Chapter

Technical Contributions to the Quality of Telerehabilitation Platforms: Case Study—ePHoRt Project

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Abstract

This chapter proposes three main technical contributions for the development of a telerehabilitation platform, named ePHoRT, for patients recovering from hip surgery. The first contribution is the application of a diffuse 3D model for the detection of rehabilitation exercises after hip surgery. The model applies fuzzy logic, which allows identifying in real time if a patient is performing a right or wrong movement, assisted by an avatar in 3D. The avatar copies the movements of the patient through a Kinect camera. The second contribution involves the proposal of an iterative method to improve the usability of telerehabilitation platforms along the development life cycle. The proposed method involves the use of an inspection method and includes protocols and instruments. This method has been validated in the ePHoRT project. Finally, the chapter describes accessibility guidelines for educational resources. It proposes accessibility standards for the content of educational resources in video and PDF formats in the telerehabilitation platform according to the Web Content Accessibility Guidelines (WCAG).

Keywords: eHealth, telemedicine, telerehabilitation, hip surgery patients, fuzzy logic, usability, accessibility, educational resources, WCAG

1. Introduction

The ePHoRT platform allows hip replacement patients to perform part of the rehabilitation treatment at home and communicate the evolution of the recovery process to the physiotherapist. The ePHoRT platform has a "practice module" organized into three stages that are meaningful for the patient's recovery process. These stages are characterized by a growing level in the intensity of the exercises. Stage 1 is carried out during the week following the surgery and consists mainly of exercises performed lying down. Foot rehabilitation movements begin in stage 2 (the second week after surgery). Finally, stage 3 is characterized by functional exercises, which consist of preparing the patient to recover a regular walk. The ePHoRT platform is in the design stage and follows a process of agile and collaborative development focused on the user.

2. Application of a diffuse 3D model for the detection of rehabilitation exercises after hip surgery

At the present time, it has been seen that intelligent systems embrace a large number of daily life tasks and activities of the society. The objective of these systems is to solve a variety of existing problems in society more efficiently and with accurate results. One of the characteristics of these systems is the interaction between the user and the computer [1], which allows the optimal handling of these systems intuitively.

The present work proposes the development of a virtual representation of the body structure of a patient who performs rehabilitation exercises. This digital representation is called avatar [2], which duplicates the movement of the human being that has been detected by a Kinect camera from Microsoft's Xbox One.

The captured movements are imitated by the avatar and executed in real time. Subsequently, if the patient performs an incorrect exercise, the system will show an alert with the part of the body where it is moving wrongly, with colors that help the patient's interaction. A detector subsystem applies the diffuse logic technique that identifies the execution of rehabilitation exercises; this allows the avatar to be a means of interaction between human and computer.

In the work presented by Ichim et al. [2], the development of three-dimensional facial avatars is detailed. The system detects facial expression from a template and a sequence of recorded images through an optimization that integrates the tracking of expression characteristics. This study helps the design of new applications of computer animation as well as online communication based on personalized avatars. In addition, demonstrations of several applications in real time that verify the process of avatars creation are presented.

In the work published by Pavone et al. [3], the application of immersive virtual reality and electroencephalography recording is presented to explore the avatar's error incorporation when it is viewed from a one-person perspective. The avatar activates the error monitoring system in a patient's brain and helps its development. The results show that immersive virtual reality can obtain optimal results with the application of an artificial agent. These tools improve the fine-tuning learning (motor skills), up to critical social functions (reading or anticipating the other people's intentions).

The study published by Belal et al. [4] presents the study of pulse oximetry. It is a technology used to monitor oxygen saturation in neonates and pediatric patients. The equipment that measures the pulse oximetry is not precise, whereby they generate false alarms. This study proposes the development of a knowledge-based system that uses fuzzy logic to classify plethysmogram pulses into two categories: valid and artifact. The model correctly classified 82% of the valid segments and 93% of the distorted segments.

The study developed by Guevara et al. [5] proposes a model of real-time movement detection of patients of rehabilitation from hip surgery. The model applies the fuzzy logic technique to identify correct and incorrect movements in the performance of rehabilitation exercises using the motion capture device called Kinect of Xbox One. It proposes an algorithm that works with a multivariable logic model. The diffuse model identifies movements of the patient during the performance of rehabilitation exercises. On the other hand, a 3D avatar is applied, which copies and graphically displays the real-time exercises performed by the patients.

2.1 Data analysis

The information used for the avatar development was obtained from the capture of body points by the Kinect camera of the Xbox One (**Figure 1**). In this study, we gained information of four patients who have gone through hip surgery. This

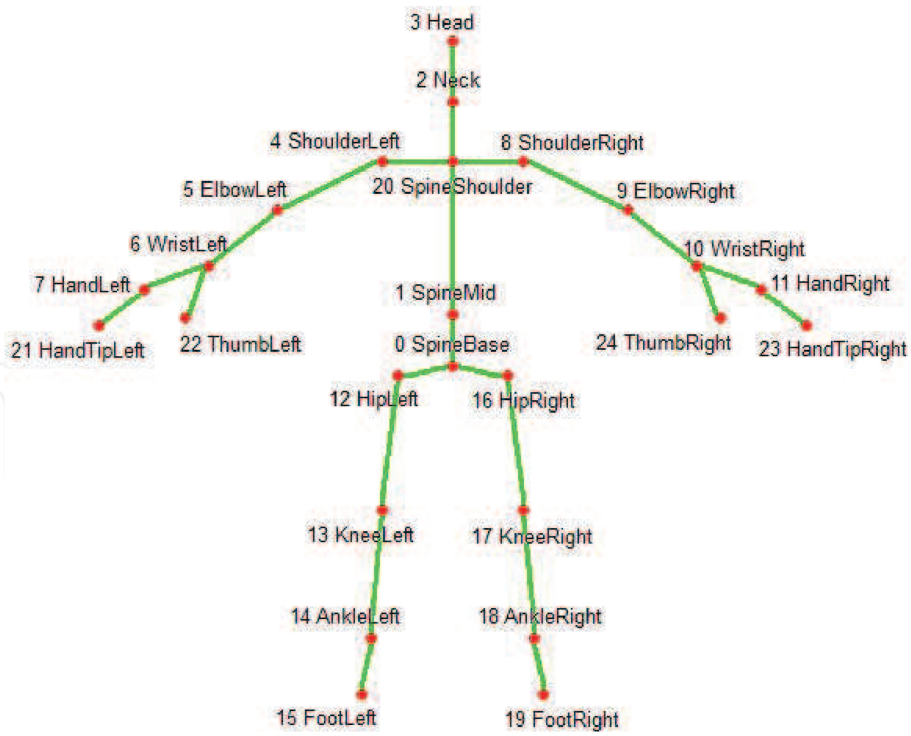

Figure 1.
Body points captured by Microsoft's Kinect [6].

information was collected during 5 weeks of rehabilitation, with high-, medium-, and low-difficulty exercises. Patients performed a set of exercises correctly and incorrectly, which enabled the avatar real movement.

The detected points were 25, the same ones that can identify any movement in three dimensions. For this reason, the database contains 75 attributes. An information preprocessing has been carried out to identify the relevant information, eliminating repeated data as well as noise.

The attribute selection for the algorithm has been identified as 18 essential points of the skeleton detected by the Kinect Xbox One. The specific points are 0y, 6x, 6y, 10x, 10y, 12x, 12y, 13x, 13y, 14x, 14y, 15x, 15y, 16x, 16y, 17x, 17y, and 19x. These points determine the movement in a more detailed way, allowing depth and opening angle detection. The points selected for the front step exercise are those shown in **Figure 2** as well as in the lateral step exercise, as shown in **Figure 3**.

2.2 Proposed model

The proposed model uses the points identified in the previous section. With this information, we will calculate the speed and angle of the limb opening that have performed the rehabilitation exercises correctly. This information is vital to build the diffuse model and to determine the patient's correct posture while performing the exercise (arms, shoulders, and head), as well as the execution speed and the opening angle.

