Motor Rehabilitation and Biotelemetry Data Acquisition with Kinect

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Abstract: Accessibility and inclusiveness of people with disabilities is a recurring theme that is already perceived as an issue in the field of human rights. Ramps, elevators, among other devices aim at the inclusion of these individuals with limited mobility. Various types of motor limitations, specially partial limitations, are linked to corresponding physical-motor rehabilitation process, with the purpose of reducing or eliminating the patient's dependence on a caregiver or devices for adaptation. Patients with motor disabilities must practice physiotherapeutical exercises along a physician in order to perform body and muscle analysis to ensure the patient's well-being. To reach a more accurate analysis, physiotherapists use a range of devices to acquire patient data, such as the spirometer, to acquire the patient's breath intensity and lung capacity. Similarly, there are other technologies capable of acquiring motion data and quantifying them. This work aims to develop a system that, paired together with an exercise game project (exergame), can acquire and transmit the motion data acquired in-game for an easier and faster analysis of the patient's growth, relying on graphs, tables, and other visual indicators to improve the evaluation of physiotherapeutic treatments. The usage together with an exergame also has benefits such as increased patient compliance with the treatment and improvements in well-being.

1 INTRODUCTION

Present as one of the strongest entertainment industries(Cummings, 2007), videogames have evolved over the decades in many forms since its first appearance in 1958 with *Tennis for Two*. Many of its improvements are reflected in the way the player is able to input commands in order to play the game, ranging from simple button presses to the usage of complex technology. In order to innovate and gain their consumer's attention to buy their game consoles, some companies invest in the way the player is able to interact with the game and input these commands. One of the most known and successful examples is Nintendo's Wii, which used motion capture technology as a form of controlling the game.

Motion capture technologies are not limited only for entertainment purposes, however. For example, the Wii was used for physiotherapeutic rehabilitation in Parkinson's disease patients, where it was relevant to the treatment as a supplementary activity, named Wii-hab(Herz et al., 2013).

Interfaces that have human-computer interactions that involve human motion, such as Nintendo Wii©controllers, are known as Natural User Interface (NUI). Another strong example of NUI usage is the *Kinect*©, which uses only sensors to acquire data and does not require any controller in the player's hand, unlike the previous case. That's why it has become a revolutionary (Martin-SanJose et al., 2017) device for the video game industry. Like the Nintendo Wii and other NUI devices, Kinect has also been widely used for therapeutic purposes (Szykman

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et al., 2015)(Da Gama et al., 2015)(Dehkordi et al., 2018), where it has gained notoriety in projects involving stroke patients (Robertson et al., 2013)(Hsieh et al., 2014)(Dukes et al., 2013), cerebral palsy, Parkinson's disease, people with cognitive disabilities (Nazirzadeh et al., 2017), among other conditions that limit physical movement.

2 JUSTIFICATION

There are about 46 million individuals in the Brazilian territory. About 24% of the population claim to have some form of disability, which may cause difficulties in performing many essential tasks of daily life. Approximately 7% of the population declares to have some motor disability that indeed causes difficulties in this type of tasks. Keeping that data in mind and the various diseases and illnesses that lead to these disabilities, it is possible to observe in many situations that the systems designed to promote accessibility to persons with disabilities are neglected and often inoperative when they exist.

Research for motor disability treatment and rehabilitation commonly comes across a problem: An applied solution to one condition does not necessarily work for another, even if similar. There is even the possibility that solutions that could be successfully applied to one patient may not serve another with the same limitation. This could be due to different factors such as the disease itself, the severity of each case, and the area of the body affected. Thus, meeting this demand for solutions for each case can become an arduous and laborious task.

The benefits of physical therapy treatment for patients are many: (Costa et al., 2005) mentions, for example, that an individual's ability to stand up from a wheelchair decreases their dependence on a caregiver and reduces or eliminates problems deriving from the condition, such as blood clots, muscle atrophy, bladder and urinary tract infection, and osteoporosis. More benefits are also seen in the psychological part, with an improvement in the patient's self-esteem, family and social relationship, directly reflects on treatment.

