Rehab System

A video-based interface for physical therapy

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Abstract - **According to the World Health Survey, around 785 million people 15 years and older live with a disability, while the Global Burden of Disease estimates this number to be around 975 million people; indicating a higher prevalence in older people and people with lower income [4].**
These groups of people represent a wide sector of the population that must be taken care of in order to improve their living condition . Considering the limited number of physical therapists available, it is clear that only a small percentage of the people affected are able to access appropriate treatment.

In an effort to increase access to physical therapy, a video-based software interface able to track and measure physical activity (repetitions, patterns, and range of motion) was developed to help people with a motor disability improve their mobility on everyday activities. The proposed system is intended to be used at the physical rehabilitation center as well as at the user's home or workplace. The camera-based rehabilitation system can be customized for each patient with specific exercise profiles, routines and feedback determined by their therapist, whom will have access to the activities recorded. User and therapist feedback is provided in a graphic user interface that gives real-time information of the activity being performed. The objective of the rehabilitation system is not only to provide access to motor rehabilitation but to also make it a fun and challenging activity the user will enjoy performing.

I. BACKGROUND

According to the World Health Survey, around 785 million people 15 years and older live with a disability, while the Global Burden of Disease estimates this number to be around 975 million people; indicating a higher prevalence in older people and people with lower income [4].

People with disabilities are particularly vulnerable to deficiencies in services such as health care, rehabilitation and support. For example, in South African countries only 26-55% of people received the medical rehabilitation they needed; in United States, 14.2% of the population has any kind of physical disability and only a 78% of them has access to rehabilitation services. [5] The direct medical costs related to disability were estimated at $160 billion in 1994, medical costs account for over 60% of all personal bankruptcies and $195 billion dollars are lost each year due to unemployment or underemployment of persons with disabilities. [6]

It's important to consider the costs of physical therapy per patient. For a patient covered by health insurance, therapy costs consist of a copay of $10-$75 per session; for patients not covered by health insurance, physical therapy costs from $59-$350 per session. When adding more services such as gait training, massage, home training and initial evaluation, the cost increases to an approximate total of $204-$528 per hour. [7] Depending on the person and the therapy, the exercises can be performed at home, which involves buying extra equipment and performing unsupervised therapy.

Another aspect to consider is that costs are not good indicators of the quality of services that people receive. [5] Poor coordination of services, inadequate staffing and weak staff competencies affect the quality, accessibility and adequacy of the services for persons with disabilities. [4] The World Health Survey data revealed that people with disabilities were more than twice as likely to report finding health care provider skills inadequate to meet their needs. [add reference] A study in the United States of America found that 80% of social care workers had no formal qualifications or training. [4]

Some existing solutions in the market consist on a mobile application that links therapy exercises videos with each patient's phone or tablet so they can watch it at home and perform these exercises correctly; another one analyses a video of the patient doing a task and calculates the joints angle, this is done off line. Another app creates a personal training profile and gives progress information according to the finished exercises you input. [1-3].