2.3 Limb opening angle calculation

To calculate the angle of the limbs, we identified starting points defined as $B(X_i, Y_i)$ and ending point $C(X_j, Y_j)$. The value of the angle between points B and C is defined as α, as shown in **Figure 4**. In the same way, the execution speed defined as ρ will be calculated.

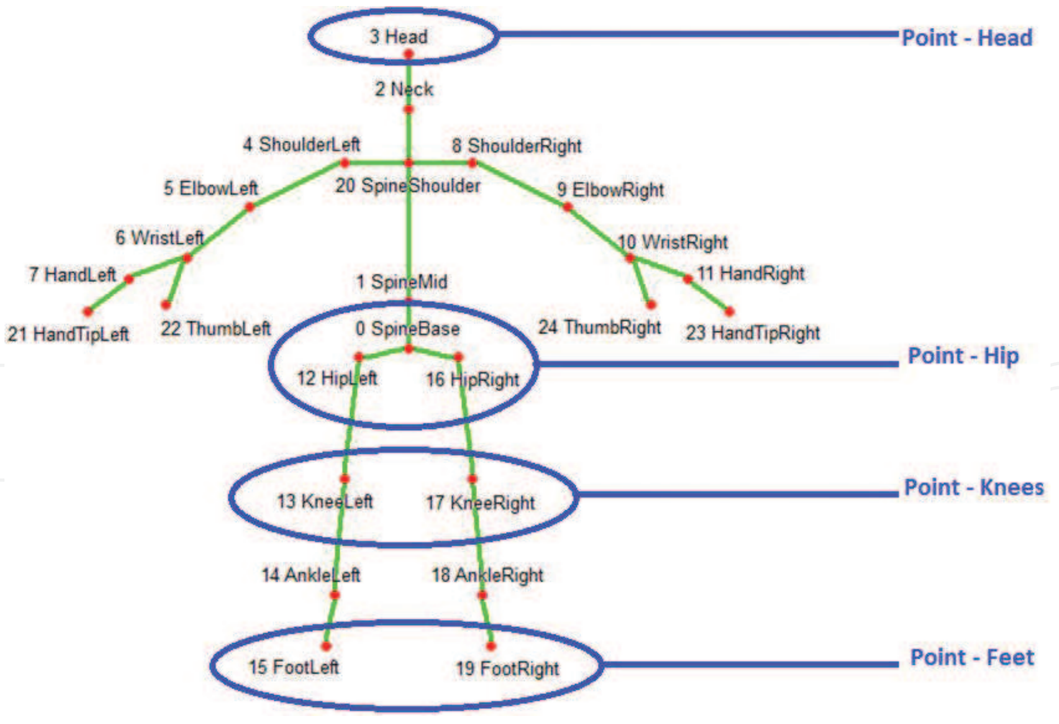

Figure 2.
Selected points for front step exercise.

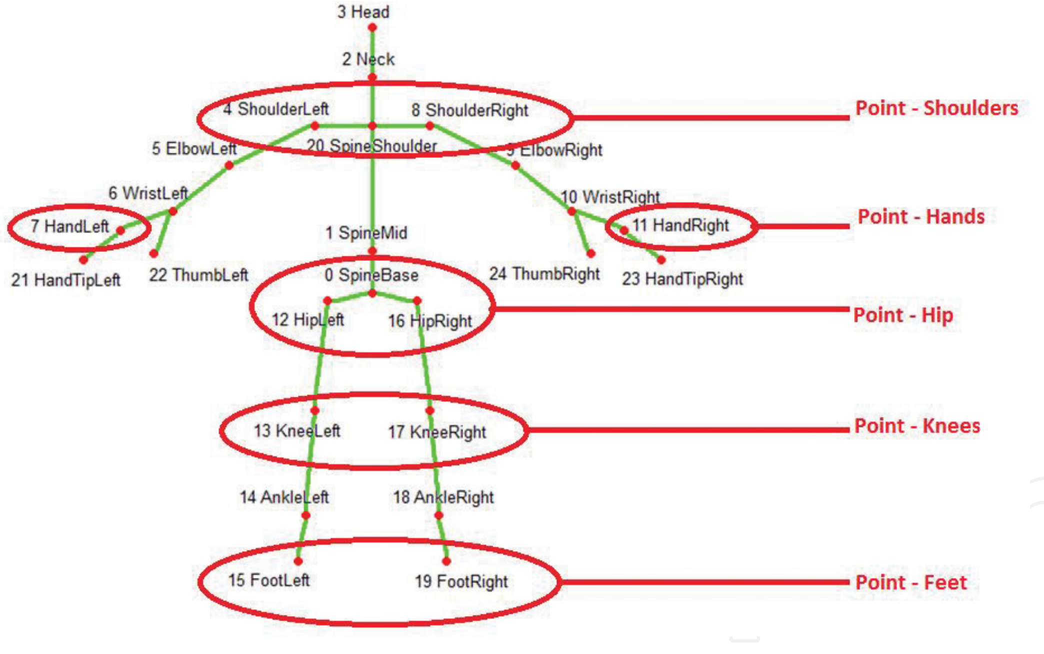

Figure 3.
Selected points for lateral step exercise.

To complete the movement modeling of the limbs, it has been based on **Table 1**, which details when the rehabilitation exercise is performed in a low, correct, or high way.

The diffuse model is based on **Table 1** variables, where the patient's correct movement is obtained while performing each of the rehabilitation exercises. Any exercise that is outside the range identified as "good" will be detected as "poorly executed exercise," where the system will give an alert that the variable is being performed incorrectly. The diffuse model is presented in **Figure 5**.

The following section describes the avatar design and development process in three dimensions using the Blender tool, based on the information captured from

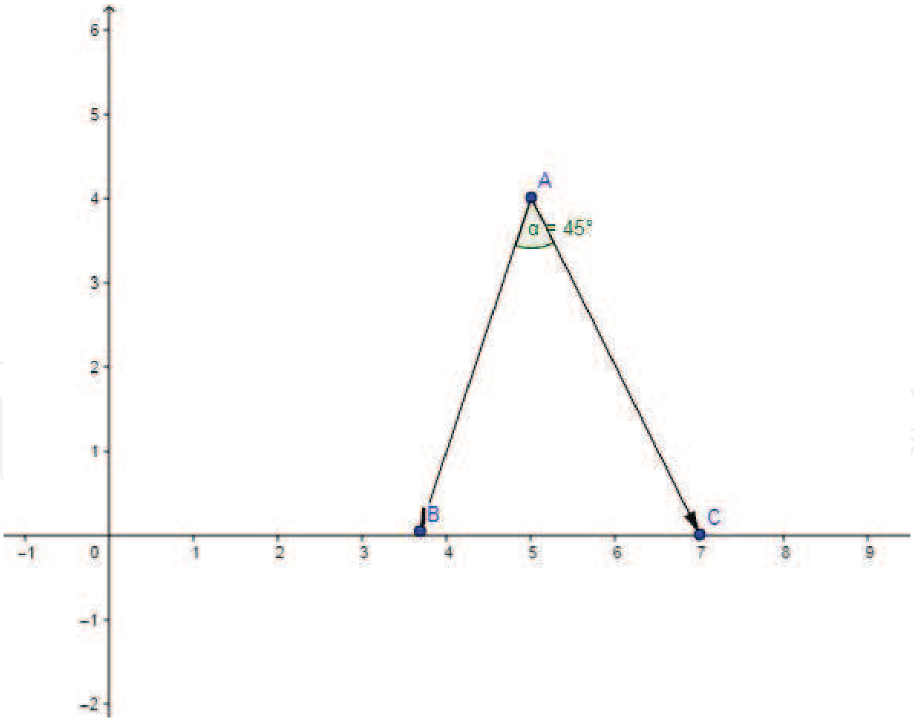

Figure 4.
Limb opening angle calculation.

	Low		Good		High	
	Min	Max	Min	Max	Min	Max
Angle of legs (degrees) α	0	24	25	45	46	90
Hip movement (cm) μ	-	-	0	10	11	20
Shoulder movement (cm) β	-	-	0	10	11	20
Head movements (cm) δ	-	-	0	10	11	20
Execution speed (cm/s) ρ	20	30	10	19	5	9

Table 1.
Rules to determine correct or incorrect movement of rehabilitation exercises.

several patients who performed physiotherapy exercises over a period of 4 weeks. The exercises performed in this data collection phase were lateral step and front step (**Figure 6**).