3 TECHNOLOGY AND VIDEOGAMES IN MOTOR REHABILITATION

The employability of video games for physiotherapeutic purposes is commonly researched in the academic field through the gamification of activities used in the treatments. According to (Hamari et al., 2014), gamification can be defined as a process that aims to improve a service through motivational gains, creating game-like experiences. For the treatment of a patient, a variety of technologies can be employed, aside from commercial video game consoles aimed at home use and commonly for entertainment purposes. Since rehabilitation activities and exercises aim to stimulate patient movement, the technologies employed are usually reactive to the user's movement or action, such as the use of pressure sensors and sensors that calculate the individual's breathing strength in lung exercises. NUI tools are included in this range of applied technologies. They ensure user interaction with the computer, which responds appropriately.

Game-creating software tools known as Game Engines provide the ability for people or groups to create their own custom games. In combination with NUI tools such as Kinect, this makes it possible to create solutions that address both the treatment of people with disabilities and the accessibility of players with motor disabilities when using these devices. A great example is Kinect Wheels(Gerling et al., 2013), which used the C# library provided by the manufacturer, Microsoft, to create gestures so that wheelchair users can replace movements they can't do.

4 BIOTELEMETRY AND DATA ACQUISITION

One aspect that can be explored for understanding a patient's situation regarding their treatment is data acquisition. The act of acquiring measurements and data at a distance is known as **Telemetry** (Cooke et al., 2004). In turn, **Biotelemetry** represents the use of this data acquisition within biology, medicine, and health to acquire patient data such as vital signs (Kim and Cho, 2001). An example of using biotelemetry is to acquire and store a person's heart rate, possibly giving an alert when there is an abnormality.

(Cooke et al., 2004), in a paper analyzing biotelemetry as a research tool for animals and ecosystems, saw immense potential for researchers. In humans, biotelemetry can be used as a means of monitoring rehabilitation patients, like acquiring a patient's heart rate while performing a rehabilitation exercise(Kim and Cho, 2001). It can also be used to check any abnormalities in an elderly person's body in case of emergency at home(Penhaker et al., 2007).

The data acquisition that biotelemetry provides can be useful as an auxiliary tool in motor rehabilitation exercises. Acquiring numerical data during treat-

ment helps to measure, for example, treatment effectiveness over time by comparing treatment initiation data and the most recent data.

A project currently under development (Antonio Valente, 2019) uses the Unreal Engine 4 game engine to create a Kinect application that seeks to save and display the time a patient takes to touch an object when prompted. The intention of the project is to analyze and provide data on the movement of a patient with motor disabilities, as well as allowing the customization of the exercises as the physiotherapist needs.

By analyzing the time it takes for a patient to perform a simple task, such as grasping an object in front of him, it is possible to infer from real data the performance and effectiveness of the treatment. In the physiotherapeutic environment, the method used for measurements and evaluations are dynamic, where professionals make judgments according to observed data and their experience (Gil, 2015). By receiving the patient's data via biotelemetry, it is possible to obtain a more accurate and less empirical treatment analysis, avoiding interpretation problems if, for example, the physical therapist responsible for a patient is changed. In the event of a change, the report left by the previous manager may be interpreted differently from the intentional one by the new physical therapist. Given this, a system for managing this data can prove to be a useful tool to remedy these and other problems.

An online system enables quick and convenient analysis of treatment data from anywhere, whether by the physiotherapist or the patient himself. Depending on the types of data that are obtained during the session, they can be updated immediately after the session ends for consultation. If the data is more complex or needs longer treatment, the patient can be informed and access the results online at home.

5 TIME-OF-FLIGHT CAMERAS

In order for data to be acquired from a patient's body, a sensor must be employed depending on the type of data sought. For example, to obtain a patient's heart rate data, an electrode is placed to receive the signal. Similarly, to acquire data from a person practicing physical therapy exercises it is necessary that a sensor that obtains the individual's movements be connected to obtain the movements for the computer.

The motion capture process, also known as MoCap is performed, according to Vital et al.(Vital et al., 2017), acquiring the body segments' acceleration, velocity, time and position of an individual. This data can be measured using specialized sensors that can acquire them in different ways depending on the technology employed. In her work is also shown the different methods and apparatus for the acquisition of this data, as well as their advantages and disadvantages.

