Libraskê: Development of a Karaoke-Inspired Serious Game to Support Engagement and Dissemination of Brazilian Sign Language

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Abstract. Introduction*: Accessibility remains a challenge in the entertainment industry, especially for the Deaf community, which often faces barriers due to limited fluency in written language and reliance on sign language as a primary form of communication.* ***Objective****: Develop and evaluate Libraskê, a game that combines Brazilian Sign Language (Libras) with karaoke elements to promote learning and dissemination of Libras.* ***Methodology****: In the game, a 3D avatar performs signs for selected song lyrics using VLibras. Players replicate the signs, which are captured and analyzed through computer vision techniques to generate performance scores.* ***Results****: An exploratory study involving Deaf and hearing participants showed promising engagement, suggesting the game's potential as an inclusive tool for entertainment and Libras education.*
Keywords:*Sign Language, Accessibility, Serious Game*

1. Introduction

Currently, most official languages worldwide rely on auditory and oral modalities, using hearing and speech as their primary means of communication [Melo 2009]. In Brazil, the official language is Portuguese; however, specific groups, such as the Deaf community, Indigenous populations, and certain immigrant communities, use their own languages. Among these, only the Deaf community communicates through gestures, facial expressions, and body movements—a language system known as Libras. Libras is a visual-gestural language with its own grammatical structure, functioning as a complete linguistic system for conveying ideas and information.

Since 2002, Brazil has officially recognized Libras as a legitimate means of communication and expression. As a result, schools, universities, government agencies, and public service providers are required to offer interpreters for Deaf individuals [Brazilian Sign Language Law 2002]. In this context, electronic games — due to their accessibility and engaging nature — have the potential to reduce barriers arising from human limitations, offering entertainment for both Deaf and hearing individuals while promoting the learning and dissemination of Libras. Technology, therefore, emerges as a key ally in bridging the gap between sign language and spoken language [Bragg et al. 2021]. Currently, digital media is embedded in the daily lives of most individuals, whether for leisure, communication, or education.

Serious games, which are designed not only for entertainment but also for purposes such as education, skill development, and professional training, can play a significant role in the dissemination of Libras and the promotion of inclusion in the digital environment [Brashear et al. 2006]. In this context, Libraskê is introduced as a serious game that resembles karaoke, but utilizes Libras instead of spoken language. The primary objective of Libraskê is to promote engagement with Libras among hearing individuals through an entertainment-based approach that incorporates Portuguese-language songs, while also offering Deaf individuals a sensory experience of the music's rhythmic and melodic elements.

The primary objective of this study is to design and develop a serious karaoke-style game in Libras that fosters the engagement of hearing individuals with sign language through an entertainment-based approach, while providing Deaf individuals with a sensory experience of the music's rhythmic elements.

As part of this research, a web-based game was developed featuring a digital currency system designed to encourage user participation. The game includes a training module that introduces the signs corresponding to the selected songs, as well as a component that employs a computer vision approach to analyze the player's signing performance, assessing the accuracy of the user's interpretation of the song in Libras.

2. Related Works

Several serious games have explored the use of music as a pedagogical resource for language learning. One prominent example is Lyrics Training, which enhances foreign language skills by displaying video clips with lyrics and prompting users to complete missing words at timed intervals. This mechanic supports grammar reinforcement, vocabulary expansion, and listening comprehension through contextual cues [Nguyen 2023]. The platform offers multiple difficulty levels and a wide range of song choices, including variations in accents that contribute to more authentic linguistic experiences [Martinez et al. 2023]. Performance is measured using metrics such as the number of correct and incorrect words filled in, along with remaining lives displayed via a progress bar [Borromeo García 2015]. A Karaoke mode is also available, allowing users to sing along; however, it does not analyze or assess user pronunciation.

Lyrics Gap follows a similar structure but lacks core gamification elements such as challenge, reward, or progression. It offers three modes—Karaoke, Multiple Choice, and Text Quiz—and enables content customization and performance tracking [de Moraes 2017]. Despite these features, its limited interactivity positions it more as a pedagogical tool than a full-fledged game.

