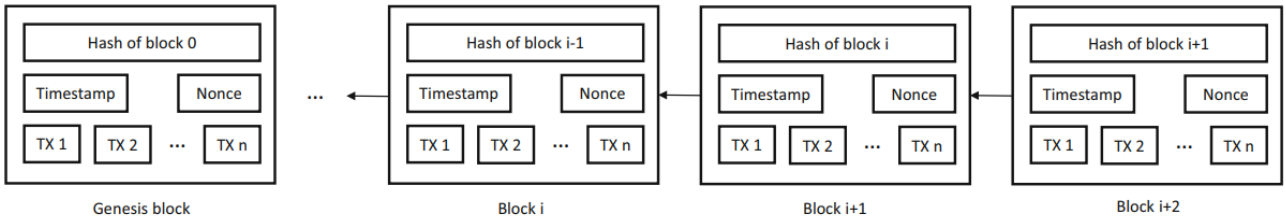

Figure 1. Blockchain and its blocks according to Nofer et al. (2017).

history [Nofer *et al*., 2017].

The network stores the information of a group of transactions in blocks, marking each block with a timestamp and date record. At regular intervals (10 minutes in the blockchain), a new block of transactions is formed, which is linked to the previous block.

The blocks are interdependent and form a chain of blocks (hence the name: blockchain). This makes the technology perfect for recording information that requires trust, such as in the case of a bitcoin and other crypto transactions [Fantini, 2020; Nofer *et al*., 2017]. According to the authors, the blockchain network is formed by miners who verify and record transactions in the block. In order for this to be possible, miners lend computational power to the network. As an incentive to continue collaborating and make the network sustainable and more secure, they receive a reward in digital coins [Zyskind *et al*., 2015].

When developing a virtual machine program on the Ethereum blockchain, it is necessary to pay gas to set up and use the said program. This gas on the Ethereum network is considered a transaction fee. Testnets, or test networks, are highly useful tools for Ethereum virtual machine development, making Ethereum software testing easier and providing developers with a secure layer to test their programs before running them on the main network. Testnets are similar to the main network in almost every aspect, except that Ether on these networks has no value. Public TestNets are accessible to anyone connected to the internet and can be accessed through wallets like Metamask [Coutinho *et al*., 2020; Shaker *et al*., 2021].

2.2 The concept of NFT

A Non-Fungible Token (NFT) is a type of cryptocurrency [Fairfield, 2022] derived from Ethereum smart contracts [Wood, 2014]. NFT was initially proposed as an improvement of Ethereum ERC-721 [William *et al*., 2018] and later developed into ERC-1155 [Witek *et al*., 2018]. NFT differs from classic cryptocurrencies [Shirole *et al*., 2020] such as Bitcoin in its intrinsic characteristics [Nakamoto, 2019]. According to InfoMoney [2020], Bitcoin (BTC) and Ethereum (ETH) paved the way for the emergence of new formats of digital assets that attracted thousands of investors and moved billions of dollars.

Between January and September 2021, according to data from the analytics website DappRadar [2021], the sales volume of these tokens reached $13.2 billion, a value larger than the Gross Domestic Product (GDP) of Acre, Amapá, and Roraima combined. Thus, a token in the cryptocurrency universe is the digital representation of an asset, such as money, property, or a registered artwork on a blockchain.

2.3 Blockchain Games

Blockchain games, or cryptogames, are digital games that utilize blockchain network technology for their creation and implementation. These games allow for micro transactions within the game environment, carried out through smart contracts [Min and Cai, 2019]. Being a digital technology, its application in the context of games is a natural choice [Fantini, 2020] . According to Min and Cai [2019], cryptogames operate differently from traditional digital games. Before starting a gaming session, players need to register an address on the corresponding blockchain platform. This address, accessed through a digital wallet, functions as a unique identity and is the location where all of the player's virtual assets are stored.

3 Development of the cryptogame

In this section, we will present the entire development process of the Baziyo cryptogame, as well as the research process conducted for the implementation of blockchain technology within the scope of the game.

For the Baziyo project, we chose to use the agile Scrum method as the development framework. This choice is due to its iterative and collaborative approach, which allows us to deliver functional increments of the game over time Sutherland [2014]. The game development team adopted sprints, daily meetings, and other agile practices to optimize the development process.

The flow of research and game development execution followed the following stages:

3.1 Creation of NFTs Images

This stage was crucial in the development of the cryptogame, as it involved the creation of the necessary artwork for implementation in the game. It was necessary to define the dimensions and aesthetic patterns of the artwork that would be transformed into NFTs. In the case of the Baziyo game, the art creation process was carried out in Adobe Photoshop version 2022.

The playable characters in the game, has unique characteristics in terms of colors and shapes. However, all the characters follow the rectangular size of 32x32 pixels, as defined in the aesthetics and asset art documents (Figure 2).

Next, all the images were exported in the .PNG format to be subsequently transformed into NFTs.

Figure 2. Images of the characters created for the game.

3.2 Storage of Images

The second step was to store the created images in a decentralized network. Among the available free options, the most accessible ones are IPFS (InterPlanetary File System) and Pinata Cloud. These storage platforms stand out from others due to their ability to store files without size limits and share them through a peer-to-peer (P2P) connection [Daniel and Tschorsch, 2022].

For the Baziyo game, Pinata Cloud was selected for storing the assets to be used in the game. This application utilizes IPFS but adds a layer of user control over the uploaded files. After the images were inserted into the decentralized platform, a HASH code was generated, which was used in the minting process, adding the NFT to the blockchain.

3.3 Creation of the Smart Contract

According to Samir Kerbage, CTO of Hashdex, smart contracts are the digital expression of commitments established between two or more parties, representing a mutual agreement. These contracts are encoded in a programming language and automatically executed once the predefined terms and conditions are met, eliminating the need for an intermediary to ensure execution Martin [2022]. To create a Smart Contract, it was necessary to understand the standardizations within the blockchain universe. The models used are ERC721 and ERC1155.

In the Baziyo game, the ERC-721 standard was adopted, which is used to standardize NFT tokens on the Ethereum blockchain. Below, in Figure 3, is the code of the smart contract used in the project. As this is a case study, this contract is limited to defining the currency used for the NFTs (characters) and the process of creation (minting). Other functionalities, such as assigning value to transactions, were not implemented in this context.