Time-of-flight cameras are optical devices that have the ability to detect their surroundings by calculating the time light takes to reach an object and return (Mutto et al., 2012). An example of using this technology is the later version of Kinect™ (Kinect V2), also mainly used in the digital gaming business. Unlike depth cameras, they offer 3D images at a good frame rate per second (also called FPS), also bringing a depth gauge for each pixel of the scenario (Vital, 2015). Although intended to be used as a form of control for digital games, it is a tool that produces, even in its first version, acceptable results, but inferior to a *Vicon*™ passive marker system, for example(Dutta, 2012).

Their advantages and disadvantages(Vital, 2015) are:
Advantages: Depth at each pixel with high framerate; light weight; small and compact design; self lighting; and reduced power consumption. **Disadvantages:** Susceptibility to illumination; Multiple reflections - ToF cameras illuminate an entire scene; and interference. That means that if multiple ToF cameras are running at the same time, they may disturb each other's measurements, depending on multiplexing time and modulation frequencies.

With its approximate price of $200, it is greatly advantageous compared to other tools available on the market.(Steward et al., 2015).

How to choose which equipment to use is a critical topic that underpins the development of a motor rehabilitation solution for patients. To achieve good results, you should consider the following aspects of the tool: *Price; Data capture quality; Market accessibility; and value in money.*

Comparing the tools currently available to each other is essential to understanding each one's strengths and weaknesses. This comparison procedure is called *Benchmarking*.

Vital et al.(Vital, 2015) for example, benchmarks the main aspects of the tools available in the market, comparing with the proposed solution in her work: the FatoXtract™.

Using the data raised by Vital et al.(Vital, 2015) and through analysis of the results of the review articles presented by Da Gama et al.(Da Gama et al., 2015), Szykman et al.(Szykman et al., 2015), and Dekhordi et al.(Dehkordi et al., 2018), it is noticed that the Kinect is able to detect and replicate user

movements in a portable way, achieving good results, and costing less than 10% of the value of the other high-end tools.

Between the Kinect V1 and V2 cameras, which have a low price difference, the most reliable and recent one is the Kinect V2 for Xbox One™, using time-of-flight technology to map the body and ensuring better performance. The responsible company (Microsoft) offers a developer tools package, also known as Software Development Kit (SDK), allowing the tool not only to be used for MoCap, but for anything the developer may need to create an application.

About the accuracy of the data acquired, Dutta(Dutta, 2012) reports that Kinect V2 has acceptable accuracy, but less than that of a Vicon system by at least one degree of magnitude. It also reports that some may choose to sacrifice some accuracy in exchange for portability. Another point to note is the availability of Kinect, which can be purchased *online* or in physical stores with little effort and few inventory or delivery issues.

6 OBJECTIVES

6.1 General Objectives

Seeking a better quality of life for people with physical disabilities, this work seeks to create a tool that demonstrates the acquisition of data from patients undergoing motor rehabilitation. The purpose of this project is also to help standardize the evaluation of acquired data and give both patient and physiotherapist support and convenience in accessing this data.

6.2 Specific Objectives

This work aims to produce a software using the Django platform and its libraries to program in Python language an API (Application programming interface) that will perform data acquisition, storage and request operations using the Django REST Framework library. Along with the API, an application, also in the same Django project, must be created as an interface for navigating its users who wish to view the data.

Data acquisition should be done through a pre-existing application(Antonio Valente, 2019) made using Unreal Engine 4.20 integrated with Kinect V2 and its computer adapter. This application is responsible for acquiring patient movement data and communicating with the Django API via the VaREST plugin for requesting, packaging, and sending data in JSON format.

7 THEORETICAL BASIS

Several researchers have conducted studies in the area of motion capture. Many use motion capture tools for healthcare applications, and others research their use to automate processes with gesture recognition.

Despite being a fairly recent technology, many applications and research have already been done achieving great results. The result of these researches were works that generated important data for the creation of this article.

