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Reh@Store: An Open-Source Framework for Enhancing ICT-Based Health Interventions with Secure Distribution, Maintenance, and Data Collection

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Abstract

Health-related intervention tools such as virtual reality, serious games, and brain-computer interfaces have become increasingly important in the field of healthcare. These tools have the potential to improve the quality of life for individuals with special needs and have been shown to be effective in rehabilitation and therapy. However, the distribution, maintenance and remote data collection of these tools have presented a challenge for healthcare providers, researchers, and developers. In this article, we propose Reh@Store, an open-source solution designed to assist professionals and patients in using, deploying and maintaining health-related intervention tools. The solution is designed to allow easy installation, updating, and removal of software on users' devices, as well as the automatic backup of generated data to an SFTP server. A usability test, stress test and a real-world case study were conducted. The solution was also validated and is ready to be deployed and used in production environments.

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1. Introduction

Health-related intervention tools such as virtual reality (VR), serious games (SG), and brain-computer interfaces (BCI) have become increasingly important in the field of healthcare since these tools have the potential to improve the quality of life for individuals with special needs and have been shown to be effective in rehabilitation and therapy[3][4][5]. By targeting specific therapy goals and tailoring them to the individual needs of each patient, the serious games are able to improve the therapy quality and turn a very monotonous therapy or rehabilitation experience into an engaging one for their patients to participate in, thus improving motivation and engagement in the therapy process [4]. Besides improving the therapy experience for the patient, a serious game can also be used to collect, in real-time, the patient's therapy information such as the types of exercises performed, time spent on each exercise, the accuracy of the movements, and frequency of the therapy sessions. This information is a vital part of the therapy and provides important feedback to the therapist, allowing for the customization of the applied therapy by helping to identify the areas where the patient may be struggling.

Distributing and maintaining health-related tools can be challenging, especially in clinical settings. The process of distributing and updating software tools is complex when they must be installed and updated on multiple devices. This challenge is particularly acute in rehabilitation settings, where the focus should be on delivering quality care to patients, not managing software-based health tools installations manually [2]. Additionally, the lack of a centralized data collection platform has also made it challenging to collect and analyse data on the effectiveness of these tools and the applied treatments. Without such a platform, monitoring and consulting multiple patients undergoing rehabilitation progress and generating information, in order to adjust the current treatment plan accordingly, could present a challenge. As a result, there is a need for a centralized solution that would streamline the distribution, maintenance, and data collection process for health-related intervention tools.

The challenges presented by the lack of a centralized platform for distribution, maintenance, and data collection led to the development of Reh@Store. Reh@Store is an open-source solution that provides a centralized and remote platform for the distribution, maintenance, and data collection of health-related intervention tools [2]. The Reh@Store was developed within the NeuroRehabLab [1]. The NeuroRehabLab conducts interdisciplinary research in technology, neuroscience, and clinical practice with a focus on developing innovative and affordable rehabilitation technologies (VR, SG, BCI) that target specific brain mechanisms related to functional recovery, in order to enhance the quality of life for individuals with special needs.

2. Proposed Solution

This paper introduces Reh@Store, a free open-source framework designed to enhance and assist ICT-Based Health Interventions of researchers, clinicians, developers, patients and owners of health-related tools. Reh@Store enables remote distribution, updating, and maintenance of any health-related software intervention tools, as well as control over their access and usage. Additionally, the framework provides secure data collection, backup, and storage capabilities, along with remote support for end-users. Reh@Store also supports the utilization of various technologies used by distributed health-related software intervention tools and has been validated through a usability test, server stress test and a real-world case study.

3. Methodology

The necessary requirements for enhancing the distribution, maintenance, data collection, and remote support process of health-related intervention tools were determined through a systematic approach. Firstly, interviews were conducted with clinical members, developers, and researchers affiliated with the laboratory. These interviews aimed to gather insights into the utilization and scenarios of serious games and research tools developed by the laboratory. Then, the information obtained from the interviews was converted into functional and non-functional requirements for the Reh@Store. Lastly, the Reh@Store was implemented based on the previously defined requirements, followed by its evaluation and validation through a series of tests.