Later, the contract was transferred to a dedicated IDE for the Ethereum network, known as REMIX. This IDE was used to ”compile” the contract code and execute its functions. One of the most commonly used functions is mint, which is responsible for adding the NFT to the Ethereum blockchain.

For the execution of projects using the Remix platform, it is imperative to install a digital wallet (wallet) in the browser, with Metamask being one of the most commonly used. Essentially, it is necessary to define the network on which the smart contract deployment will occur. For the purposes of this study, the Kovan test network was chosen. The process

```
// SPDX-License-Identifier: MIT
pragma solidity 0.8.6;
import "https://github.com/0xcert/ethereum-
erc721/src/contracts/tokens/nf-token-metadata.sol";
import "https://github.com/0xcert/ethereum-
erc721/src/contracts/ownership/ownable.sol";

contract newNFT is NFTokenMetadata, Ownable {

  constructor() {
    nftName = "Baziyo";
    nftSymbol = "BZY";
  }
  function mint(address _to, uint256 _tokenId, string calldata
_uri) external onlyOwner {
    super._mint(_to, _tokenId);
    super._setTokenUri(_tokenId, _uri);
  }
```

Figure 3. Base of the Smart Contract used in the Baziyo game.

of compiling the code in the Remix environment is referred to as ”deploy”. Upon completion of this stage, the mint function becomes available for use. Within the context of the mint function, and as stipulated by the smart contract developed for the game in question, specific parameters need to be inserted. These include:

1. Token ID: This parameter is used to determine the number of the non-fungible token (NFT) that will be associated with this contract. Thus, it is possible to have multiple NFTs operating under the same contract, but with distinct IDs.
2. URI: This parameter represents the address of the files that will be converted into NFTs. Common examples include the hash generated on IPFS or Pinata Cloud. It is important to note that, although it may seem intuitive to directly insert the address of the images created for the game, in reality, what is inserted here is the address of the JSON file associated with the image. This aspect will be explored more in detail in the following section.
3. To: To: This parameter refers to the wallet address of the owner of the NFT. After inserting the necessary parameters, the function is executed and the required GAS fee is paid. In this specific case study, a test currency often referred to as ”faucet”, which has no real value and is used solely for testing purposes, was used.

After this process, the first NFT of the Baziyo game was created and added to a test network, the Goerli[2] is a revised and extended version of Silva et al. [2023]. TestNet.

3.4 Attributes in NFTs

Depending on the scope of the game, it may be necessary to add attributes to the NFT, such as maximum power, life, attack speed, among others. The metadata of the NFT should be included in the JSON file of the used image. These metadata typically include the following items:

- Name: The name of the NFT.
- Description: A brief description or summary of the NFT.
- Image: The URL or file path of the image associated with the NFT.

[2]When this paper was being developed the goerli was active.

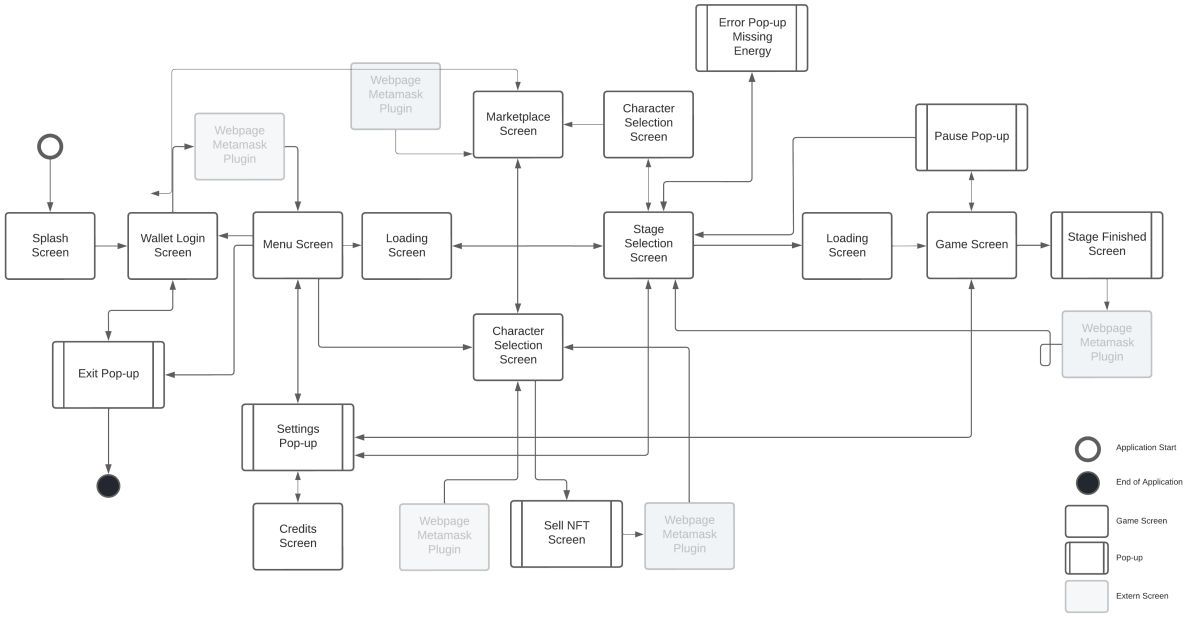

Figure 4. Screen Flow of the Baziyo Cryptogame.

In the game Baziyo, the characters have the following attributes: name, description, multiplier, and maximum energy. These attributes are used to classify a character as common, uncommon, or rare, according to the specifications of the game designer. Each NFT has its own JSON code, which was stored in a specific folder on Pinata Cloud.

3.5 Unity and blockchain integration

To perform token transactions and establish the game's connection with the blockchain, it was necessary to integrate the ChainSafe [2023] package into the Unity engine. ChainSafe is a company dedicated to research and development of blockchain-connected applications. For the game development, this package was chosen to provide classes and methods that allowed for a direct connection to the Ethereum network or a test network such as Goerli.

3.6 Performing Wallet Login

When it comes to game development with NFTs, many games require user validation to retrieve the assets belonging to that player. Therefore, a login screen is necessary to connect the game with the user's wallet and retrieve their NFTs. The term "wallet" refers to a virtual purse or wallet where we can manage our cryptocurrency assets. It is software or hardware designed exclusively to store and manage the public and private keys of our cryptocurrencies Kaushal *et al.* [2017].