The increasing use of motion capture technology, as previously mentioned, has grown significantly since its first appearances and public availability, especially in healthcare and medicine. With this growth, a review article is necessary for a better follow-up of these results obtained in the academic and scientific community. Szykman(Szykman et al., 2015), Dehkordi(Dehkordi et al., 2018), and Da Gama(Da Gama et al., 2015) conducted research including the use of Kinect for physical therapy rehabilitation, including patients with autism, cerebral palsy, multiple sclerosis, and stroke, among other conditions.

Dehkordi et al.(Dehkordi et al., 2018) explore the use of applications with Kinect, demonstrating in some of the results the successful use of the tool with patients with autism, children with psychological or emotional disorders and their monitoring. Most studies included in the research refer to stimulating physical movements and motor skills, some relying on some kind of gesture recognition for functioning.

Dehkordi et al. points out that the research and its implementation are partly employed in the school environment or at home, but according to the results obtained, the use of the Kinect system can also be applied in many other environments, including hospitals and clinics, where new applications are being developed and tested.

However, some limitations on Kinect were discovered during the analysis:

- Limitation on movement capture of participants due to lack of space;
- The height of adult participants and objects between player and researcher or Kinect does not allow the system to correctly detect participant movement;
- Kinect Systems Unable to Support Multiple Disabled Participants

- The Kinect sensor must be fixed in one place, and has a range of around ten meters, meaning that the movement should occur only in front of the sensors.

In addition, the study proves a beneficial relationship between Kinect systems and training games, and findings that suggest facilities for caregivers such as teachers, therapists, physicians, and family members.

Szykman et al.(Szykman et al., 2015) expresses how video games have strayed from being not just entertainment gadgets, but also valuable tools that, using Natural User Interface (NUI), could be used to heal and treat metabolic, neurological, and vascular complications.

The authors use a automatic search system to acquire data and keywords from various scientific databases. It was found that research involving the development of games for people with disabilities is increasing, as well as reporting significant improvements in patients' well-being and the data doctors can obtain to conduct a better treatment

One of the clearest benefits found was the motivation generated by games and applications that persist during treatment, where many researchers take advantage of this element as a way to enhance the treatment performed.

8 METHODOLOGY

For the creation of a software that fulfills its intended purpose, a mechanism for storing and manipulating data is seen as a key to its operation. To achieve this functionality, the Django platform was used along with the Django REST Framework plugin to develop a system that has the ability to function online. Working online is also an essential attribute for the most convenient display of this data to the target audience, ie physiotherapists and patients, enabling them to access the data at any time.

For a demonstration of the data that the system can manage, this software will initially process the data obtained from the previous project at Unreal(Antonio Valente, 2019), which will be developed along with the program described in this work. The software (called 'KinectAPI') consists of a Django project with a single app called 'kinect'

Using Django and the Django REST Framework plugin, you able to create an API that can create, store, and display custom objects in a database. This means that we can *abstract* real data into a form that the system understands and is free to manipulate. In Django, these entities are abstracted to objects of a model. Therefore, we can think of a physiotherapist as an object model that has important data from the actual physiotherapist. This object would have, for example, the name of the physiotherapist, his clinic, his CRM (Brazilian Physician Credentials), e-mail, telephone number, among other relevant data.

Like the physical therapist, other entities need to be abstracted before they can be stored. These other entities also need to be relevant in the treatment aspect of the patient. Are they:

- Physiotherapist;
- Patient;
- Treatment;
- Treatment Session;
- Exercises;
- Time.

In Django, to implement this abstraction, you need to create a model for each of these entities. With models created in the 'models.py' file, Django itself generates the database automatically for immediate use.

Models, like their real entities, have relationships with each other. For example: A treatment is made up of a physical therapist, a patient, and has a series of sessions of an exercise. All of these relationships must be represented and implemented as per the actual cases. These relationships can most easily be seen in the *class diagram*:

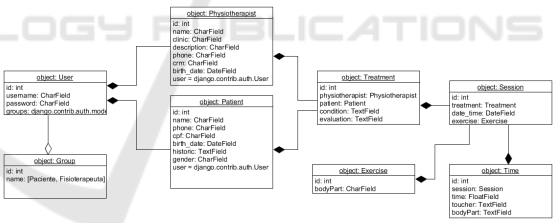

Figure 1: Class Diagram.