3.1. Interviews

Interviews were conducted to identify obstacles and difficulties encountered during the development and maintenance of research projects, with the aim of defining crucial elements that the Reh@Store should impact positively, thus, resulting in the definition of system requirements. Two separate types of interviews were conducted to address the simplification of maintenance and configuration processes for the tools used. The first targeted serious game users, while the second focused on developers. After the interviews and the establishment of Reh@Store's requirements, the development was initiated. Once implemented, the platform's effectiveness, usability, and user satisfaction were evaluated through a series of tests.

3.2. Implementation of the Solution

The requirements for the proposed solution, Reh@Store, were categorized into two main types, functional and non-functional. The former type was derived directly from the results of the interviews and pertains to the features and functions that end-users require to accomplish their tasks. On the other hand, non-functional requirements were defined based on aspects such as data protection, security, ease of use, and system fault tolerance. These requirements not only improve the overall human-computer interaction, which in turn enhances the success and maintenance rate of health-related intervention tools but also enable the solution to adapt to the needs of the users.

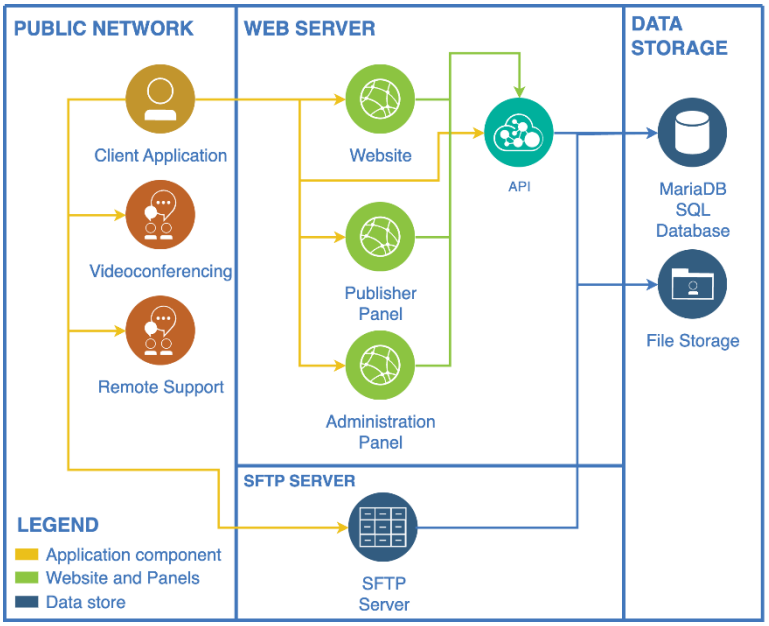

Fig. 1. System Architecture.

Following the defined requirements, the solution's architecture was separated into 7 components (see Figure 1), a database, a file storage component, a web server, a Secure File Transfer Protocol (SFTP) Server, a remote support component, a video-conferencing component and an application.

3.2.1. Database and File Storage

To ensure efficiency and data consistency, a relational database was chosen since the data to be stored have some form of relationship with each other.

The storage of software installers and data generated during software execution should be managed within a designated folder in the server's file system, along with other critical data that cannot be lost. To ensure data

integrity and the ability to revert file modifications, all editions within this folder are backed up and made reversible at any given time by using a local Git. Whenever the application disconnects from the SFTP server, the Git repository makes a commit of the current data.

3.2.2. Web Server

The web server was implemented using Node.JS, due to its performance, integration capabilities, and component interaction [2]. For the publisher and administration panels hosted on the web server, the React framework was selected. The publisher dashboard facilitates the streamlined publication and management of software, encompassing tasks such as version and subversion control, software installer uploads, platform compatibility declaration, and definition of access permissions for subversion sets associated with their authored software. On the other side, the administrator dashboard streamlines user management within the solution, enabling administrators to effortlessly view, edit, and delete user accounts. Additionally, it offers comprehensive server statistics including RAM consumption and occupied file storage space.