A more advanced example is Slions, a multilingual karaoke-based application that uses automatic speech recognition (ASR) to provide real-time feedback on users' pronunciation. Its curated song selection prioritizes clarity and repetition, and final scores are presented with detailed, line-by-line assessments [Murad 2018]. According to Murad et al., the tool showed improvement in user pronunciation, though with limited vocabulary gains.

In a different approach, FluentU combines multimedia content (videos, subtitles, and definitions) with traditional language exercises. While users can interact with individ-

ual words to access translations and definitions, the engagement is largely passive, with no gamified assessment of speech or writing [Altynbekova and Zhussupova 2020].

Although these platforms demonstrate the educational potential of music-based language learning, they primarily target hearing users [Huang and Chen 2024] and offer little to no accessibility features for Deaf individuals. In contrast, Libraskê is designed as an inclusive serious game that integrates karaoke-inspired interaction with Libras. It uniquely addresses accessibility by enabling Deaf users to engage with signed content through visual-spatial input, while also supporting Libras learning among hearing users. By combining computer vision for sign evaluation with game elements such as scoring and feedback, Libraskê positions itself as both an accessible entertainment experience and a pedagogical tool tailored to the sociolinguistic realities of the Deaf community.

3. Libraskê

Serious games, when designed with digital accessibility in mind, aim to provide adaptable and inclusive experiences by considering users' diverse needs and limitations. However, individuals with disabilities—particularly those with sensory or motor impairments—often face significant barriers to engaging with traditional gaming environments.

Karaoke is a musical entertainment format in which players select a song from a predefined list and perform it by singing into a microphone, guided by subtitles and visual cues displayed on a screen. The user's vocal performance is captured and analyzed in real time by the system, which compares pitch and timing against a reference track. At the end of the performance, a score is generated, providing immediate feedback and gamifying the experience.

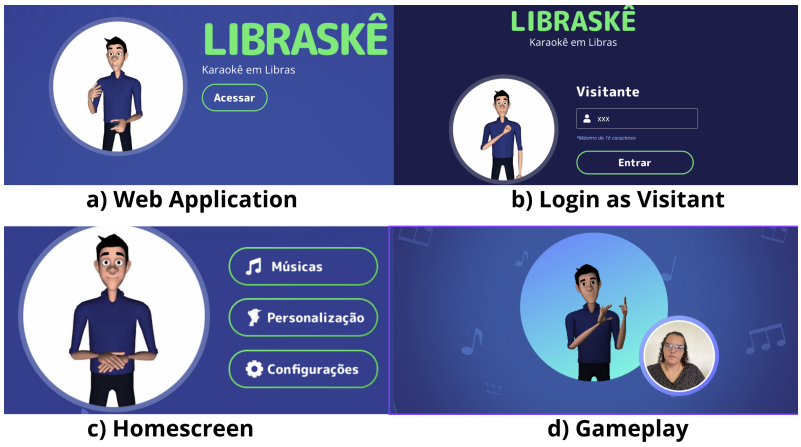


Figure 1. Screenshots of the Libraskê user entry, Home Navigation and Gameplay

In this context, Libraskê is introduced as a serious game aimed at promoting the learning and dissemination of Libras. The game offers Deaf users access to song lyrics through sign language and provides hearing individuals with an engaging tool to explore Libras in a playful way. To support this functionality, Libraskê integrates the VLibras platform [Araujo 2015], an open-source translation system developed by the Brazilian Federal Government that converts written Portuguese into Libras using a 3D virtual avatar.

Libraskê reimagines the karaoke format by substituting vocal performance with sign language interpretation. Players express song segments in Libras, engaging through visual-spatial communication rather than audio. To evaluate performance, the system captures static image frames at predefined intervals aligned with the lyrics. These frames are analyzed using computer vision techniques to assess gesture accuracy, providing an inclusive alternative to traditional audio-based karaoke systems.

To balance performance and scalability, Libraskê employs a frame-based image capture approach instead of real-time video streaming. Static frames of the user's signing are collected at predefined intervals and sent to a microservice for processing. This design choice reduces server load, storage demands, and client-side bandwidth. Image analysis is performed using the Mediapipe library, which extracts key points related to hand gestures, body posture, and facial expressions. The captured frames are then compared to reference images recorded by a Libras specialist to evaluate gesture accuracy.