In the game, it was necessary to obtain the number of Baziyos that the user owned and their respective images in order to start the game. For this purpose, the Metamask wallet was used, which allows communication with the Goerli TestNet, where fees could be paid with TestNet faucets (test coins).

By using the functions provided by the Chainsafe library, it was possible to implement the login mechanism with the user's Metamask wallet. After this implementation, some handling was required, such as verifying the smart contract signature in the Metamask wallet. The screens flow was represented in Figure 4.

3.7 Character Selection

One of the objectives of the Baziyo cryptogame is the use of NFTs within games. As a result of this demand, these digital assets were used as characters in the game. Through Chainsafe, the game system makes requests to the blockchain and retrieves the NFTs present in the contract. The NFTs are displayed on the character selection screen and within the gameplay scene.

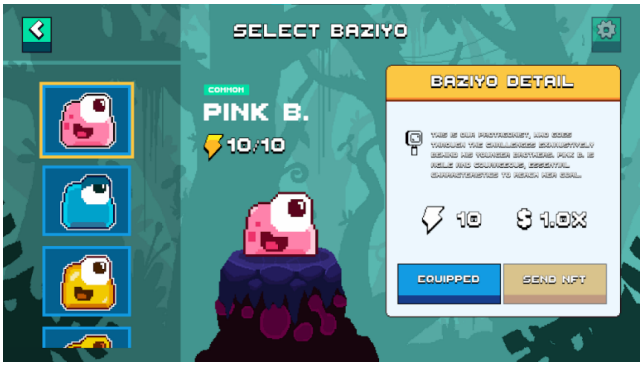

Figure 5. NFT Character Selection Screen.

3.8 Transactions with NFTs

In the development of the code for the transfer of non-fungible tokens (NFTs), it is crucial to declare variables that

are fundamental for the execution of the transaction. Among these, the digital wallet (wallet) address of both the user and the recipient stand out, as well as information pertinent to the costs associated with the transfer, specifically the ”gasPrice” and the ”gasLimit”. In the provided example, the recipient’s wallet address is already predefined in the variable ”toAccount”. When initiating the transaction process, the user is automatically redirected to a browser that has the Metamask plugin installed. It’s important to mention that ChainSafe offers error handling for connectivity issues through its contract copy module, which adds an additional layer of resilience to the process. According to the business rules established for the game, the transfer is prevented in the following situations: if the active account in the game does not match the account logged into Metamask in the used browser; if the user tries to transfer the NFT to the address of their own wallet; or if the user refuses the transaction request during the web request process.

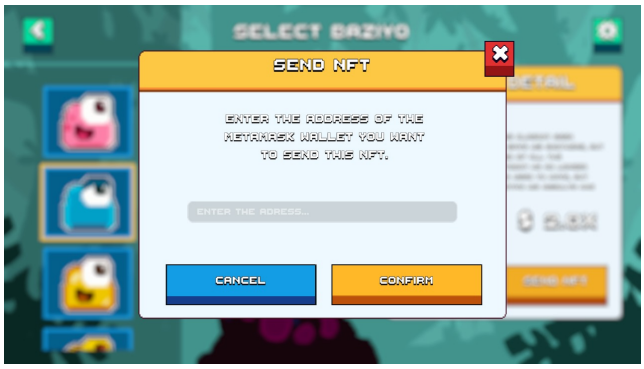

Figure 8. Transfer Screen.

3.9 User Testing and Usability test

As a final step in the development of the cryptogame, two playtest sessions were conducted by the authors, which involved playing the product in development with the aim of discovering if it delivers the desired experience [Schell, 2011]. There are six types of playtests according to Fullerton [2014]: one-on-one testing, group testing, survey, interview, open discussion, and data hooks, which can be combined and tailored to different types of developers. For the playtest of the Baziyo game, a one-on-one testing approach was conducted with 13 participants, where a facilitator guided the player through activities while observing and collecting data on their performance.

Figure 9. Playtest Session.

At the end of the playtest sessions, participants were invited to a discussion to express their positive and negative feelings about the experience. Some feedback highlighted the absence of notifications after transactions were made.

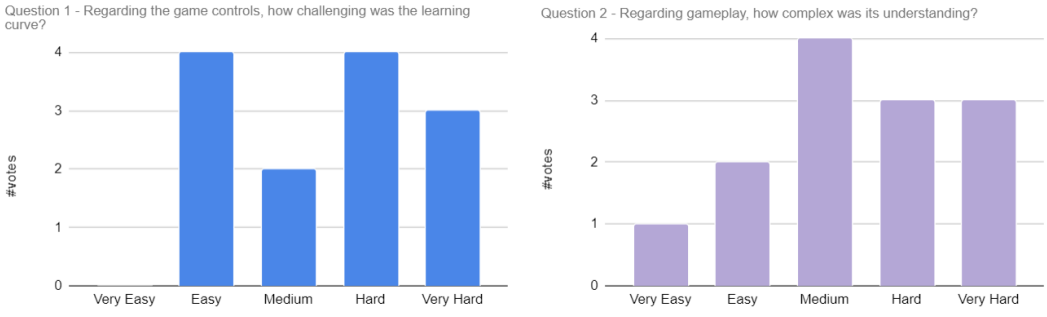

Figure 6. Graphs on game controls and overall gameplay.

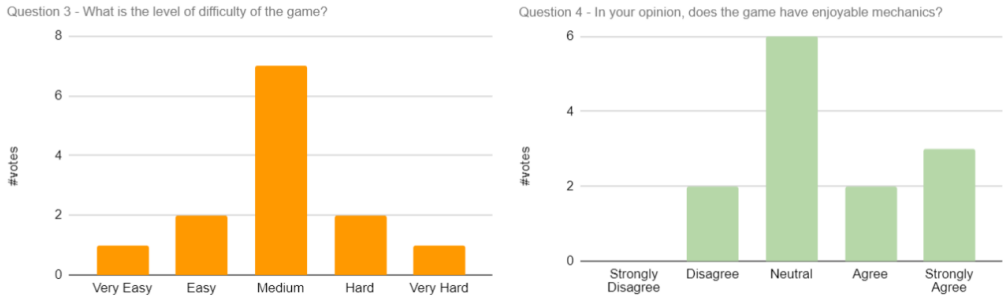

Figure 7. Difficulty and Enjoyment Graphs of Baziyo Game.