3.2.3. SFTP Server

The SFTP server is utilized by the Reh@Store application to create and store backups of the software-generated data. To ensure robust data security measures, access and retrieval, access is strictly limited to authorized users by identifying both the software responsible for data generation and the specific user executing it. Clinical users are restricted to accessing their data exclusively, while developers and researchers have access not only to their data but also to data generated by the utilization of their published software. Furthermore, administrators of the Reh@Store are granted comprehensive access to all data managed by the SFTP server.

3.2.4. Remote Support and Video-conferencing Component

Remote support assistance in Reh@Store is facilitated through the integration of Tawk [6], a cost-free help desk system. This help desk system offers real-time chat functionality, streamlined assistance request management, agent assignment capabilities, and seamless integration with web technology components. In addition to the aforementioned features, users can also contact Reh@Store support via email. Among the available options, the decision was made to utilize Tawk [6] due to its inclusion of a free real-time chat feature, which is hosted and maintained by third parties. This choice helps in minimizing maintenance and implementation costs [2].

Video-conferencing is intended to be utilized for meetings and as a supplementary tool for remote support to Reh@Store users. Among the various available options, Jitsi [7] was selected for its cost-free nature and compatibility with web technologies, enabling seamless integration with the Reh@Store application.

3.2.5. Client Application

The primary objective of the Reh@Store application is to offer an accessible and efficient solution for managing and utilizing health-related intervention tools through a user-friendly interface, allowing to easily install, update, and remove them from the devices. Additionally, the application automatically backs up the generated data from these tools to an SFTP server. To enable the functionality described above, installing the Reh@Store application on all devices that will be used for the distribution of health-related intervention tools is mandatory.

The application offers users personalized functionalities based on their permissions, leading to a customized interface. For developers and researchers, the application includes various tools to simplify the software creation process. These tools encompass configuration, creation, installation, and extraction of installer files. Additionally, a shortcut is provided to access the publisher dashboard. Similarly, administrators can conveniently access Reh@Store's administration panel via a shortcut. The application interface also enables end-users to utilize remote support and video conferencing services. To facilitate these features, the interface incorporates Tawk [6] and Jitsi [7] as the underlying technologies.

The client application possesses self-updating capabilities by identifying its runtime environment and establishing communication with the API to install any available updates. Currently, the client application exclusively supports Windows, although the code can be readily adapted for compatibility with other operating systems such as Linux or macOS.

3.3. Evaluation tests

To validate the Reh@Store and evaluate its effectiveness, usability and user satisfaction, a technical evaluation, usability evaluation and real-world case study were conducted. The technical evaluation was primarily concerned with assessing Reh@Store's performance, while the usability evaluation and real-world case study focused on user experience, human-computer interaction and Reh@Store's behaviour in a production environment.

3.3.1. Technical Evaluation

A stress test was conducted on the web server using a tool called Autocannon to assess its latency when subjected to high traffic [8]. The latency measurement was carried out by simulating a thousand simultaneous connections. While this test only measures the web server latency, it cannot measure a real-world scenario latency where multiple users interact with at server's API. This led to the development of a custom tool, that simulated a scenario where multiple Reh@Store applications are connected to the web server by using a bot that contained a portion of Reh@Store's application source code. Every 10 seconds, a new bot connected to the web server API and started using the API. The test finished when the web server was being used simultaneously by 360 bots.

3.3.2. Usability Evaluation

The conducted usability test aimed to assess the user-friendliness of Reh@Store for prospective users, including students, health-related professionals, and researchers. The test required the participants to not have prior knowledge and to not have previously interacted with the solution. Participants were also required to complete the following tasks: create a Reh@Store account, install the Reh@Store application on their computer, launch the application and log in to their account, install a random serious game available on Reh@Store, launch the installed serious game using Reh@Store, uninstall the installed serious game using Reh@Store. After completing the tasks, participants were asked to fill out a questionnaire where they rated each aspect of Reh@Store's application on a system usability scale [10] of 0 to 10, with 10 indicating excellent and 0 indicating poor [2]. The questionnaire covered aspects regarding client applications' legibility, ease of use, user interface satisfaction, accessibility, and experienced errors. Participants also had the opportunity to provide feedback on any difficulties they encountered while using the client application.