Given that interaction in Libraskê occurs through Libras, a virtual assistant was incorporated to guide and support players during gameplay. A 3D VLibras avatar [Araujo 2015], displayed at the center of the screen, Figura 1-(d), performs the signs corresponding to the lyrics, while Portuguese subtitles appear in the lower corner. Acting simultaneously as guide and translator, the avatar facilitates intuitive and immersive learning, enabling players to assimilate Libras naturally through visual association.

To enhance user experience, Libraskê includes a mirror-mode interface that displays the player's camera feed alongside the VLibras avatar, allowing real-time visual comparison of movements(Figura 1-(d)). Additionally, the system provides visual feedback by displaying a score after each frame is processed. This immediate response, based on gesture accuracy, reinforces user engagement and encourages performance improvement during gameplay.

3.1. Development Process

For the development of Libraskê, we incorporated several formal software development methodologies, with primary emphasis on agile practices. According to [Kumar and Bhatia 2012], agile methodologies possess four main characteristics: planning, interactive and evolutionary development, rapid response, and flexibility to change. In light of this, we employed the agile Scrum methodology to support project management.

We developed the solution for the web using the following technologies: React JS for web page implementation, the Unity 3D graphics engine for game development (using the C# programming language), and Node.js for the development of backend microservices. The selection of these technologies was based on considerations of usability, implementation time, and the development team's familiarity with each of them.

Once we defined the technologies, we developed a formal description of the solution's functionalities. This process began with a survey of the game's features, which helped us better understand the problem domain and identify the specific requirements for developing a playful solution aimed at the general public, with particular emphasis on the Deaf community.

For the development of the game and the web page, we designed the interaction

interface using UI/UX design techniques and methods, primarily guided by the heuristics defined by [Nielsen and Molich 1990]. These principles supported the creation of a smooth, intuitive, and easily navigable user experience. Based on these considerations, we defined the screens and navigation flow for the entire application.

The development of Libraskê was guided by continuous internal validation conducted by a multidisciplinary team that included Deaf individuals and Libras interpreters. These collaborators were involved from the early design stages, contributing to decisions related to sign clarity, interface accessibility, and interaction flow. Before user testing, exploratory evaluations led by Deaf team members helped identify and address usability and accessibility issues. Their feedback informed refinements to layout, avatar timing, and feedback mechanisms, ensuring the experience aligned with the visual and communicative expectations of Libras users.

3.2. Game Architecture

We designed the architecture of Libraskê based on a microservices framework. This architectural approach consists of decomposing the system into small, independent components, each responsible for a specific functionality. Such decomposition promotes modularity, facilitates maintenance, and reduces the impact of failures by isolating affected services when necessary. Following this strategy, we defined the system's architecture through the analysis of component interrelations and iterative development, resulting in a backend composed of four distinct microservices, as illustrated in Figure 2.

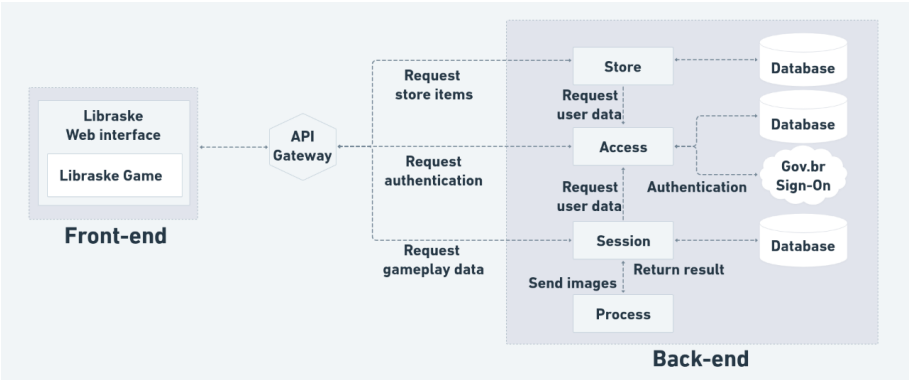


Figure 2. Libraskê archictecture

3.3. Presentation Tier (Front-end)

On the front-end, we structured the application into two layers: the Frontend Client and the Libraskê Game. The Frontend Client corresponds to the virtual interface accessed via web browsers, through which users interact with the platform. We developed this layer using the React JS library, employing JSX to define the page structure and CSS to style the visual components. The Libraskê Game layer is responsible for executing the core game functionalities and managing data exchange with backend APIs related to sessions, music, and user information. We developed this component using the Unity3D graphics engine, which supports WebGL compilation and integrates with standard JavaScript libraries. We wrote the entire game codebase in C#, incorporating native libraries to perform essential tasks such as data persistence, camera image capture, and web request management.