The following section describes how the patient's avatar was designed. This avatar will imitate the patient's movements during rehabilitation.

2.4 Avatar development

The avatar design is fundamentally based on the skeleton in **Figure 1**, which describes all the points detected by the Kinect. This design was then loaded to Blender and the scale of the header image adjusted, as shown in **Figure 7**.

To generate a three-dimensional avatar was necessary to generate two 3D windows (two windows for the avatar frontal and lateral view), as can be seen in **Figure 8**.

For the avatar design, the work has to be simultaneous with the modeling of two avatars, both doctor (male) and nurse (female). This development has been implemented with all the characteristics of clothing, ethnicity, and age of the employees

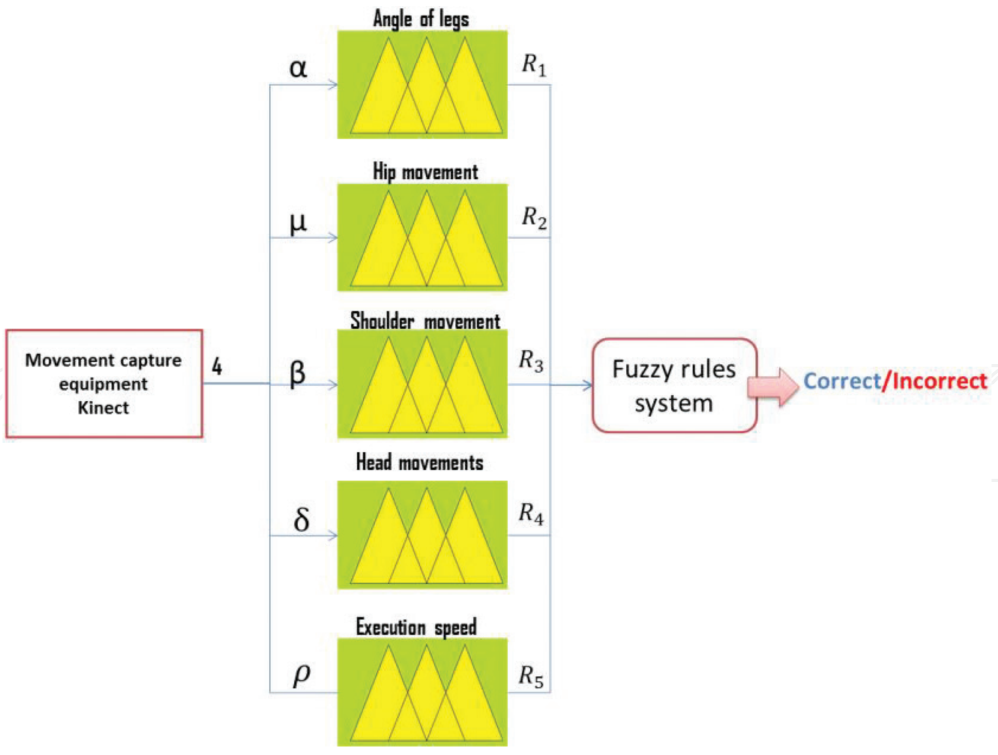

Figure 5.
Diffuse model for exercise detection in telerehabilitation [5].

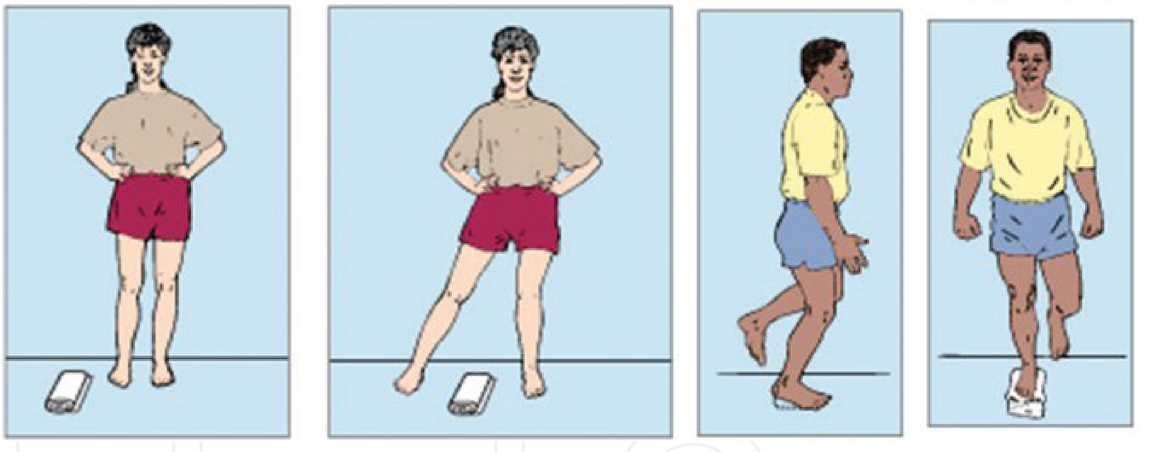

Figure 6.
Exercise images for lateral step and front step.

that work in a health center, as shown in **Figure 9**. Part of the body of the avatar is designed with proportional measures as well as with skin and clothing textures in order to have a real shape and contour avatar.

Finally, we obtained two functional avatars that will imitate the patient's movements in three dimensions. These avatars will be able to move thanks to an interconnected system between the Kinect and a diffuse model of detection of speed, rhythm, and angles of movement of each of the 75 corporal points. This diffuse model is connected to the avatar through Python language and Java for online movement, which results in efficient response time.

2.5 Implementation

The telerehabilitation model implementation was obtained with N-layer development architecture of the intelligent system. As shown in **Figure 10**, the architecture covers layers such as a database, application server, web server, and application.

Figure 7.
Skeleton detected by Kinect uploaded to the Blender tool.

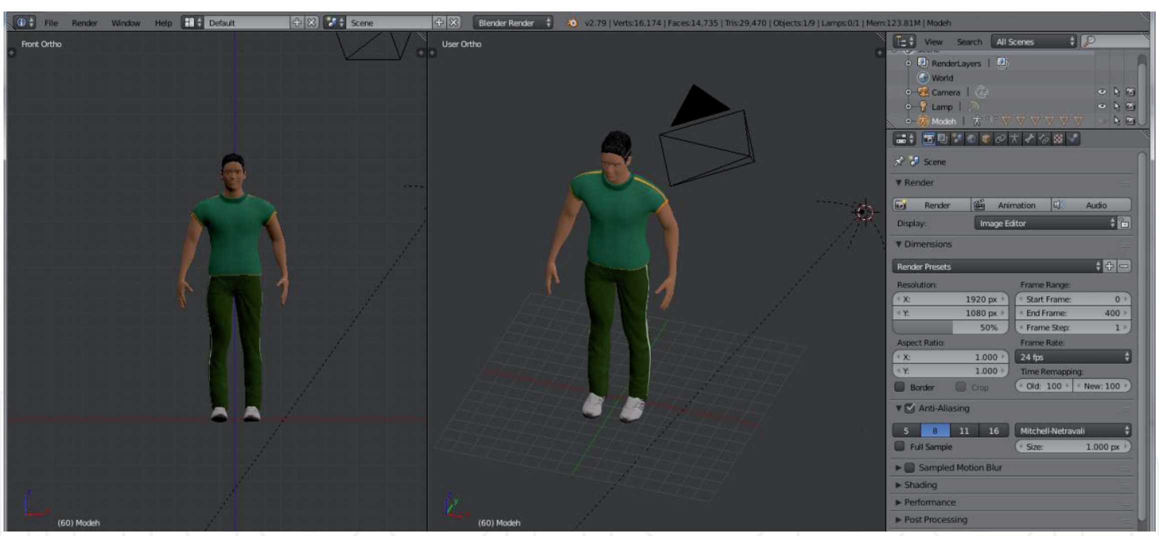

Figure 8.
Front view and side view windows of the doctor avatar.