Players reported feeling insecure when performing these actions, as the game did not provide clear feedback on the success or failure of the transactions. Another issue raised was the loading time from the login screen to the game menu, which was prolonged, around 10 seconds, without displaying a loading screen.

After each match, participants filled out a Likert-scale-based form, elaborated by the authors, to assess the game mechanics in terms of:

- Ease of understanding the controls: This criterion evaluates how intuitive and accessible the game controls are. A good understanding of the controls is essential for players to interact effectively with the game, without facing technical or learning barriers.
- Overall gameplay: This criterion addresses the gaming experience as a whole, including the fluidity, fun, and engagement provided by the game mechanics. It assesses whether the player's interactions with the game are satisfactory and if the game offers interesting and stimulating challenges.
- Difficulty: This criterion examines the balance between challenge and skill in the game. Well-adjusted difficulty is crucial to keep players engaged and motivated. If the game is too easy, players may lose interest quickly; if it is too difficult, they may feel frustrated and give up.
- Aesthetics: This criterion evaluates the visual and sound aspects of the game, including graphics, music, sound effects, and interface design. The aesthetics of the game play an important role in creating an immersive and appealing atmosphere that contributes to the overall player experience.

Additionally, the manipulation of NFTs was evaluated, including selection, transfer, and receipt of these assets. The collected data was analyzed and is available in the images above.

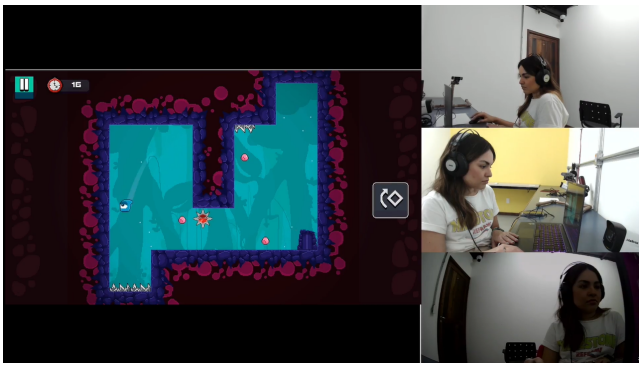

Figure 10. Baziyo game usability testing session.

Regarding controls, players expressed difficulties in understanding the commands independently, requiring multiple attempts and assistance until the gameplay mechanics were grasped. In terms of gameplay, players expressed satisfaction and enjoyment upon completing the levels. This statement is supported by the graph shown in Figure 6.

It is worth noting that the version used in the playtests was not balanced, presenting a high level of difficulty for some users. Regarding the manipulation of NFTs, players were invited to perform the action of selecting an NFT and transferring it to another participant, as well as receiving an NFT. All participants successfully carried out these actions. This statement is supported by the graph shown in Figure 7.

The feedback collected based on players' observations was essential to enable the next stage of the research. This is because it allowed for the review and correction of specific usability points, crucial for the next phase of adapting the game to connect with the blockchain.

Furthermore, more detailed analyses were conducted with the software testing team in a different environment. These analyses utilized Nielsen's heuristics Nielsen [2007] to identify potential technical usability issues and propose solutions. The testing environment was designed to capture expressions of frustration or enjoyment as participants engaged with the proposed activities. At the conclusion of these tests, a comprehensive document was created. This document included tables that identified which heuristic was being analyzed and detailed how the game performed in relation to each heuristic, whether positively or negatively. Additionally, the document incorporated feedback and suggestions for improvements.

4 Adaptation to Cryptogame

As part of the study's validation and demonstration of the process of creating cryptogames, a new application of the Chainsafe library was developed in a game project initially conceived without the consideration of using NFTs (Non-Fungible Tokens) in its scope. It is important to emphasize that, in the process of implementing NFTs in games, it is essential to consider the entire structure of the game, including gameplay and user experience. Digital assets must be integrated as elements of the game, such as mechanics or aesthetic elements, including characters, items, or other aspects.

The game in question had a simple interface, which facilitated its adaptation for the implementation of the previously mentioned requirements, such as a login screen and an NFT selection screen, Figure 13. The game's scope consisted of controlling a character to cross a sequence of planets, aiming to achieve high scores and collect items. Originally, the interface did not offer options for the user to log in or choose the appearance of the character.

To adapt the game to the format of a cryptogame, it was necessary to analyze and redesign its interface to accommodate NFTs. In this context, the elements chosen to become digital assets were two: the characters and the ship piloted by them. This decision emerged as a necessity to validate the application of different categories of NFTs using the same smart contract.

After implementing the aforementioned modifications, it became clear that there was a need to establish a systematic activity flow for adapting conventional games into cryptogames. In this context, Figure 12 illustrates the process adopted for executing this adaptation. This flowchart details the steps involved, from the initial analysis of the existing game to the final integration of NFTs, providing a clear roadmap for future similar adaptations. The process structure, depicted in an activity diagram, aims to facilitate the

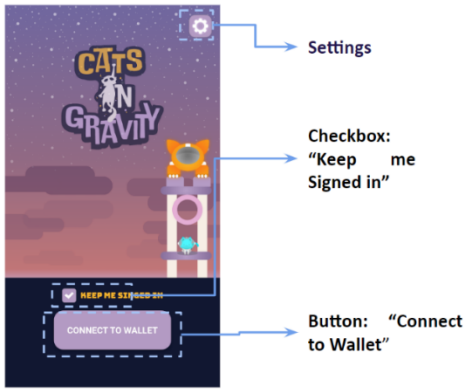

Figure 13. Screen adapted to log in with Metamask.

understanding and replicability of the methodology, thereby ensuring a more efficient and structured approach to incorporating blockchain technology into digital games.

In summary, integrating NFTs into digital games is a complex process that goes beyond the simple addition of digital assets. It requires careful consideration of various aspects, including the game's economy, user experience, and social and cultural impacts, all within the context of a secure and scalable system. This study demonstrates that, by addressing these issues in a holistic manner, it is possible to create engaging and innovative cryptogames that offer new experiences and possibilities for players and developers.

