TeleRehab: an Android-Based Physical Monitoring System Using Wearable Sensors Via Bluetooth with Remote Physician Referral and Assessment

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***Abstract*– The conventional way of rehabilitation method is by going to the therapy facility. However, this causes some problems such as missed therapy, expensive trip and dangerously to travel in some patients with mobility issues. Thus, having proven that some patients are encountered these problems, the proponents of this study aims to change this method by developing the PocketRehab. It is an android application that monitors the physical conditions, movements and exercises of the patients by using a wearable sensor connected via Bluetooth while in their home. This application has some features like Physician Referral, Videocall and Chat for the consultation and everyday updates of the patient's condition. The device consists of an Arduino Nano, Bluetooth Module, IMU Sensors, 9V non-rechargeable battery, strap and electronic components. All components were in a 3D printed case that is designed to be convenient, portable and light weight. The device and application were used to 9 patients with different exercise to performed which resulted to an accuracy rate between 60% and 100%. It can be determined that the device has the possibility to analyze the success repetitions of the exercises which provides efficiency for physician and for patients with no knowledge in the currently method in today's technology.**

***Keywords*– TeleRehab, Telerehabilitation, Android-based, Remote Physician Referral, Physician Referral, Assessment, Monitoring System, Bluetooth, Sensors, Wireless Wearable Sensors, Wearable Sensors, MPU6050, HC-05, Gyrometer, Accelerometer, Knee Ostheoarthritis, Frozen Shoulder,**

I. INTRODUCTION

Providing treatment for pain and difficulty movements are the job of Physical Rehabilitation. It's not only responsible for regaining mobility and muscle control, but it also strengthens one's balance and increases the quality of patient's life. Exercises must be performed several times as prescribed by the physician [1]. Rural inhabitants receive a poor health attention than those who live in urban areas and this is due to various factors such as lower socioeconomic status, absence of medical personnel, the availability of healthcare services, and having hesitations whether to see a physician [2]. On the other hand, access to a treatment is significant to have good results and lower medicinal service costs for patients and the health system.

Most of the developing countries including the Philippines, have their formal and informal referral practices in places within their designated health care system, here a patient with illness or injury that is elevated at a normal level of care and assistance is referred to a higher and improved level of care [3]. Health data can be shared nowadays, and it became a normal thing. Referring patients to different doctors has always been a job of the clinics because they are lacking equipment, services and the doctors [4]. A health referral system is one of the most used and main bases of the physician programs and its effectiveness is a factor for classifying the ranking of healthcare [5]. It uses mobile cloud computing technology to allow physicians to use the system anytime and anywhere [6]. This system can be improved significantly by including the most recent Information technology. Smartphones have become useful every day and are always available with individuals across different age groups. In just one click, people can now have a way to have their health records online [7]. ERS (Electronic Referral System) was developed to lessen waiting times and improve efficiency. Patients do not need to travel far and spend money and time trying to find a physician that will help them. Referral systems help rehab patients to give prompt diagnosis and management before the occurrence of deterioration. By using it, the previous data of physical rehab patients can be easily transferred and reviewed by the referred physician. Also, E-referrals was proposed as a solution to a paper-based referral [8].

Physical rehabilitation is concerned with the treatment of a body part that requires physical therapy with the guidance of a physical therapist. Not all cases require much supervision, but it is often helpful because patients tend to perform wrong movements or postures during rehabilitation, resulting to lesser effectiveness [9]. This is where wearable devices with sensors that are wirelessly operated and may be via WIFI are introduced in rehabilitation. One of the applications of this wearable sensor for rehabilitation patients is the mobility assessment. Mobility assessment is typical among adults especially the older ones during hospitalization and is helpful for the ones who have movement problems due to lower body part impairments [10]. Wireless wearable sensors are interconnected with the mobile devices and into the internet and worn by the patients to help the physicians monitor their health status even without hospitalizing them. It does not only give an opportunity for the patient's condition's better management but also contributes to lower healthcare costs [11].

Our goals with this study were to: (1) allow physicians at health centers to easily refer physical rehabilitation patients to experts; (2) provide a wearable device that consists of sensors that will obtain knee and shoulder assessment; and (3) develop an android application that will offer video consultations, messaging services and referral.

II. METHODOLOGY

The proponents conducted a random testing that consist of 5 people that were free from any physical mobilities and performed 30 repetitions. In developing a device and application, the factors to be considered is the convenience and weight of the device to the patient and the user interface of the application for both physician and patient.

A. Design of the Device

Figure 1 and 2 shows the proposed designs of the chassis.