The database server contains the patient's information (name, age, gender, and medical history). It also contains the data of each of the rehabilitation exercises performed correctly. This allows that during the execution of a movement in the rehabilitation, the system can identify if the patient is doing the exercises correctly or incorrectly. The application server is the one that contains all the programming to register the information in the database, interconnection with devices (Kinect), consumption of complementary applications (avatar in Blender), and system security. The application server's architecture is presented in **Figure 11**. This architecture is service-oriented, due to the fact that many add-ons to the system are not executed in Java.

In the business rules layer is the diffuse model of detection of rehabilitation exercises. The implemented model uses the points captured by the Kinect, to later calculate the angles and maximum and minimum speeds of the limbs, so that the

Figure 9.
Doctor avatar (man) and nurse avatar (woman).

patient can perform a correct rehabilitation exercise. In addition, it detects the optimal distances of movement for complementary points such as the arms, shoulders, and head. To calculate the appropriate angles for each of the exercises was necessary to identify the starting point $B(X_i, Y_i)$, the ending point $C(X_j, Y_j)$, and the value of the angle α of the triangle formed by the trajectory.

The diffuse model shown in **Figure 5** detects the opening angle between the legs, hip movement, shoulder movement, head movement, and the speed at which the exercise was executed. With these variables, it can be efficiently determined in real time if an exercise has been performed correctly or incorrectly [7, 8].

While the patient is performing the exercises, the avatar copies and performs the patient's movements in real time, which makes it easier to graphically identify the exact moment of an incorrect movement. The system's graphical interface developed in Java and hosted in an Apache Tomcat web server allows user's access around the world through an Internet domain.

The web application is deployed by the user's device, which must be connected to the Kinect motion capture device, that allows it to be connected to the system and records the patient's movement in real time. The system requires a bandwidth greater than 2 MB/s Internet access so that the application can perform optimal results.

2.6 Results

The results obtained in this proposal have revealed that the exercise detection rate is 97.42% with a false-positive percentage of 2.58%, as shown in **Table 2**.

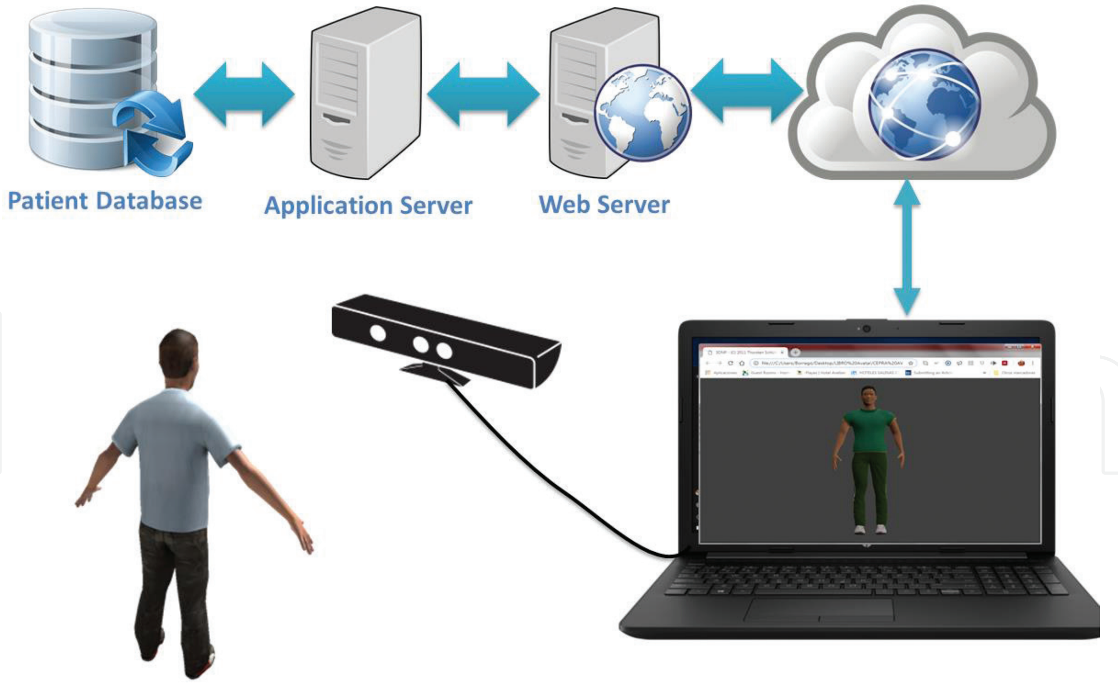

Figure 10.
N-layer architecture of the telerehabilitation platform.

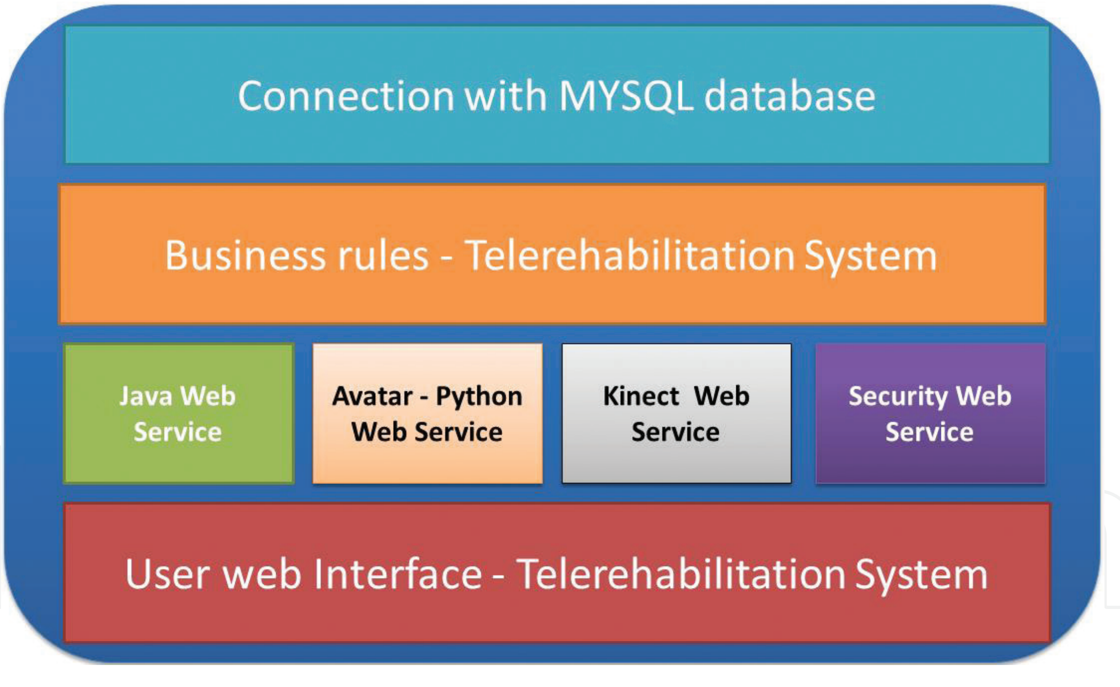

Figure 11.
Telerehabilitation system service-oriented architecture.

	Correctly classified	Incorrectly classified
Well-executed exercise	2100	0
Badly executed exercise	1310	90
Total	**3410**	**90**

Table 2.
Test results in the diffuse model of rehabilitation exercise detection.

In addition, it has been observed in the development of the tests that 18% of the time, the patients perform correctly an exercise with respect to the angle and only 27% do it at an acceptable speed during its execution. On the other hand, the detection time is 0.0045 s while training and 0.002 s in the testing phase.

3. An iterative method to improve the usability of the telerehabilitation system

Usability refers to the degree to which a product can be used to achieve goals in a specific context of use [9]. A software product that has not gone through a process of usability evaluation will not guarantee that users take advantage of the qualities and the benefits of the application. To prevent users from leaving the telerehabilitation platform, it is necessary to carry out exhaustive evaluations of usability.

Several studies have highlighted the main advantages of combining heuristic evaluation and cognitive method for usability assessment [10–13], among them: facility of interaction with the interfaces, immediacy of the response, non-intrusive methods, time or means are not expensive, these tests can be done inside a laboratory, good for the requirements refining, does not involve end users, does not require a fully functional prototype, does not require advance planning, applicable to the stages of design, coding, testing, and implementation of software.