4.1 Handling connection errors

Within the realm of cryptogames, a critical issue addressed in the study involves handling connection errors that can impair the player's experience. Throughout the implementation and testing of the analyzed game, it was identified that there was a need to incorporate new interfaces and notifications to inform players about failures due to internet connection problems. These failures were critical, as they prevented essential operations such as logging in via Metamask or executing transactions between wallets. The two main errors identified were:

1. the user's failure to sign the contract presented in the Metamask pop-up;
2. failures in requesting NFTs on the blockchain network due to internet connection instabilities.

Recognizing and resolving these issues are fundamental to ensuring a smooth and reliable user experience, essential for the adoption and success of cryptogames.

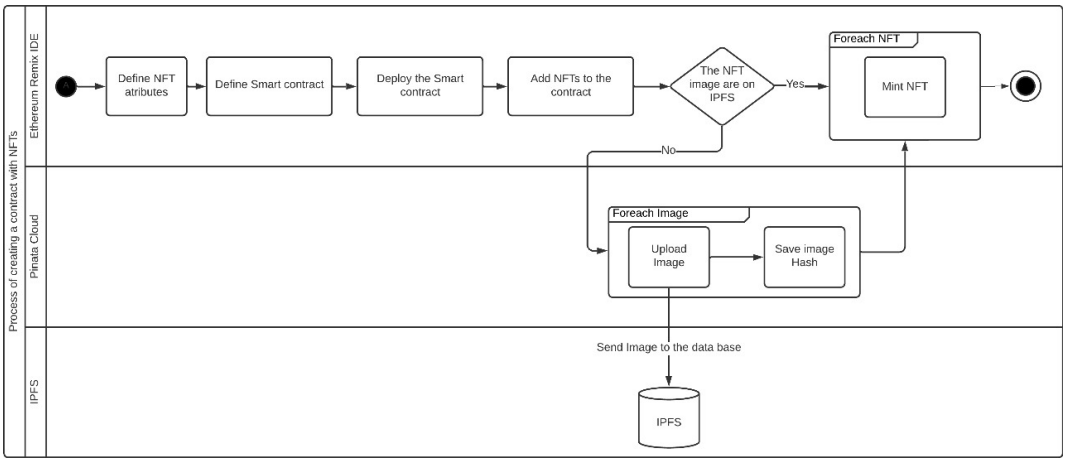

Figure 11. Activity diagram for NFT creation.

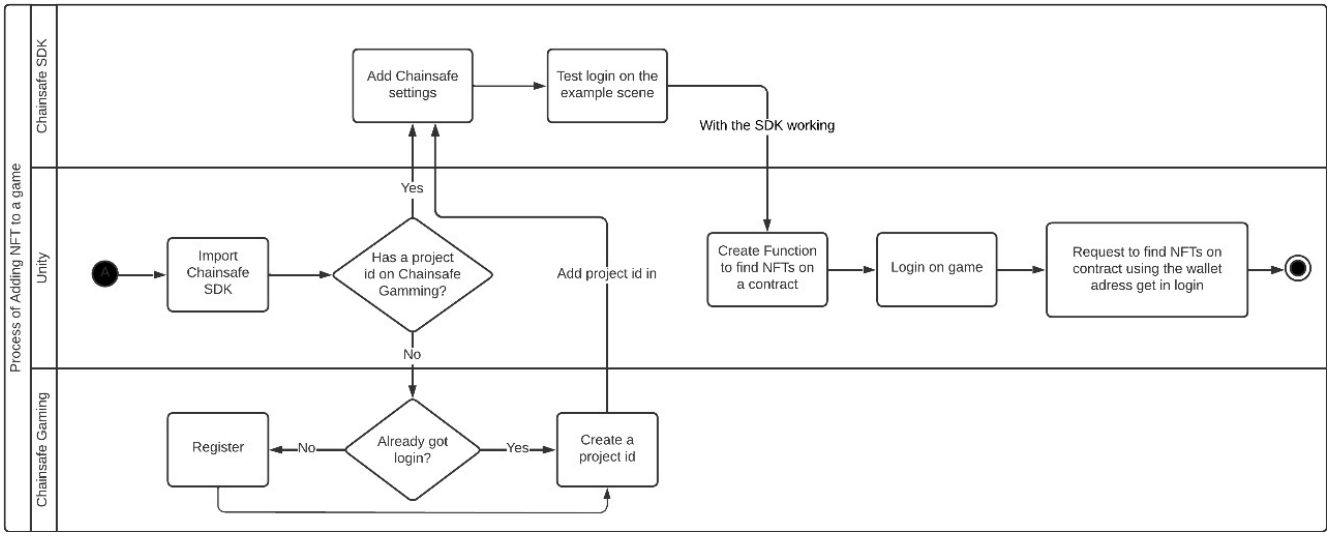

Figure 12. Activity diagram for NFT implementation in games.

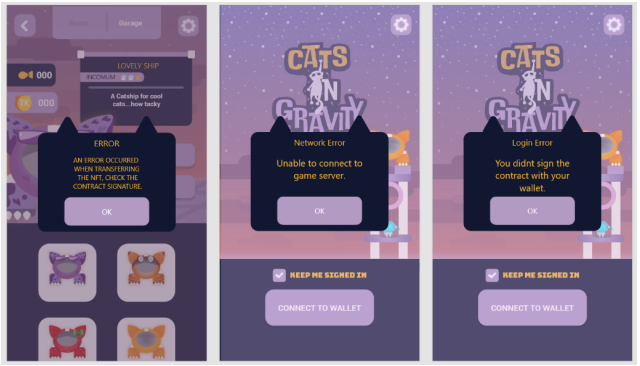

Figure 14. Pop-ups with error notifications when performing a transfer or login.

4.2 Inserting different categories of NFTs

After the process of redesigning the interface and gameplay, the game evolved to allow players to select two customizable objects: the character and their vehicle. This development introduced two new interfaces designed specifically to facilitate the choice of these objects. The first interface was dedicated to the selection of the character, while the second focused on the choice of the vehicle. It is crucial to highlight that an aspect of this project was the decision to make both elements, characters and vehicles, into Non-Fungible Tokens (NFTs), thus integrating them into the game's digital economy.

The incorporation of these objects as NFTs required the development of two distinct smart contracts, reflecting the unique characteristics of each type of digital asset. These smart contracts were designed to accommodate specific attributes, such as "speed" for vehicles and "point multiplier" for characters, among others. This design not only facilitated the distinction between the different types of NFTs but also allowed for greater flexibility and customization for the players, enriching the game experience.