The game layer communicates with the backend API via the WebSocket protocol to enable faster and more efficient interactions between the game and the server. Unlike traditional HTTP requests, WebSockets maintain an open connection, allowing real-time, bidirectional data exchange without the need for repeated handshakes. Since the game transmits files (images) along with its payload, we prioritized minimizing latency to ensure a more responsive and interactive gaming experience.

We integrated these two layers through a Unity WebGL build embedded in the React.js project. This integration makes the game accessible from a standard web page, allowing users to play directly through their web browsers.

3.4. Application Tier (Back-end)

The back-end is responsible for all data processing and storage. To take full advantage of the microservices architecture, we decomposed the application based on its core functionalities. We implemented the APIs as follows:

- **Access API**: Manages access to the other APIs and handles user authentication through integration with the Brazilian Federal Government's Single Sign-On system.
- **Session API**: Manages match sessions by linking the user, selected music, score, and related tracking data. It also receives gameplay images from the front end and sends them to the Process API, which analyzes them and returns a score (0–100) used to determine final performance.
- **Process API**: Processes the images received from the Session API using computer vision techniques by comparing them to reference models previously created by a Libras specialist.
- **Store API**: Manages the songs and avatar customization elements that can be acquired using Libraskê's virtual currency.

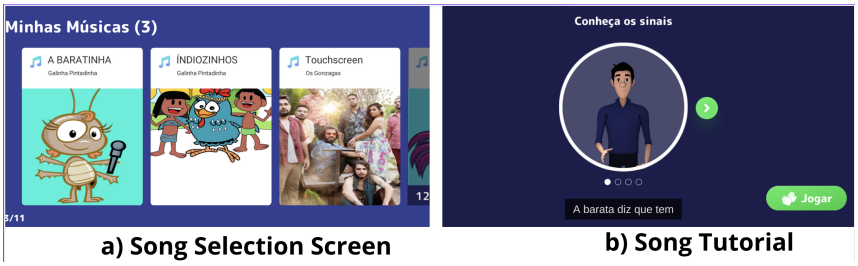
For the implementation of the Access API and the Session API (see Figure 2), we utilized Node.js with native JavaScript and the Express.js microframework to develop HTTP servers supporting the web back-end via REST APIs. While standard web requests are handled by an HTTPS server built on Express, session communication mainly relies on WebSockets.

The Session API captures images and forwards them, along with session and user data, to the image processing service through the AMQP protocol using RabbitMQ messaging (see Figure 2). This approach leverages RabbitMQ's temporary in-memory data storage to ensure reliable message delivery despite potential instabilities between APIs.

Distinctively, the Process API was implemented in Python to enable better integration with the Mediapipe library, which is critical for the computer vision functions performed by this service.

3.5. Game Mechanics

To access Libraskê, players must first log in using a personal account or as a guest (see Figure 1-(a)(b). After logging in, they are prompted to select one of the following actions: (1) choose a song, (2) customize the avatar, or (3) configure game settings (see Figure 1-(c). On the song selection screen, players have access to a variety of songs, some of



a) Song Selection Screen b) Song Tutorial

Figure 3. Gameplay system screenshot

which are unlocked by accumulating points through gameplay (see Figure 3-(a). The customization screen allows users to modify the avatar based on personal preferences. Lastly, the configuration screen enables players to adjust settings such as sound volume, sound effects, and subtitle size.