Other studies [12, 14] presented the results of the usability evaluation carried out on the iterative design of the prototypes, obtaining advantages such as facilitating future actions of the end users and improving the learning and development processes. However, the authors said that an online prototype has several drawbacks since it still presents only part of the final version and a limited one in terms of colors and interactive elements. The previous studies do not systematically present the evolution of usability, through an orderly and cyclical process. In addition, these studies do not show that it is possible to improve the use of telerehabilitation platforms without endangering patient safety.

3.1 Experimental design

An experiment was carried out to understand the perceived usability for the ePHoRt platform and to determine a baseline on which to initiate the process of iterative usability improvement of the platform. **Figure 12** shows one on the main interfaces of the platform. The experiment began with 23 participants in an age

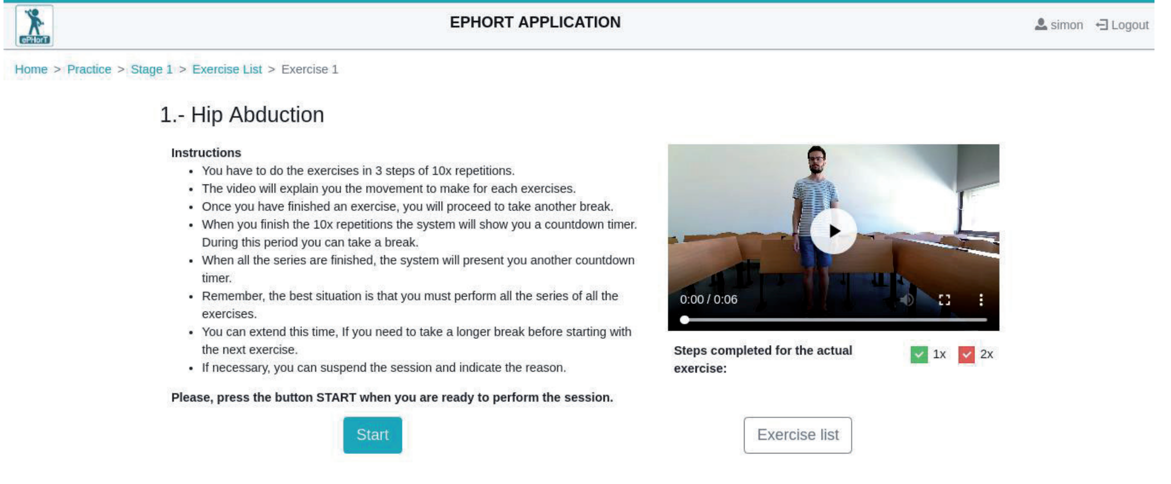

Figure 12.
ePHoRT active exercise interface.

range of 18–24 years old for the first and second iterations, corresponding to the first phase of the experiment. For the second phase, the experiment had 39 participants for the third iteration and 12 participants for the fourth iteration. The age range for these last two iterations was 18–30 years old [15].

3.2 Results

The research results showed improvements in usability through four iterations. Each of the iterations contributed with a list of improvements that were implemented according to the severity level.

In the first iteration, the experts found 39 heuristic violations; these violations were distributed as follows: 12 of high severity, 16 of medium severity, and 11 of low severity. The heuristics with higher incidence and severity were visibility of system status, help and documentation, feedback, and extraordinary users.

In the second iteration, the number of usability problems decreased. However, two atypical cases were presented: (1) increase in the number of usability problems for heuristic "user control and freedom" and heuristic "physical constraint" and (2) the number of usability problems that did not vary for the heuristic "match between the system and the real world" and heuristic "aesthetic and minimalist design."

In the third iteration, 14 mock-ups were designed considering the comments of the previous iterations. In the heuristic evaluation, there were a total of 92 heuristic violations. Experts reported that eight interfaces (57.14%) did not achieve the appropriate feedback for users. Therefore, the platform incurred a clear violation of the heuristic "visibility of system status." In addition, of these eight interfaces, the experts reported the heuristic violation of "help and documentation" on the Login interface and the password reset interface. Finally, experts considered that 42.86% of the interfaces (six) were not flexible or efficient in use.

In the fourth iteration, 17 mock-ups were designed, incorporating the observations from the previous iteration. The experts reported a total of 364 heuristic violations. However, the questionnaire interface had only three low-severity usability problems. This value had been decreasing in severity throughout the evaluation process. The experts assigned greater importance to the following interfaces: questionnaire, acute rehabilitation, active exercise (1/3); acute rehabilitation, active exercise (2/3); acute rehabilitation, active exercise (3/3); and acute rehabilitation, learn (1/5) interfaces.

4. Accessibility of educational resources for the telerehabilitation system

The Web [16] has revolutionized our daily life, becoming the primary source of information, knowledge, consultation, and provision of services and interaction in various areas. Services related to education as well as learning resources are increasing around the world; therefore, it is essential that users, regardless of their disabilities, have accessible learning resources. This study aims to raise awareness of any professional who develops educational applications that apply accessibility standards to generate inclusive and accessible applications. For within the group of possible users, there may be participants with some type of visual disability, such as users with low vision and elderly people. On the other hand, we must emphasize that developing an accessible application does not have to go against an attractive graphical interface, that is, an accessible application does not necessarily have to be "unsightly."

It is convenient to remember that not all visual disabilities are the same and computer management skills also depend on the age of the user, so in the article, these two variables will always be considered. Nowadays, it is necessary to consider the different levels of education, especially for elderly patients and those with disabilities. Therefore, the educational resources of the Tele-habilitation platform must provide instantaneous and ubiquitous access to all types of services and content, including documents and digital resources.

The digital educational resources have become a valuable alternative to support the teaching and learning processes, taking advantage of the possibility of presenting the contents through different multimedia formats. Therefore, it is necessary that educational resources for learning apply accessibility features that allow the interaction of users regardless of their conditions and preferences. This document presents a proposal for the evaluation of the accessibility of multimedia educational resources, where it is suggested to apply the WCAG 2.1 in addition to a series of phases to automatically and manually assess the level of accessibility of the educational resources used in the platform of telerehabilitation of the ePHoRT project.

Accessibility is related to the degree to which people can use or access a service, regardless of their technical, cognitive, or physical abilities [17]. Web accessibility describes methods and theories to make resources, in their multiple forms, more accessible for all people especially for the elderly and people with disabilities. In general, the educational resources of any website or platform must provide universal access, that is, if it includes videos, subtitles must be placed so that the content can be interpreted by people with visual disability or low vision; if people have hearing problems, an audio description should be included, making sure that the resources are inclusive.

The United Nations [18] "Recognizes the importance of access to the physical, social, economic and cultural environment, to health and education and to information and communication, so that persons with disabilities can fully enjoy all human rights and fundamental freedoms."

According to Kurtz et al. [19], the number of people who have undergone surgery for total hip arthroplasty (THA) has increased significantly in the last 10 years, and it is estimated that it will continue to increase.

In line with Ravi et al. [20], THA is a surgery that refers to the replacement of the femoral head and acetabulum of the hip joint. This surgery is usually performed in older adults, due to degenerative joint disease or progressive wear and tear of the joint, and the demographics of patients who decide to undergo THA has become increasingly popular.

In agreement with Salavati et al. [21], the young persons may have higher functional objectives than older persons, which may modify the structuring of rehabilitation protocols. In any of the cases, what is intended after surgery is to calm the pain, restore normal function, and improve the quality of life of people.

In this study, we started with the following question: Are multimedia resources accessible to all users of the telerehabilitation platform?

It is considered an accessible multimedia resource if the content is available to all users, regardless of their disability or application context [22]. It is of vital importance that the educational resources of the platform are accessible even for people who use a screen reader. This research analyzes accessibility problems with multimedia resources, especially those related to video and audio.

According to Rybarczyk et al. [23] in the telerehabilitation platform, learning processes can be oriented in different stages of rehabilitation and include preventive, curative, and maintenance processes.