The implementation of these smart contracts did not show major obstacles. Each NFT defined in the contracts was matched to the assets present in the user's digital wallet, allowing for a smooth and direct integration. This process occurred in two stages: initially, the ownership of the characters was verified through the respective smart contract, followed by the verification of the vehicles. In cases of failures or errors during the requests to any of the contracts, the system was prepared to display appropriate error messages, ensuring that the user was informed about any connection problems or other technical issues.

4.3 Instability in Test Networks

The utilization of blockchain test networks, such as Kovan and Goerli, is a crucial step in the development of blockchain-based projects, particularly in initiatives involving smart contracts or the creation of non-fungible tokens (NFTs). These test networks provide a secure and isolated environment, allowing developers to experiment and verify the functionality of their projects without the risk of losing valuable assets or affecting the main network (mainnet). However, it is imperative to approach these platforms with a clear understanding of their temporal limitations. Networks like Kovan and Goerli are designed with relatively short usage lifespans and may eventually be discontinued or replaced by more advanced alternatives.

This transitory nature implies that projects developed and tested on these networks should be considered only in an experimental stage and never as final solutions. Before migrating to the mainnet, developers must ensure a careful transition, reviewing and adapting the code as necessary to ensure compatibility and security. Failing to consider the temporary nature of these test networks can lead to a false sense of security and potential vulnerabilities when the project is launched on the main network. Therefore, it is essential for developers to maintain a diligent approach, using test networks as a preliminary step in the development process, and be prepared for the challenges and adjustments necessary when advancing to implementation on a mainnet, where the consequences are far more significant and mistakes can have long-reaching implications.

Both the games Baziyo and Cats in Gravity were initially developed utilizing the Goerli test network. Following updates, they required adaptation for the use of the Sepolia testnet. As of the writing of this study, the Sepolia network remains active and stable, highlighting its viability as a testing ground for blockchain-based projects. This transition underscores the importance of flexibility and the need to stay informed about the evolving landscape of blockchain infrastructure, as developers must be ready to adapt their projects to new environments to ensure ongoing compatibility and performance.

4.4 Main challenges

Blockchain game development presents a series of unique challenges, which differ significantly from those encountered in traditional game development. These challenges test the technical capabilities of developers and require a deep understanding of blockchain technology and its implications. Below, we list the main challenges encountered in this emerging sector and some actions taken to overcome these challenges:

1. Integration with Cryptocurrency Wallets and Smart Contracts: Effectively integrating digital wallets, such as Metamask, to facilitate transactions and interactions with smart contracts is a primary challenge. It is crucial to ensure a smooth user experience while dealing with authentication and transaction execution, which can be complicated due to connection errors or failures in the contract signing process. During game development, we faced the need to re-upload all NFTs from a contract if any errors were found in their information, such as errors in the description or attribute values. When this occurred, the entire contract needed to be recompiled on the blockchain network, adding complexity to development.
2. Error Handling and Connectivity: Blockchain-based games often face instability issues due to irregular internet connections. Developing a robust system that informs players about such failures and manages attempts automatically is essential for a reliable user experience.

Table 1. Representation of the converted values in dollar and real.

	Number of Applications	Cost in SepoliaETH	Cost in USD	Cost in BRL
Smart Contract Deployment	7	0.02242777 SepoliaETH	$63,11	R$ 314,80
NFT Minting	34	0.00114017 SepoliaETH	$3,21	R$ 16,01
NFT Transaction	27	0.00109685 SepoliaETH	$3,09	R$ 15,42

3. Scalability and Transaction Costs: The decentralized nature of blockchain implies that every action altering the game's state may require a blockchain transaction. This can result in high transaction costs and scalability issues, especially on networks like Ethereum, where gas costs can vary drastically. Finding a balance between cost, speed, and user experience is a constant challenge. In this instance, utilizing a testnet covers this cost and enables greater adjustment during production.
4. Transitory Nature of Test Networks: Test networks like Goerli and Sepolia are designed to be temporary, and there is always a risk that these networks may become obsolete. Developers need to be prepared to adapt and migrate their games to other networks as needed. During development, it was necessary to switch networks twice as mentioned earlier.
5. Usability: It is crucial to ensure that players understand and are comfortable with blockchain concepts. Mass adoption of blockchain games requires a user-friendly interface that hides the complexity of the underlying technology without compromising security or functionality. Understanding this process within the gameplay flow is of great importance to provide this comfort. The use of images, informative buttons, and feedback pop-ups were implemented in the game to bring this security to the player and comfort when performing actions involving the blockchain network.

4.5 Approximate Costs

The teste networks allow developers to test their innovations in an environment that simulates the mainnet without the risk associated with the use of real-value assets. It is important to highlight that the currencies used in these networks are known as faucets, which are distributed for free and do not have real-market exchange value, serving exclusively for testing purposes. In the development of the mentioned games, the Sepolia network faucets, named SepoliaETH, were used for all necessary transactions and interactions during the testing phase. Although these SepoliaETH have no market value, for the purposes of analysis and illustration, it is interesting to convert the experimental operational costs into Ether (ETH) and, consequently, into dollars (USD) and Brazilian Reais (BRL), providing a more tangible view of what these costs would represent in the production environment on the mainnet. To illustrate, consider the **Table 1** above of costs associated with the development of the game Baziyo on the Sepolia test network:

This table highlights not only the cost of using the test network in terms of "play money," but also offers a perspective on what these costs would mean if applied on the mainnet, underlining the importance of these networks for testing and refining projects before their official launch and the need for careful resource management, even in a test environment. When discussing the use of blockchain test networks and the conversion of operational costs from faucets to real monetary values, it is crucial to recognize that the values of currencies, including Ether (ETH), the dollar (USD), and the Real (BRL), undergo significant fluctuations over time. The quotations presented in the table are based on arbitrary values for illustrative purposes and do not reflect the current value of the currencies. The cryptocurrency market is notoriously volatile, and exchange rates can fluctuate widely within days or even hours. Therefore, the values presented in dollars and Real should be interpreted with caution. Investors, developers, and enthusiasts should always inform themselves about the current exchange rates before making any conversions or making decisions based on such values. This variability emphasizes the importance of a careful and well-informed approach when planning budgets for blockchain project development, both on test networks and the mainnet, considering the dynamics of the cryptocurrency market and price fluctuations.