The core mechanics of the game involve interaction between the player, the selected virtual assistant (Ícaro, Hozana, or Guga) of VLibras, and the music being played. As shown in Figure 1-(d), in the main scene of the game, the 3D avatar performs a sequence of signs that, in the context of Libraskê, represent the interpretation of the selected song in Libras. The player must replicate the signs performed by the avatar in front of their camera. During this process, we capture images of the player's signing and send them to the processing server. The game then provides visual feedback indicating whether the sign was correctly validated. This feedback is displayed after the server processes the image and returns a score, which we show on the user side as a form of encouragement for the player.

Another key mechanic in the game is the scoring system. Each time a player completes a song, we assign a score based on the accuracy with which they performed the signs during gameplay. Players accumulate points that can be used to unlock additional songs or new customization options for the avatars (see Figure 4). The avatar customization system allows players to modify skin tone, clothing colors, and eye and hair colors, providing a personalized gaming experience.

a) Skin color b) Shit color c) Pants color d) Hair color e) Eyes color

Figure 4. Customization system screenshot

3.6. Testing and Validation

To evaluate the proposed solution, a playtest was conducted with ten participants: five Deaf individuals fluent in Libras and five hearing individuals with no prior knowledge of the language. The study was approved by the Research Ethics Committee of the Health Sciences Center at the Federal University of Paraíba (CAAE No. 93096518.6.0000.5188),

and all participants signed informed consent forms. Images captured during the sessions were securely stored and anonymized to ensure data confidentiality.

Participants, aged between 18 and 45, were recruited through institutional and social channels. The sample included 60% male and 40% female, with varied educational backgrounds: 70% completed high school, 20% completed higher education, and 10% had incomplete high school. All Deaf participants were fluent in Libras, while hearing participants had no prior exposure to the language.

Regarding digital literacy, most participants reported familiarity with computers. In terms of gaming habits, 20% played daily and 30% played weekly, indicating that half had prior experience with digital games.

For the test, we allocated 20 minutes for each participant to explore the game screens and gameplay mechanics. Before the session began, we provided a brief explanation of the experiment, outlining its objectives and offering a simple overview of the game.

Each player was asked to play twice, following a predefined order of songs. The first song, "Borboletinha", a children's song, was selected for its simplicity and repetitive structure. The second, the Brazilian National Anthem, was chosen for its greater complexity, as it lacks a chorus and features more traditional vocabulary. The tests were conducted in a standardized environment, with the player centered in front of the notebook camera and interact with game.

The usability and user experience design of Libraskê was informed by Nielsen's heuristics [Nielsen 1994], with emphasis on consistency, visibility of system status, user control, and alignment with real-world conventions. Terms like "smooth" and "intuitive" refer to design choices that support clear feedback, simplified navigation, and adherence to users' mental models.

During playtests, user expectations were inferred from spontaneous verbal comments and behavioral cues such as laughter, surprise, or frustration. Although exploratory, these observations indicated that users generally perceived the experience as accessible and engaging. Key aspects considered included engagement, perceived challenge, clarity of tasks, and ease of navigation. Throughout the testing process, we observed player interactions, behaviors, difficulties, and decision-making.

4. Results and Discussions

Considering aspects such as performance, entertainment value, gameplay, tester behavior patterns, and other observations from the testing sessions, we noted that participants experienced slight difficulty during the first song. This challenge was primarily related to the difficulty of following the avatar's movements in real time. Both Deaf and hearing users expressed surprise and some initial confusion when interacting with the game mechanics for the first time. However, differences in how each group adapted to the game's controls quickly became apparent. This was particularly evident in the scores obtained by the two groups during the performance of the first song.

Therefore, all deaf players scored above 50 points (see Table 1), while all hearing players scored below 50. In the context of this work, scores above 50 (Score 0 - 100) were considered satisfactory. The average standard deviation for both groups in the first

song was identical, indicating similar behavior. However, from the second song onward, hearing participants became more focused, leading to a 30% higher average score. The standard deviation increased more significantly for hearing players, possibly due to the increased complexity of signs and vocabulary in the second song. It is hypothesized that the score improvement resulted from better understanding of the game mechanism.