For the early recovery of the patient on the platform, instructions are included on the general consequences of the procedures and their likely risks, so it is intended to guide the patient through the rehabilitation process at all stages. Proper guidance can help the patient make the right movements to reinforce the safety of functional tasks and motivate the patient to complete the rehabilitation program. Considering that the patient should perform the exercises in a standing position and at a certain distance from the computer, inclusive resources are proposed to guide the patient in the learning process. One of the main elements that have proven to be useful and efficient in education as a means of transmitting and strengthening knowledge is the implementation of multimedia teaching materials, including the use of videos, audios, and PDF files, which constitute an excellent support material. Conforming to Acosta-Vargas et al. [24], the method used to assess access to educational resources consists of identifying the type of resource, reviewing access barriers to the resource according to WCAG 2.1, combining automatic and manual methods to assess the accessibility of resources, recording identified barriers in a spreadsheet, analyzing the results, and finally suggesting possible recommendations.

4.1 Accessibility

Baruch et al. [25] indicate that multimedia accessibility policies propose that "All multimedia elements such as audio or video, produced or published must be accessible at the time of publication." Multimedia accessibility proposes a simple text transcription, so that it is necessary to place a transcript in audio-only recordings, to meet all the success criteria suggested by WCAG 2.1. On the other hand, multimedia resources according to the World Wide Web Consortium (W3C) [26] include texts, images, graphics, animations, video, and sound to present or communicate specific information. Consequently, to cover all the parameters that intervene in the accessibility of educational resources, it is necessary to evaluate a set of dependent components such as human factors, in this case all the users of the telerehabilitation platform are considered, including users with special needs, technological factors to provide accessibility, and user interaction with the device in the environment of the platform, which include criteria to favor accessibility with the indicated components. ISO/IEC 40500: 2012 [27] is equivalent to the Web Content Accessibility Guidelines 2.0 (WCAG 2.0), is related to the Web Content Accessibility Guidelines 2.1 (WCAG 2.1) which consists of 4 principles, 13 guidelines, and 76 compliance criteria (success), plus an undetermined number of sufficient techniques and counseling techniques.

The four principles are the same as those contained in WCAG 2.0:

- Principle 1—Perceptibility: information and user interface components should be presented to users in the way they can be perceived. It has 4 guidelines and 29 compliance criteria.

- Principle 2—Operability: the user interface and the navigation components must be operable. It has 5 guidelines and 29 compliance criteria.

- Principle 3—Comprehensibility: the information and management of the user interface must be understandable. It has 3 guidelines and 17 compliance criteria.

- Principle 4—Robustness: the content must be robust enough to be based on its interpretation by a wide variety of user agents, including assistive technologies. It has one guideline and three compliance criteria.

4.2 Method

In March 2012, Web Accessibility Initiative (WAI) published the Methodology of Website Accessibility Conformance Evaluation Methodology (WCAG-EM) 1.0. In 2014, a new version was published [28]. The WCAG-EM methodology allows

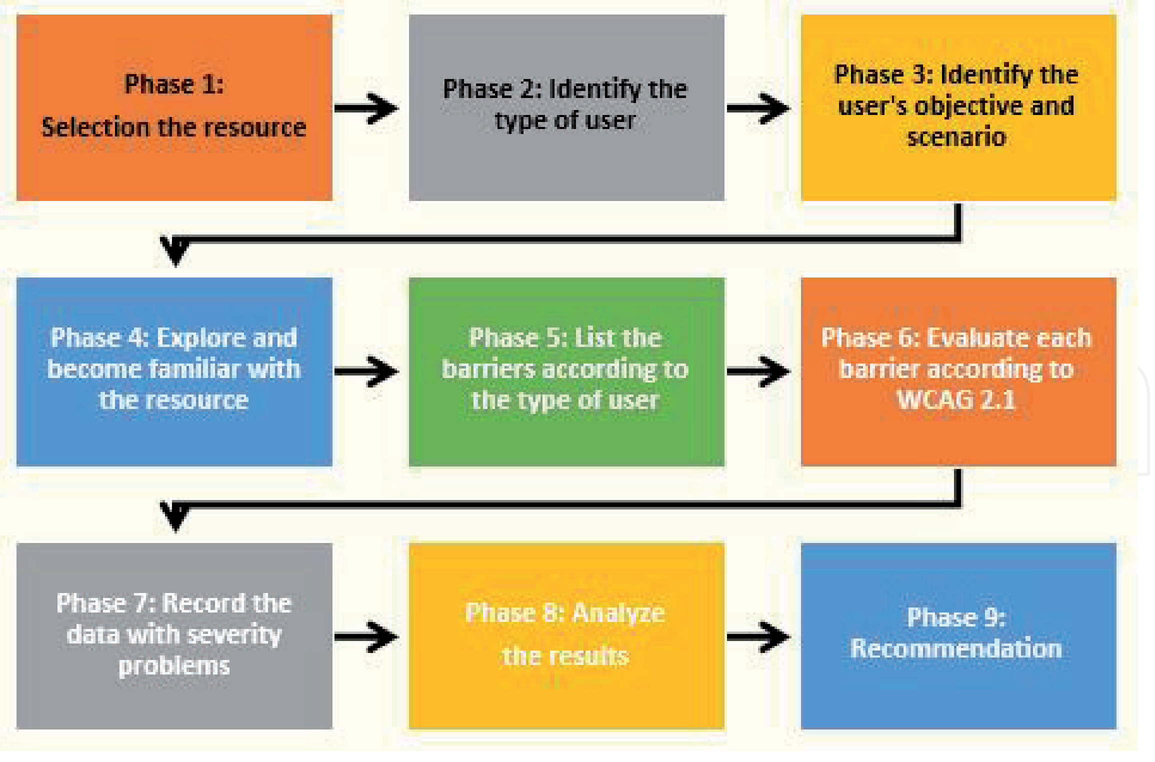

Figure 13.
Evaluation of multimedia resources.

determining if the contents of the websites are evaluated to comply with the WCAG 2.1 accessibility guidelines or not. In this research the WCAG-EM 1.0 was applied. In this case, it was used to apply the evaluation of multimedia resources specifically to the videos. It consists of five sequential phases, as shown in **Figure 13**.

Phase 1: Selection of the resource. In this phase, the educational resource to be evaluated is selected. For this study, the video located on the telerehabilitation platform was selected. **Figure 14** shows a screenshot; it is observed that the patient performs rehabilitation exercises. It should be noted that this resource is part of the patient education section and the educational resources will be hosted on the platform located at http://telerehabilitation.udla.edu.ec/learning/resource/2/media/1.

Phase 2: Identify the type of user. In this phase, the type of users is defined; for our case we will focus on older people who have age-related disabilities [29]; this may affect the way they use the web, like first, the reduction of the vision that includes a sensitivity reduced to the contrast, the perception of the color, and the near approach. This makes difficult the reading of the web pages. Second is the reduction of physical capacity including dexterity. This makes it difficult to use the mouse and click on small targets. Third is the difficulty of listening, including the difficulty to hear sharp sounds and separate sounds. This makes it difficult to listen to podcasts and other audio, especially when there is background music. Fourth, cognitive ability includes short-term memory reduction, difficulty concentrating, and being easily distracted, which makes it difficult to track browsing and online tasks. These problems are related to the accessibility needs of people with disabilities. Therefore, websites, applications, and tools that are accessible to people with disabilities are also more accessible to older users.

Phase 3: Identify the user's real scenario. In this phase, it is determined what the patient wants to learn in the telerehabilitation platform so that the educational resource adequately explains the process so that the patient learns and reinforces his learning.