4.6 Connecting to an NFT Marketplace and Custom Wallet

Upon completion, the digital assets were effectively incorporated into the game, allowing their use as visual elements in gameplay. The process of transforming the original game into a cryptogame was completed in approximately twenty days, adopting the agile Scrum methodology, which facilitated the organization and agile execution of the project.

The transparency and accessibility provided by blockchain transaction visualization platforms, such as Etherscan, along with the functionality of smart contracts that facilitate the transfer of assets, paved the way for the creation of an online marketplace and a custom Wallet. This platform enabled the commercialization of the NFTs created for both games, representing a significant advancement in the interaction between players and the game ecosystem. Thus, as a concluding part of the study, a marketplace and custom wallet prototype was developed. This custom wallet was crafted to optimize the user experience, facilitating the acquisition and management of NFTs within the game's ecosystem.

Notably, within the context of the game application itself, it was not necessary to implement functionalities directly related to the marketplace. This indicates a modular approach in the project development, where the functionalities of the game and the NFT market operate independently yet complementarily. Such a strategy not only simplifies the mainte-

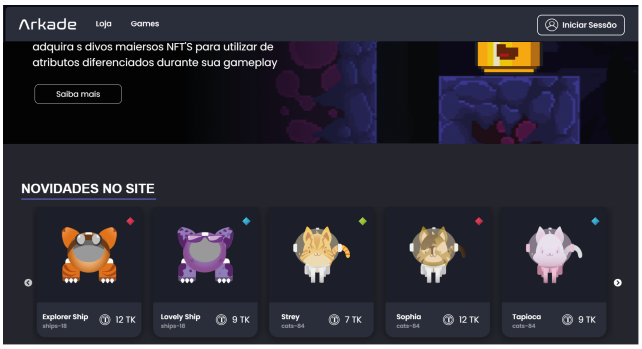

Figure 15. Marketplace Arkade Screen.

nance and updating of the system but also offers users a fluid gaming experience, without overloading the interface with elements external to the main gameplay. This functional separation reinforces the flexibility and scalability of the project, allowing for future expansions in both the game and the marketplace.

The implementation of Arkadeverse's own wallet represents a significant advancement in how players interact with the NFT system. Instead of relying on third-party digital wallets, users can now conduct all NFT-related operations directly within the Arkadeverse ecosystem, providing a more integrated and secure user experience. This integration eliminates the need for complicated transfer procedures between different platforms and reduces the learning curve for new users, making the process of buying, selling, and exchanging digital assets more accessible.

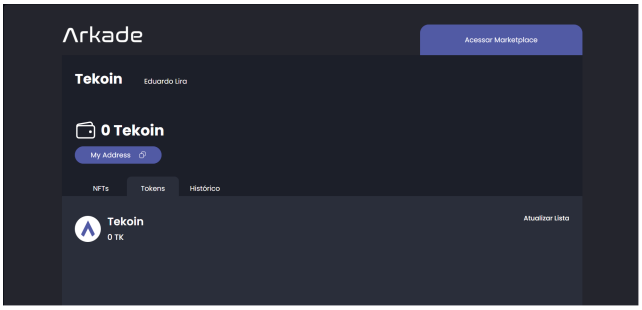

Figure 16. Arkade Wallet Screen.

5 Conclusions and Future Work

When we talk about games and NFTs, we are dealing with two rapidly expanding markets. However, despite the great potential of this combination, there are few developers who invest in this idea compared to other genres of game development. Additionally, there is a scarcity of learning resources available for those interested in entering this new technological world.

With this in mind, the creation of the cryptogame Baziyo was proposed as a means of learning the key theoretical and technical concepts necessary for NFT game development. The project not only served as a rich learning tool but also served as a foundation for teaching and training other developers.

During the production of the game, research was conducted and put into practice on topics such as what an NFT is and its relationship with the blockchain, the definition of wallets, as well as the numerous options available on the internet, the creation and deployment of smart contracts, NFT minting, the connection of a Unity project with NFT assets, wallet connection functions, recovery of NFTs within a smart contract, and transfer of NFTs between different users (different wallets), which serves as an introduction to developing the entire business logic for NFT sales within a game.

Baziyo was successfully completed as a functional NFT game (cryptogame), even though it is still in a TestNet. By establishing the connection between Unity and the blockchain, Baziyo successfully utilized blockchain technology to enhance gameplay mechanics and provide players with a unique and immersive gaming experience. There are several other functionalities that can be addressed within its scope, such as multiplayer mechanics, and it can also provide momentum for future research on the use of NFTs in gaming. However, the main goal of its well-documented development process was to introduce others to the vast concept of Web3.0.

Additionally, the phases of inserting digital assets into a finished game included significant adaptations in its interface and gameplay to incorporate NFTs, such as the selection of characters and vehicles, and the creation of specific smart contracts for each type of digital asset. Moreover, the implementation of a marketplace as part of the project exemplifies the integration of complementary functionalities into the game, expanding the possibilities for interaction and transaction among players.

The development and implementation of Baziyo as a functional NFT game underscore the potential and challenges of integrating blockchain technology into gaming. A critical aspect of this case study, not to be overlooked, is the cost associated with utilizing blockchain technology, particularly in the context of test networks. As evidenced in the operational costs detailed earlier, the use of Sepolia testnet and its faucets (SepoliaETH) for transactions and interactions during the testing phase highlighted a non-monetary but equally important investment: the time and resources dedicated to understanding and leveraging blockchain for game development. While the faucets used do not possess real-world value, converting these operational costs to real-world currencies such as Ether (ETH), dollars (USD), and Brazilian Reais (BRL) offers a tangible perspective on what the financial implications might be when moving a project from a testnet to the mainnet. This aspect of development is crucial for developers to consider, as it encompasses not only the direct costs of transactions but also the broader economic considerations of deploying and maintaining a game on the blockchain. The case study of Baziyo, therefore, serves as a comprehensive guide not just for the technical integration of NFTs into gaming but also for the financial planning and resource management required to realize such projects. The exploration of these costs further contributes to the growing discourse on the feasibility and sustainability of blockchain and NFTs within the gaming industry, providing valuable insights for developers and investors alike.