Having now all models put and associated as needed, now you have to create and manipulate this data. For the correct registration of objects, an initial interface is required before they can be created. This can be done through Django's Forms, coupled with a View class and an HTML website template.

Views in Django are responsible for managing requests for the software and their responses to each. In this case, it displays the site with the data to be filled in by the user, and when submitting, properly acquires and processes the data received. With this, we can create a screen for the user to register, be it a patient or a physical therapist.

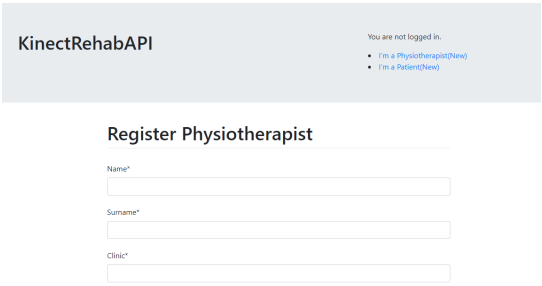

Figure 2: Register screen.

Like the registration screen, a login screen has been implemented. With registered users, they must be given actions that can be performed with the data. These actions should also include the registration of subsequent objects, *exercise* and *treatment*. And encompassing all the necessary actions, you can create a *use case diagram*:

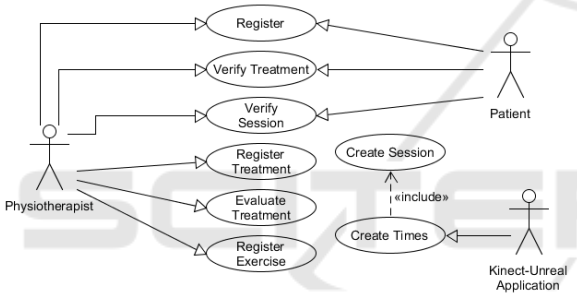

Figure 3: Use case Diagram.

The physiotherapist must be able to perform all necessary operations before using the application on Unreal. Therefore, he/she should first register the treatment, with all necessary data, including the patient's id (can also be selected from a list of patients) and the prognosis of the problem to be solved. After the treatment has been registered, the Unreal application may be used.

To perform the exercise in the application, the physiotherapist must enter the username and password along with the registered treatment ID. Thus, it is not necessary to enter patient data or write about the prognosis, all these data were previously entered and processed. As soon as the physiotherapist enters the required data, he is taken to a menu screen where the corresponding exercise can be selected.

Any operation involving data transfer between the application in Unreal and the Django API is performed through *JSON requests*. The API has a series of URL addresses where the application can make these requests to perform a desired operation. When logging in, for example, the credentials obtained are

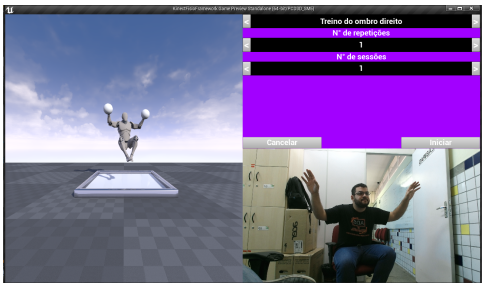

Figure 4: Training selection screen.

registered and sent to the API. It then checks the entered credentials and, if authorized, returns a Token. This token is stored so that it can be used in place of the username and password for subsequent operations.

Once the exercise is selected, a session is created and assigned to the treatment whose id was provided, along with the exercise date, time, and name. Times are sent each time the patient touches an object when asked. In the Unreal app, the exercise is performed from a series of static objects floating over the patient, all semi-translucent in color, which turn golden when the patient must move and stretch to reach them. Only one of the objects activates and turns golden at a time. At touch, the name of the touched object as well as the limb used to touch are sent to the database. Like login, session creation and time recording are also requests with JSON.

With the interaction between the two systems implemented, it now remains to create an interface for users to see the data acquired, and in the case of the physiotherapist, create and manage this data. In the Django API itself it is possible to provide this interface in the same way as the register. A view is created to manage each operation made. When logging in, the user must have operations available in a menu according to their type: Physiotherapist or Patient.