Phase 4: Explore and become familiar with the resource. In this phase, we review the resource format for our case study and review the video format, size, and

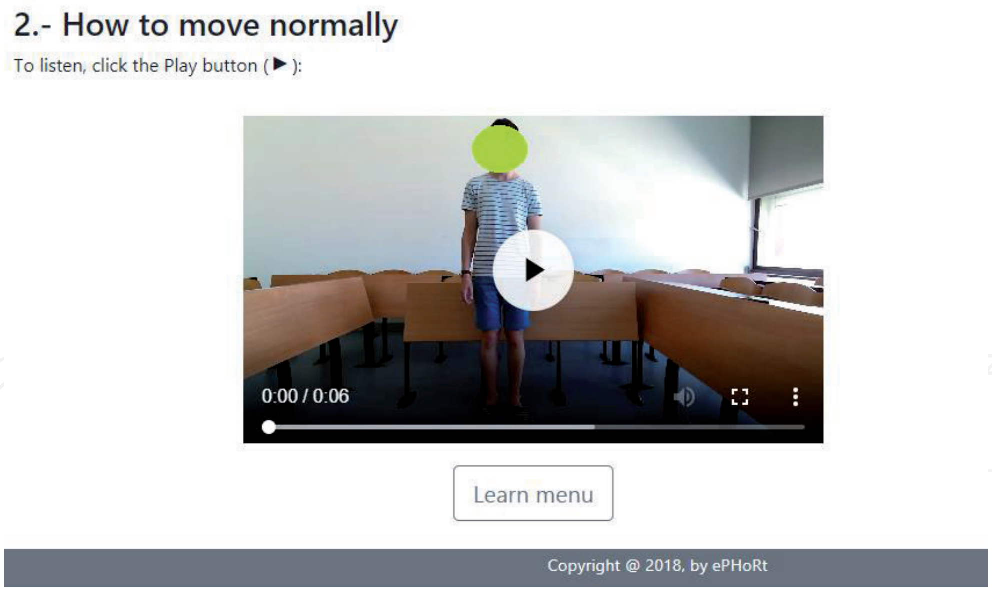

Figure 14.
Screenshot of the resource to evaluate.

duration. This information is relevant to review with the Photosensitive Epilepsy Analysis Tool[1] (PEAT) [30] of the University of Wisconsin Trace Center. It is required that the video is in Audio Video Interleave (AVI) format.

Table 3 records the results obtained in the evaluation with PEAT. It contains the video identifier, length of material, luminance flash failures, red flash failures, extended flash warnings, result status, and percentage.

Phase 5: List the barriers according to the type of user. In this phase, the possible barriers that the user can find in the resource are established, such as the keyboard compatibility, the colors with good contrast, the design and bright design, the text of voice, extensive links, buttons and controls, video descriptions, customizable text, speech recognition, understandable content, notifications and comments, and selection to different language types. That relates to the WCAG 2.1 success criteria detailed in **Table 4**.

Phase 6: Evaluate each barrier according to WCAG 2.1. In this phase, the criteria of success are evaluated manually according to WCAG 2.1. About the principle of perceptible [31], the Guideline 1.2 related to time-based media. According to the criterion of success 1.2.1, either only audio or only prerecorded video (Level A), it is necessary to provide an alternative that describes the content of the prerecorded video, for example, placing an audio track. Criteria of success 1.2.2 subtitles

URL	Description	Standard	Success criterion	Fr	Lm	Rs	Lff	Rff	Efw
http://telerehabilitation.udla.edu.ec/learning/resource/2/media/1	Patient in the process of learning exercises on the telerehabilitation platform	WCAG 2.1	2.3	25	00:06.19	P	0	0	0

Fr = frame rate, Lm = length of material, Rs = result status, Lff = luminance flash failures, Rff = red flash failures, Efw = extended flash warnings, P = passed

Table 3.
Evaluation with the photosensitive epilepsy analysis tool.

[1] http://trace.umd.edu/peat

Success criterion	Level	Comply
1.2.1 Audio-only and video-only (prerecorded)	A	1
1.2.2 Captions (prerecorded)	A	0
1.2.3 Audio description or media alternative (prerecorded)	A	0
1.2.4 Captions (live)	AA	0
1.2.5 Audio description (prerecorded)	AA	0
1.2.6 Sign language (prerecorded)	AAA	0
1.2.7 Extended audio description (prerecorded)	AAA	0
1.2.8 Media alternative (prerecorded)	AAA	0
1.2.9 Audio-only (live)	AAA	0

Table 4.
Manual evaluation of the video resource.

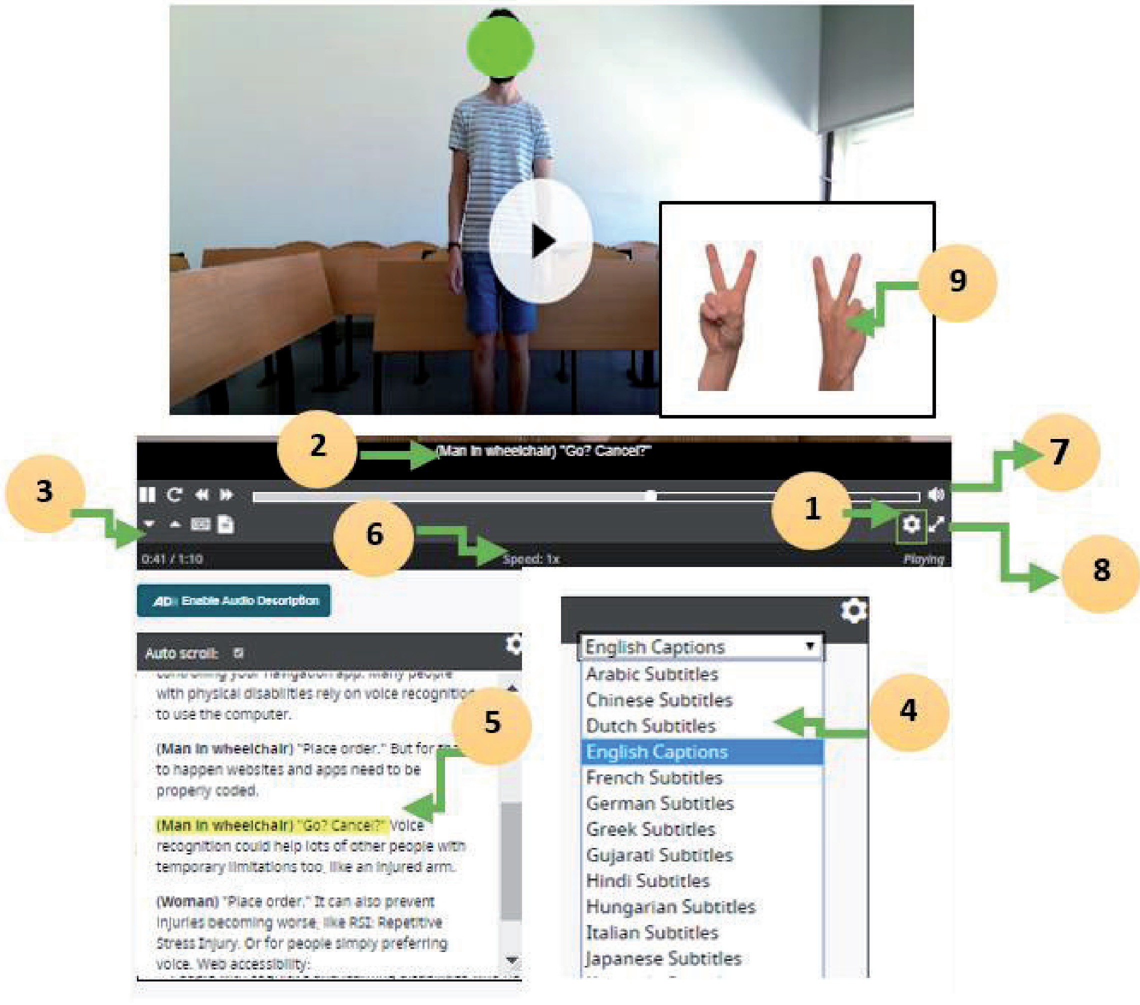

Figure 15.
Recommendations for the creation of accessible videos.