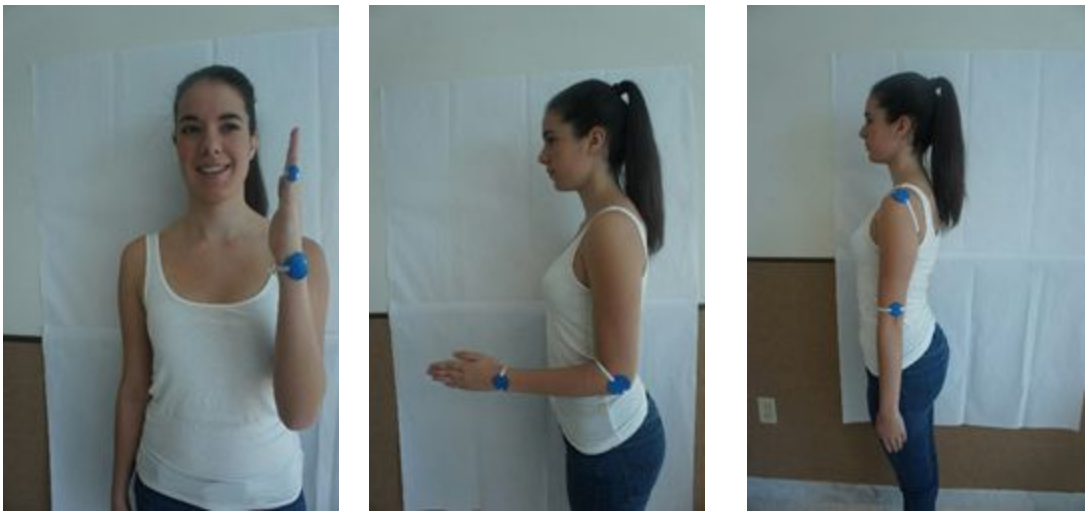
II. APPROACH

To reduce the problems that people with physical disabilities have, we need to make all levels of existing health care programmes more inclusive and accessible, to achieve this we designed and developed a video-based system () and software application for mobile devices (app) that helps in the rehabilitation process by setting specific tasks for the user to do; this tasks are exercises defined by the therapist according to the level of incapacity the patient has. The user activity is recorded and monitored in real time using a video and marker system that tracks the prescribed exercises. Markers are placed in specific locations as required by the prescribed activity. The system analyses the exercise execution and provides visual feedback on the angle of movement of the body segment; this assures proper execution of the activity when a therapist is not present. By encouraging the user to perform a specific amount of repetitions in an specific way, we expect to incentivise the the user to complete each task in a didactic manner. We included a point scoring system rewards the user when an activity is executed correctly.

The Rehab system is easy to use, accessible and comfortable so that the user can do this at home, at a health center, or workplace. It also provides progress statistics to the user and the therapist for its interpretation.The system can be customized for each patient by generating a personal profile that is updated every time an activity is completed, providing statistics of progress with visual aids such as graphs through the rehabilitation program.

III. DESCRIPTION OF FINAL DESIGN

The system consists of a mobile device app, a video interface and adaptable tracking marks. For this stage of the project we developed an iOS app for iPhone and a video system for three different left upper limb exercises: wrist flexion, elbow flexion and shoulder extension. The two blue tracking marks are separated and placed in specific locations for these different movements (Figure 1).



a) b) c)

Figure 1. Placement of marks for a) wrist flexion b) elbow flexion and c) shoulder extension

The tracking module of the rehabilitation system was programed using OpenCV in C++. The program detects only blue spots in the screen, calculates its position in the x and y axis, sets one of the detected spots as a reference and traces a horizontal line from its center; using trigonometric functions, the angle between the two marks is calculated and displayed on screen. According to the task selected a line is placed on screen so the user can align the marks with this reference to start the rehabilitation. It is important to mention that for the measurements to be correct, the marks need to move in an orthogonal direction to the camera axis.

The system performs a calibration before starting with the rehab repetitions; this step consists of performing the prescribed movement to the joints maximum permitted angle (obtaining the range of motion, ROM), so that later on this angle can be set as a reference for repetition count and. The next step is the performance of rehabilitation exercises, in this part the line of reference is set as in the calibration step only this time the angle is already saved; the user has to perform the movement and reach the reference angle, return to the baseline position and repeat this process as many times (repetitions) as prescribed by the therapist. At the end of the task the screen displays a message that the exercise routine has been completed successfully.

The application initializes with a section where the user can create a personal profile using an e-mail address. If you already have an account, the patient or the therapist may login and move to a profile screen. In the profile screen will be held the personal information of the

patient such as name, age, gender and the type of disability; here you have to register your therapist so he or she can gain access to your profile and can add more tasks or view your progress. The tasks screen shows the tasks that have already been assigned to the patient, and showing the part of the body to be trained, a short description of the exercise and the due date. The patient can mark the task as completed when he or she has achieved the number of repetitions required. Both the patient and the therapist are able to add task. The patient will receive a notification every time a new task is added or when the time to make an activity comes. Adding a task will be held in the add task view, where the task, a brief description and the due date will be set. Also, there is an option to add pictures or a link to a video to help the patient perform the activity correctly. Finally, in the progress view the patient will be able to access his or her record and will be able to review exercise and progress charts so that the patient and therapists are aware of the progress achieved at anytime.

IV. OUTCOME: Results, Discussions and Limitations

The idea was presented to a physical therapist at CRIT de Occidente (Teletón, Guadalajara, Jalisco, Mexico), so we could evaluate if the clients would like to provide this type of service in their rehabilitation therapy programs. CRIT is a rehabilitation center focused in children, and the interviewed therapist was excited about the idea since the children tend to get easily frustrated when they felt that there is no progress. Also the measurement of the angles in real time was a characteristic that the therapist liked since it was a way of assure that the exercise is being performed the right way and provides another parameter to be measured.