The patient can check his treatments in a list, and check each exercise session, from the same point of view of the physiotherapist. The physiotherapist has more operations, such as recording a treatment, adding an evaluation to a treatment, recording a new exercise, among other views that can be seen in the use case diagram (Figure 3).

After selecting a treatment, information about it can be viewed on the screen as either a small table sorted with the time taken to perform the exercise action and the limb used.

As in the session details, a graph is also shown when selecting a treatment, with performance data per session. All graphs are generated using the Graph.js extension, enabling automatic generation of an interactive graph using the JavaScript language. These

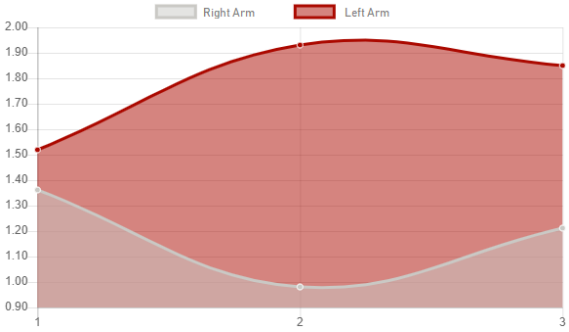

Figure 5: Performance Graph per Limb (Right/Left Arm).

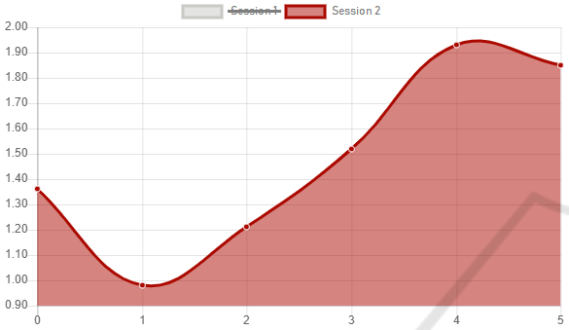

Figure 6: Performance Graph per Session.

charts can display or omit information according to your user's needs. So if the user wishes, only one or all sessions can be displayed at a time.

9 CONCLUSIONS

From the results obtained from the integration between the two platforms, it is possible to demonstrate the ability of both systems to communicate and exchange information with each other, enabling the acquisition of patient movement data through the Unreal application and the processing and display of data obtained using a Django system. In addition to communicating and receiving application information, the API is also capable of using graphical systems and tables for proper data display, facilitating and ensuring better and faster understanding by both the physiotherapist in charge and the patient that wants to check their own performance.

9.1 Testing with Wheelchair Users

As stated by Da Gama(da Silva et al., 2007), a common problem seen in many studies related to motor rehabilitation with Kinect is the lack of actual patient testing. However, for successful and properly tested tests, the approval and follow-up of the Brazilian Research Ethics Committee (CEP) with human beings is required and to be in accordance with international ethical guidelines (Declaration of Helsinki, International Guidelines for Biomedical Research involving Human Beings - CIOMS) and Brazilian (Resolution CNS 466/12 and complementary). This follow-up process requires an extensive process that takes months to complete before testing procedures.

That said, during project development, the objectives and prototypes were delivered and tested with one person, both wheelchair user and physical therapy professional. During the tests, exercise protocols were presented and the data acquisition proposal validated, besides participating in proposed exercise sessions. However, for more extensive research with more concise data, more physical therapists and volunteer wheelchair users are required, which again requires the presence of the Research Ethics Committee.

10 FUTURE WORKS

With both functional systems in hand, there remains, in addition to wheelchair research and testing, the improvement of the exercises to be used and their application to different parts of the body and in different environments. Another progress to be implemented in the project is the expansion of data obtained via biotelemetry and its processing, which may range from the patient's heart rate to the angle of the limb in interest.

Another necessary implementation is the direct experimental use of the system in a hospital environment and in physiotherapy clinics, for a better analysis of the strengths and weaknesses of the system and their appropriate corrections. With appropriate changes made, the system should be retested until it is ready for actual use in rehabilitation clinics.

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