(Level A) are as follows: subtitles are provided for all prerecorded audio content in synchronized media, except when the media are an alternative media for text and are clearly labeled as such. The criterion of success 1.2.3 related to the description of audio or alternative of prerecorded media (Level A). It suggests that an alternative is provided for synchronized media, except when the medium is a multimedia alternative to the text and is clearly labeled as such. Success criteria 1.2.4 subtitles (live) (Level AA) are as follows: subtitles are provided for all live audio content in synchronized media. Success criterion 1.2.5, which refers to the description of prerecorded audio (Level AA), provides audio description for all prerecorded video content in synchronized media. Success criterion 1.2.6 sign language (level AAA) provides sign language interpretation for all prerecorded audio content in synchronized media. Success criterion 1.2.7 related to having an extended audio description for all prerecorded video content (Level AAA) to use when the foreground audio is insufficient to convey the meaning of the video. Success criterion 1.2.8 on the prerecorded media alternative (Level AAA) provides an alternative for time-based media for all prerecorded synchronized media and for all prerecorded video media only. Finally, success criterion 1.2.9 audio only (Level AAA) provides an alternative for time-based media that presents equivalent information for live audio-only content on media only. **Table 2** shows the data of the manually evaluated video resource. It contains the success criterion of WCAG 2.1 of the perceptible principle, level, and compliance that indicate whether it meets the success criteria, where 1 indicates that it meets and 0 indicates that it does not comply.

Phase 7: Record the data with severity problems. In this phase, the results are recorded in a spreadsheet; in this case, Microsoft Excel was used. The data record and the analysis of the results to replicate the research are available in the Mendeley dataset.[2]

Phase 8: Analyze the results. In this phase, the authors used Microsoft Excel statistical graphs. The dispersion graph was applied with the trend line to analyze the value of R between the success criteria and compliance with the WCAG 2.1.

Phase 9: Recommendation. In this phase, some recommendations are suggested so that the video resource is accessible and inclusive, according to WCAG 2.1. In **Figure 15** according to the numbering, it is described what it should contain in each element so that the video resource is more inclusive and accessible. See details below:

1. Preferences. In this option, it should allow the configuration of subtitles, descriptions, keyboard, and transcription.

2. Show the subtitle settings. In this case, it should include the options to configure according to the preference of users such as position, font, font size, text color, background, and opacity.

3. Video speed, subtitles, and audio in the application. The user should have the option to customize the speed of the video, subtitles, and audio according to the user's preference and disability.

4. Language. In this option, the user could customize and choose the language for the audio description and subtitles. This option should allow moving the window to the position you want the user to.

5. Audio description preferences. In this option, the media player must allow the configuration of the audio description format in several ways so that it is displayed in the highlighted form of the color the user wishes while the video is presented. In addition, it is vital to include the option of automatic video pause and the option to make the description visible. On the other hand, it is essential to include keyboard preferences using keyboard shortcuts. This option should allow moving the window to the position you want the user to.

[2] http://dx.doi.org/10.17632/tjf47zxmv2.1

6. Visualize the speed of the video. In this option, the user can visualize the speed in the video according to the configured speed.

7. Volume. In this option, the user can configure the volume of the audio.

8. Screen. In this option, the user can view the video in full screen.

9. Sign language. In this option, you can include a screen with a description of it in sign language.

5. Results

In the evaluation of the accessibility of an educational resource, it is vital to combine the automatic tools with manual evaluation. In this case, for the video, a resource is not yet known as an automatic tool that performs the evaluation at 100%. In the automatic evaluation, the tool PEAT was applied, which helps to identify the luminance flaw faults, the red flashing faults, and the extended flashing warnings that would affect users with epilepsy. According to the PEAT report, it is observed that it overcomes the problem.

The evaluation was complemented with a manual analysis when considering the possible barriers for the users of the telerehabilitation platform. The results are detailed in **Table 4**.

In **Figure 16**, it is observed that the video does not comply with the WCAG 2.1 guidelines, that is, it is not inclusive. When applying the correlation between the success criteria and compliance, the coefficient is −0.5. This implies that the correlation is negative and moderate. Failures are related to the absence to configure user preferences by including keyboard compatibility, colors with good contrast, bright design, text to speech, links, buttons and controls, video subtitles, customizable text, speech recognition, understandable content, notifications, and comments.

The results of this study show that the multimedia resource evaluated did not reach an acceptable level of accessibility. Therefore, it is necessary to correct the

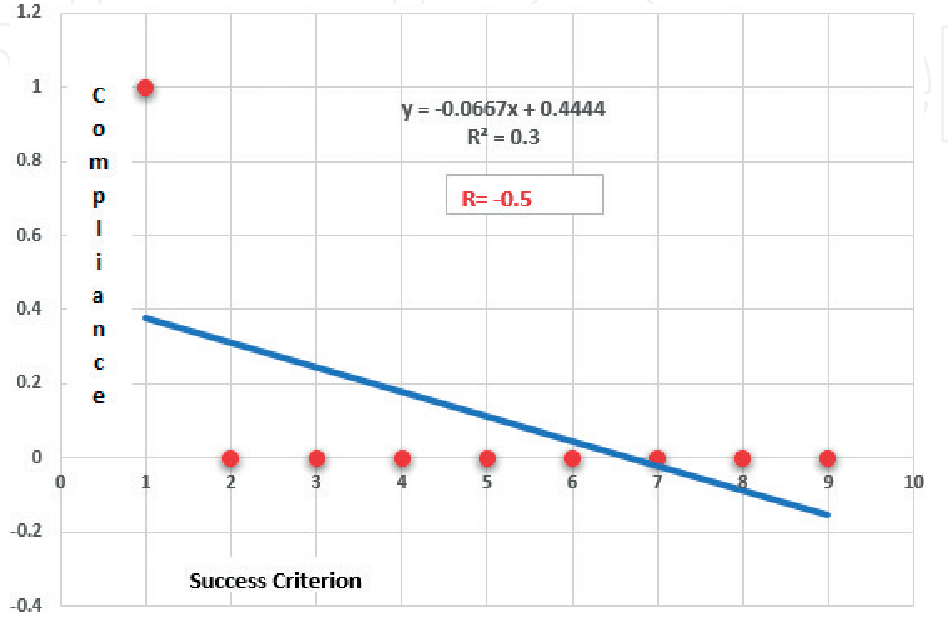

Figure 16.
Analysis of success criteria vs. compliance.

faults to comply with the level of accessibility recommended by the W3C. It is necessary to include accessibility measures in the development of educational materials through the application of a checklist to correct the problems identified. The results obtained in the evaluation can serve as a starting point to implement future video resources considering WCAG 2.1.

The recommendations suggested in phase 9 can provide ideas on how to develop and create educational videos to make them more accessible and inclusive. This research can serve as base information for future projects with a more significant number of educational resources. Future research may propose new methods to evaluate multimedia resources. With respect to the videos and sound recordings, in both cases, a transcription of the dialogues, a description of the sounds, and control of the reproduction speed must be provided. However, the inappropriate use of multimedia elements may cause a barrier to user access.

6. Conclusions

The application of the fuzzy logic technique in a telerehabilitation platform allowed identifying correct and incorrect movements in the execution of rehabilitation exercises of patients after hip surgery. The main contributions of the proposed fuzzy detection algorithm are flexibility, tolerance with inaccuracy, and the ability to identify features that best predict different points of movement.

The design of avatars allowed the digital representations of the patient's movements captured with Microsoft's Kinect. The main contributions are to monitor exercises in real time, to identify the recovery progress of patients, to provide medical information to physiotherapeutic, and to facilitate an engaging experience for patients.

The limitation that we found in the implemented model is that it was very useful for exercises that are performed standing; however there are exercises that the patient performs lying down, in which Kinect was not able to capture patient's movements, and it is recommended for future work to use other type of sensors.

The web application of a diffuse 3D model for the detection of rehabilitation exercises after a hip surgery is systematically related to the usability and accessibility of the telerehabilitation system in search of achieving inclusive websites that display correctly on any device.

The method applied in improving the usability and accessibility of educational resources for the telerehabilitation system is very important since access to the Internet is a growing trend. This project addressed the importance of applying the principles specified in WCAG 2.1 to develop accessible resources. The development and execution of this project can serve as a starting point to develop targeted strategies to raise awareness about the importance of the stages of design of a website or educational resources, where the accessibility guidelines and criteria must be applied in order to achieve equal access to information for all people.

Finally, the system has limitations since it is not possible to guarantee for a web page or educational resource to be accessible for all types of users with disabilities or to comply with all accessibility standards.

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