Declarations

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References

Abramova, S. and Böhme, R. (2016). Perceived benefit and risk as multidimensional determinants of bitcoin use: A quantitative exploratory study. In *2016 International Conference on Information Systems, ICIS 2016*, pages 1–20.

Belotti, M., Božić, N., Pujolle, G., and Secci, S. (2019). A vademecum on blockchain technologies: When, which, and how. *IEEE Communications Surveys Tutorials*, 21(4):3796–3838. DOI: https://doi.org/10.1109/COMST.2019.2928178.

ChainSafe (2023). Building on blockchain the right way. `https://chainsafe.io`. Accessed: 06/06/2024.

ConsenSys Software Inc. (2021). Metamask: A crypto wallet gateway to blockchain apps. `https://metamask.io/`. Accessed: 06/06/2024.

Coutinho, E. F., Maia, D. J. H., Bezerra, W. L. B., and Abreu, A. W. d. S. (2020). Avaliando o custo de contratos inteligentes em aplicações blockchain por meio de ambientes de simulação. *MSSiS*, pages 56–65. DOI: https://doi.org/10.5753/mssis.2020.12495.

Daniel, E. and Tschorsch, F. (2022). Ipfs and friends: A qualitative comparison of next generation peer-to-peer data networks. *IEEE Communications Surveys Tutorials*, 24(1):31–52. DOI: https://doi.org/10.1109/COMST.2022.3143147.

DappRadar (2021). Nft explorer. `https://dappradar.com/hub/nft-explorer`. Accessed: 06/06/2024.

Fairfield, J. A. T. (2022). Tokenized: The law of non-fungible tokens and unique digital property. *Ind. LJ*, 97:1261.

Fantini, L. (2020). Precisamos realmente de jogos blockchain? estudo a partir dos reflexos jurídicos da propriedade de criptoativos em jogos digitais. In *sbgames.org*, pages 851–858.

Fullerton, T. (2014). *Game design workshop: a playcentric approach to creating innovative games*. CRC Press.

Giles, D. C., Póvoas, P. G., Marcondes, R. L., Nascimento, V. F., and Costa, T. R. M. d. (2021). A evolução financeira no mercado de jogos eletrônicos. Repositório Universitário da Ânima.

InfoMoney (2020). O que são nfts? entenda como funcionam os tokens não fungíveis. `https://www.infomoney.com.br/guias/nft-token-nao-fungivel/`. Accessed: 06/06/2024.

Kaushal, P. K., Bagga, A., and Sobti, R. (2017). Evolution of bitcoin and security risk in bitcoin wallets. In *2017 International Conference on Computer, Communications and Electronics (COMPTELIX 2017)*, pages 172–177. DOI: https://doi.org/10.1109/COMPTELIX.2017.8003959.

Martin, E. (2022). Smart contracts: O que são contratos inteligentes e para que servem. `https://investnews.com.br/guias/smart-contracts-o-que-sao/#:~:text=contracts%20são%20seguros%3F-,O%20que%20são%20smart%20contracts%3F,um%20comum%20acordo%20entre%20elas.` Accessed: 06/06/2024.

Mattos, O. B., Abouchedid, S., and Silva, L. A. (2020). As criptomoedas e os novos desafios ao sistema monetário: uma abordagem pós-keynesiana. *Economia e Sociedade*, 29(3):761–778. DOI: https://doi.org/10.1590/1982-3533.2020v29n3art04.

Min, T. and Cai, W. (2019). A security case study for blockchain games. In *2019 IEEE Games, Entertainment, Media Conference (GEM 2019)*. DOI: https://doi.org/10.1109/GEM.2019.8811555.

Nakamoto, S. (2019). Bitcoin: A peer-to-peer electronic cash system.

Nielsen, J. (2007). *Usabilidade na web*. Elsevier Brasil.

Nofer, M., Gomber, P., Hinz, O., and Schiereck, D. (2017). Blockchain. *Business Information Systems Engineering*, 59(3):183–187. DOI: https://doi.org/10.1007/s12599-017-0467-3.

Oliveira, F. R., Maziero, R. C., and Araújo, L. S. d. (2018). Um estudo sobre a web 3.0. *Revista Interface Tecnológica*, 15(2):60–71. DOI: https://doi.org/10.31510/infa.v15i2.492.

Schell, J. (2011). *A arte de game design-The art of game design: a book of lenses*. Elsevier, Campus, Rio de Janeiro.

Shaker, M., Shams Aliee, F., and Fotohi, R. (2021). Online rating system development using blockchain-based distributed ledger technology. *Wireless Networks*, 27(3):1715–1737. DOI: https://doi.org/10.1007/s11276-020-02514-w.

Shirole, M., Darisi, M., and Bhirud, S. (2020). Cryptocurrency token: An overview. In *IC-BCT 2019: Proceedings of the International Conference on Blockchain Technology*, pages 133–140. DOI: https://doi.org/10.1007/978-981-15-4542-9_12.

Silva, E., Araújo, C., Júnior, J., Gomes, R., and Carvalho, L. (2023). Baziyo: Development of a cryptogame with unity on an ethereum blockchain test network. In *Brazilian Symposium on Computer Games and Digital Entertainment (SBGames)*. DOI: https://doi.org/10.5753/sbgames_estendido.2023.234052.

Sutherland, J. (2014). *SCRUM: A arte de fazer o dobro de trabalho na metade do tempo*. Leya.

Voshmgir, S. (2021). *Economia dos Tokens (Edição Portuguesa): Como a Web3 está a reinventar a Internet e a relação entre os agentes económicos*. Token Kitchen.

William, E., Dieter, S., Jacob, E., and Nastassia, S. (2018). Erc-721 non-fungible token standard. Ethereum Improvement Protocol, EIP-721.

Witek, R., Andrew, C., Philippe, C., James, T., Eric, B., and Ronan, S. (2018). Eip-1155: Erc-1155 multi token standard. Ethereum Improvement Protocol, EIP-1155.

Wood, G. (2014). Ethereum: a secure decentralised generalised transaction ledger. Technical Report 151, Ethereum Project Yellow Paper.

Zyskind, G., Nathan, O., and Pentland, A. S. (2015). Decentralizing privacy: Using blockchain to protect personal data. In *Proceedings - 2015 IEEE Security and Privacy Workshops, SPW 2015*, pages 180–184. DOI: https://doi.org/10.1109/SPW.2015.27.