The system was tested in one person to evaluate if it was comfortable, easy to use and friendly. We guided the user in her first exercise just like the therapists would do; we taught her (user) to place the markers in position for each task, to initiate the video system and to position her arm in the correct way so the camera could detect and calculate angles correctly. Afterwards, the user performed three tasks (wrist flexion, shoulder extension and elbow flexion) by herself following the instructions displayed on screen in the video-based interface. She had no trouble following the instructions and completing the tasks successfully. The user mentioned that “the steps are easy, there's no need for extra guidance after you had shown me how to use it”. With this we proved that the system can be easily used by patients in their own home, workplace or any other location to achieve recovery both in the rehabilitation center and at home.

The problems presented in this prototyping stage of the product were mainly in the video interface. The correct tracking of the markers depends on the room light, background color and user's clothes color; we tested the Rehab System under ideal conditions (white background, and white clothing), we used an external light source to illuminate the user too. Measuring angles correctly depends on the tracking of the markers; the video system can only calculate the x and y coordinate of the marks, but it can´t know the positioning in the depth, z axis. At the current design stage the mobile app does not have a direct connection with the video interface system, so the information of the type of exercise and number of repetitions selected in the app had no effect on the rehabilitation process; we modified these parameters directly in the program before

running it so the task and repetitions could change. We will continue working on the limitations of the the current system.

As future work we will develop dynamic position trackers using accelerometer and gyroscope on a chip, this will help get the position of the marker more accurately, solve problems due to parallax, help the computer to avoid detecting false markers in the monitoring area, and will give us the orientation of the limb that is being analyzed. The communication between the computer and the mobile device (phone or tablet) is in development. The current system requires that the patient marks a task as complete in the mobile app, but we are in the process of making a direct line using serial communication. Finally, we will talk to several therapist in order to get a database of exercises to establish reference lines for each activity, and to add photographs and videos that will describe the exercise.

This rehabilitation system can expand and adapt to other techniques and training technologies in addition to video analysis;

V. COST

According to CREW, a company dedicated to quote projects, the estimated cost of the development of a mobile application is : 19,200 USD[8]. Which considers an application for Apple iOS, where the users sign up with an email account, create their personal profile, making money from Upfront Cost and with a stock look. This cost also covers the salary of top freelance designers and developers.

VI. SIGNIFICANCE

The utilization of the Rehab System is expected to increase the access to physical therapy for people with a motor disability; by providing user specific, high quality and low cost therapy. Children with disabilities will feel more enthusiastic with therapy because it will be like a game, with scores and rewards that will make therapy a fun and challenging way to improve,

This system could give the rehabilitation centers an extended product to offer to their clients and make the rehabilitation process faster because the patient is going to be able to continue and complement their treatment at home, workplace. The therapist could be able to attend more patients in a day due to the reduced time implicated in prescribing home exercises, rather than seeing each patient in person.

The costs of physical therapy will be reduced primarily by the reduction of people needed to perform the therapy and secondly by the reduction of money spent on transportation to any Rehabilitation Center. It is going to be possible to create small centers at rural areas without the necessity of a therapist being there the whole time; thus increasing the accessibility of rehabilitation services.

VII. ACKNOWLEDGMENTS AND REFERENCES

[1] Apple Inc. (2016). *iTunes Preview*. BlueJay PT - Physical Therapy: https://itunes.apple.com/us/app/bluejay-pt-physical-therapy/id858081432?mt=8

[2] Apple Inc. (2016). *iTunes Preview*. KCapture: https://itunes.apple.com/us/app/kinesio-capture/id449938687?mt=8&ign-mpt=uo%3D4

[3] Capterra. (s.f.). *Top Physical Therapy Software Products*. http://www.capterra.com/physical-therapy-software/

[4] WHO. (2011). World Report on Disability. Retrieved April 10, 2016, from http://apps.who.int/iris/bitstream/10665/70670/1/WHO_NMH_VIP_11.01_eng.pdf

[5] Department of Health and Human Services. (2014). National Health Interview Survey. Retrieved April 10, 2016.

[6] Ma, V., Chan, L., & Carruthers, K. (2014). The Incidence, Prevalence, Costs and Impact on Disability of Common Conditions Requiring Rehabilitation in the US. *The Incidence, Prevalence, Costs and Impact on Disability of Common Conditions Requiring Rehabilitation in the US*. Retrieved April 10, 2016, from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4180670/&h=FAQGvUpcA

[7] Costhelper. (n.d.). Physical Therapy Cost. Retrieved April 10, 2016, from http://l.facebook.com/l.php?u=http://health.costhelper.com/physical-therapist.html&h=FAQGvUpcA

[8] CREW. (n.d.). How much to make an app? Retrieved April 10, 2016, from http://howmuchtomakeanapp.com/