3.3.3. Real-world Case Study

The objective of this real-world case study was to analyse the behaviour of the Reh@Store in a production environment, address any encountered bugs, and identify potential areas for optimization. To achieve this, this study was carried out at a regional health institution over a period of two months, involving professionals associated with the institution and members of the laboratory responsible for the projects deployed at the interactive tables used by the regional health institution.

4. Results and Discussion

The Reh@Store underwent a series of evaluations including technical evaluation, usability evaluation, and a real-world case study, to validate its effectiveness. Before this series of evaluations, the Reh@Store was implemented based on the system requirements inspired by the results of the interviews.

4.1. Interviews

The interviews included 9 participants with diverse roles: 5 clinicians, 5 developers, and 3 researchers. Some participants held multiple roles, such as 1 participant being both a clinician and developer, 1 participant being a clinician and researcher, and 1 participant being a developer and researcher simultaneously. Regarding gender, 3 participants identified as males, 4 as females, and 2 preferred not to disclose their gender. The gathered information from the participants was further processed and classified into 7 distinct categories.

4.1.1. Distribution of Serious Games and Tools

According to some participants, multiple institutions such as clinics, hospitals, and research facilities use the research project they're inserted on. Those research projects, such as Microsoft Kinect for Unity3D and serious games (such as NeuroAIReh@b Platform, Reh@City, and Task Generator) [11][9][12][13], require continuous development and improvement. In some instances, it is also necessary to maintain their installation at the laboratory or third-party devices. The serious games, deployed at the equipment of related institutions, are installed, maintained, updated, and removed in-person or remotely using a remote support software. When done in person, those responsible for maintaining the serious game or tool must physically travel to the installation site for each maintenance operation. As such, developers and researchers participants felt that not only the speed and simplicity of project maintenance but also their configuration (where they were inserted) could improve.

4.1.2. Data collection from serious games and tools

The usage of serious games (and tools) in therapy or research context produce various types of data (e.g., therapeutic data) that are further collected. For use cases such as clinical treatments and studies, their collection is a vital part. According to some clinical participants that participated in the interview, some health professionals and patients possess low computer literacy. This presents an obstacle to the consultation of patient data (or end-user) and may consequently reduce the treatment success rate or, in some extreme cases, render their realization impossible. Therefore and whenever possible, access to and visualization of data should be standardized and simple. Also, some participants' data from serious games and research tools, when collected in person, were done using a USB mobile storage device. The usage of this method of data transfer presents a high risk to all devices involved in case one of them happens to be compromised.

4.1.3. Versioning of projects

Some serious games have one or more base versions. These versions serve as a basis for the creation of subversions that meet their end-users' needs. Due to that fact, those subversions cannot be distributed using a website and require their manual distribution by one or more members of the laboratory. It is then observed that a solution for versioning and distributing serious games and tools to only their end-users was a key missing element in the distribution chain.

4.1.4. Obtaining feedback

Understanding the end-user experience with the versions and subversions mentioned above becomes essential. This type of information enables health-related intervention tool developers to diagnose any issues and introduce new features, if the end-user desires or needs them. Participants indicated that feedback was collected personally or through one or more electronic means of communication in the projects where they were inserted. The ideal solution, to reduce the probability of the end-user not knowing how to get in touch with the developer, is to reduce and centralize those electronic means of communication.

4.1.5. Human-computer interaction

Clinical users and health professionals are unaware of certain technical concepts about serious games due to the fact that developers configure and maintain those serious games. Occasionally, clinical users feel difficulty performing certain tasks, such as consulting the data generated by the serious game in the context of ongoing treatment. These factors create a strong dependence between clinical users, developers and researchers, which can lead to a suboptimal treatment for the patient.

4.1.6. User Manual for Projects

Instruction manuals and tutorials are essential for intervention tools to have, according to some clinical participants and developers. In addition to easy access, the user should be able to access the latest version of this document at any time. The existence of such documents reduces the likelihood of serious game misuse, which potentially positively reduces the likelihood of a treatment being poorly applied due to the misuse of this technology.