User	Type	Score - Song 1	Score - Song 2	Average score
U1	Deaf	55	60	58
U2	Deaf	58	62	60
U3	Deaf	60	65	63
U4	Deaf	53	57	55
U5	Deaf	56	61	59
Mean (Deaf)	–	56.4	61.0	59.0
Std Dev (Deaf)	–	2.70	2.92	2.92
U6	Hearing	40	52	46
U7	Hearing	42	55	49
U8	Hearing	38	50	44
U9	Hearing	45	58	52
U10	Hearing	43	39	41
Mean (Hearing)	–	41.6	50.8	46.4
Std Dev (Hearing)	–	2.30	6.72	4.10

Table 1. Scores of Deaf and Hearing Users - Scale 0 to 100

In addition to quantitative metrics, observational analysis during the playtests revealed patterns of engagement, frustration, and learning. These observations, recorded by researchers and Libras specialists, showed that hearing participants initially hesitated, relying on visual approximation to replicate signs. Over time, however, many demonstrated improved accuracy in hand configuration and movement synchronization, suggesting short-term learning effects facilitated by repetition and visual feedback.

Deaf participants exhibited greater fluency and confidence, but occasional frustration arose due to avatar pacing and timing mismatches in gesture recognition. These issues were alleviated through minor repetitions and clarifications, highlighting the importance of precise timing and responsive feedback for fluent signers.

In terms of emotional responses, we observed that deaf players did not experience the game as fully as hearing participants. This was primarily due to the fact that their only available sensory input was visual. Deaf players were unable to experience the rhythm, harmony, and melody of the music, having access only to the lyrics and poetics of the song. In contrast, hearing participants benefited from both visual and auditory stimuli, which made the game more engaging and enjoyable for them.

Signs of frustration were also observed in both groups, primarily due to the difficulty of following the avatar in real-time. This was particularly evident when players abandoned attempts to perform certain signs in response to the rhythm of the music, leading to the omission of some words. This challenge resulted in delays and omissions in the

execution of signs, which likely affected the overall performance of the players.

With regard to user behavior, both groups demonstrated a high level of immersion, largely because the game demands constant attention to replicate the signs accurately and in real time. As a result, some players expressed satisfaction when they were able to follow the signs successfully for longer periods.

Both groups expressed enjoyment—through smiles, laughter, or positive comments—especially after successfully completing a song or earning high scores. These behaviors reflect the state of flow [Csikszentmihalyi 1990], where challenge and skill are balanced to foster deep engagement. Features such as real-time scoring and a leaderboard reinforced motivation and goal-oriented behavior.

Overall, the findings indicate that Libraskê promotes active participation and short-term engagement, while pointing to areas for refinement in timing calibration, gesture recognition, and adaptive difficulty.

5. Conclusion

This paper presented Libraskê, a serious game designed to entertain and promote the dissemination and engajament of Libras through an interactive experience. The game features navigation via buttons labeled in Portuguese, all of which are translated into Libras using a virtual interpreter represented by a 3D avatar.

Our proposed solution incorporates mechanics similar to traditional karaoke; however, the interpretation of the songs is performed through Libras gestures. These gestures are captured by a camera and sent to a server for analysis, processing, and scoring. The navigation and gameplay mechanics were designed to accommodate both Deaf and hearing users equitably. Nevertheless, it was essential to validate these aspects through user testing.

To that end, we conducted an exploratory and observational case study involving ten participants—five Deaf users and five hearing users with no prior knowledge of Libras.

The results indicate that the game performed well in terms of enjoyment, usability, user performance, and audience expectations. Specifically, Deaf participants, along with their hearing counterparts, reported feeling comfortable with the solution but a challenge, particularly among hearing users, was the difficulty in following the signs in real time.

Overall, the game fulfilled its intended goal: to provide a serious game that is both enjoyable and accessible to Deaf and hearing users alike. The solution was well-received by the target audiences. However, some improvements are still needed—such as implementing music speed control and adding more songs to increase the game's appeal and replay value.

As future work, we plan to address user-reported issues by implementing distinct profiles for deaf and hearing players, allowing customization of the avatar's signing speed and corresponding music tempo adjustment. We also intend to integrate immersive devices for deaf users, such as tactile feedback bracelets that convey rhythm, melody, and harmony through touch. Additionally, a mobile version of the application will be developed to enhance accessibility and convenience. Finally, we aim to conduct user testing focused on evaluating human-computer interaction aspects.

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