4.1.7. Technical Support

The participants stated that technical support for serious games was provided in person or remotely, using remote control tools, video conferencing, and screen sharing. In the case of being remote and also due to the existence of several methods of electronic contact and remote support, we are presented again with the problem related to multiple electronic means of communication. As a result, it will be confusing for users to request help, and in some cases, they end up giving up. So, a bad support experience increases the likelihood of a particular project becoming inoperable by its users.

4.2. Technical Evaluation

The Reh@Store underwent two stress tests after its implementation, one using Autocannon and another using a custom-made tool. When using Autocannon, the average latency per request was determined to be 0.68 milliseconds. This test's limitation was the fact that it only measured the web server's performance in general and not the API performance. As such, the custom-made stress tool that addressed this limitation was used to benchmark Reh@Store's web server API. The obtained results by the custom-made stress tool revealed that an improvement was needed in the web server. For 360 simultaneous users, each API call was taking 66 seconds to complete. After a later optimization and improvement of the web server, the same test was repeated and the average time taken to complete the task was reduced to 30% (20 seconds).

4.3. Usability Evaluation

The usability test comprised 5 participants, consisting of 2 researchers, 2 students and one health-related professional who had no prior knowledge of the solution. In order to calculate this test's result, firstly all questions results for each questionnaire of each participant were summed up. Then, each questionnaire's result was converted into a scale from 0 to 100% by multiplying by 2. Finally, we calculated the average score of all questionnaires obtaining an average score of 94%. However, some participants encountered difficulty in understanding certain terminologies, such as "branch", and identifying which software was being installed since feedback regarding installation was conveyed solely through Windows notifications.

4.4. Real-world Case Study

During the two months of the real-world case study, Reh@Store successfully deployed the serious games, safeguarded and versioned their statistical data alongside their diagnostic data, such as error logs generated by the deployed serious games. During this case study, 3 issues were observed and corrected on the final version of the Reh@Store. One of those observed issues was related to the end-users interaction with the data generated by the distributed serious games. Users were trying to manipulate the data inside the installation folder rather than Reh@Store's data folder, which gave the impression to the end-users that the data was being erased. To address this usability issue, developers were given the option to choose whether to use the data backup functionality. The other issues were related to a bug on the web server and Jitsi [7]. The first bug made the server recognize that the storage was full when in fact it was not, while the second bug made Jisti stop working after an update by its developers. Despite these issues, Reh@Store performed well and was easily usable by its users. All issues related to Reh@Store were fixed remotely and the patches were autonomously deployed using Reh@Store's application remote self-update feature.

5. Conclusion and future work

In this article, we presented Reh@Store, a free open-source platform designed to assist professionals, patients and health-related tools owners in using, deploying and maintaining health-related intervention tools, which is available at https://rehstore.arditi.pt. Through a series of evaluations, including technical evaluation, usability evaluation, and a real-world case study, the Reh@Store was validated and is ready to be deployed and used in production.

The technical evaluation revealed that Reh@Store's web server needed optimization to improve its performance. A custom tool, developed for simulating a scenario where multiple Reh@Store applications connected to the web server API, was used to test Reh@Store's web server and provided valuable insights into Reh@Store's limitations.

The usability evaluation demonstrated that Reh@Store is fast and easy to use, with minor issues related to users' understanding of certain terminologies and feedback on software installation. The carried real-world case study provided valuable insights into Reh@Store's behaviour in a production environment, which allowed for its enhancement and refinement. Also, the real-world case study demonstrated that Reh@Store is a reliable, efficient and useful platform for distributing and maintaining health-related intervention tools.

Reh@Store's benefits include its user-friendliness, reliability, and efficiency. However, the platform has certain limitations, such as a slow web-based API in a high-usage scenario. Future research could focus on optimizing Reh@Store's web server, improving the platform's API performance, and expanding its use to a broader range of health-related intervention tools and compatible operative systems. Overall, Reh@Store has the potential to be a valuable tool in the healthcare industry and is capable of providing aid in the deployment and maintenance of health-related intervention tools for professionals, researchers, developers and patients.

As the writing of this article, multiple health-related institutions in Portugal and Spain use the Reh@Store. This deployment of the Reh@Store is maintained by the NeuroRehabLab and available at https://rehstore.arditi.pt.

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