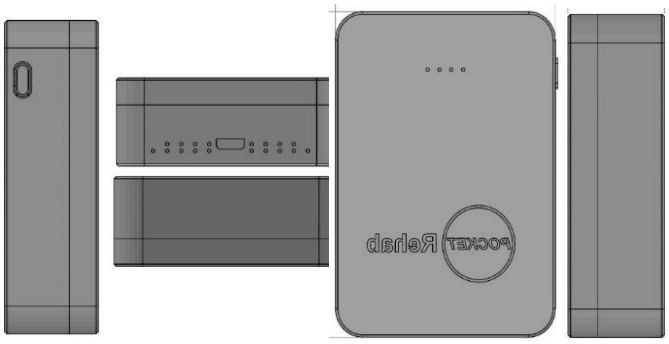

Fig. 1 Chassis Design for Version 1

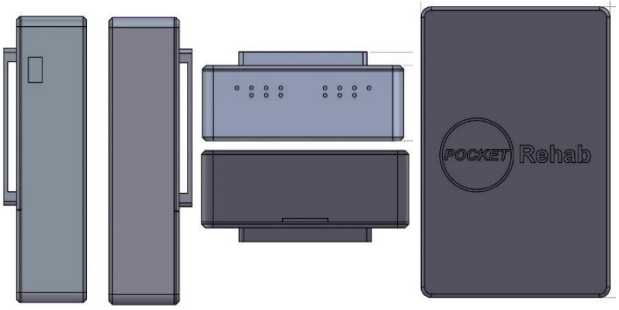

Fig. 2 Final Version of Chassis Design

The size of the chassis in version 1 is 90mm in length, 65mm in width and 26mm in height. This device was not deployed because the proponents realized that it is inefficient and too bulky for the patients. However, this version was tested for the specification of the device needed. In final version, the size of the chassis is 84.40mm in length, 54.90mm in width and 20.50mm in height. This design seems to be more portable and handier than the design of version 1. Also, it is designed and developed for the convenience of the patient.

B. Design of the Application

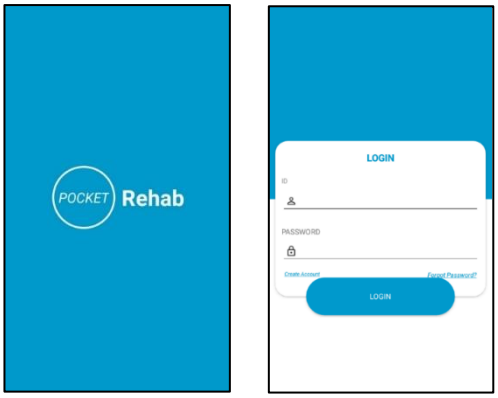

Fig. 3 PocketRehab Splash Screen and Log-in UI

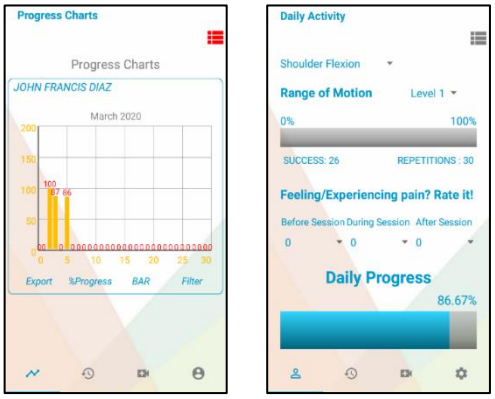

Fig. 4 PocketRehab Daily Progress and Progress Chart

Figure 3 and 4 shows the final GUI design application for the project. Aside from daily progress and progress chart, there is also a physician referral and progress history for both patient and physician to see the previous exercise of the patient. And, there are some features of the application like message, online chat and videocall for the online consultation with the physician. This application is paired to the device via Bluetooth. The parameters that can be seen in the application was from the physician.

C. System Flow

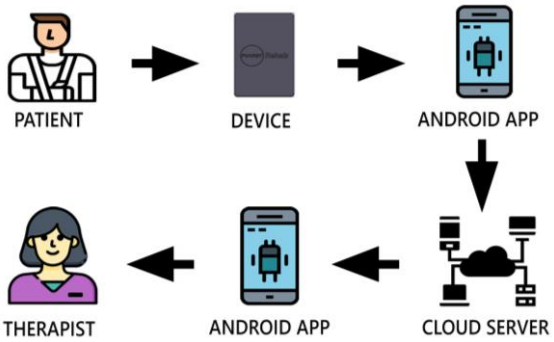

Fig. 5 Physical Rehabilitation

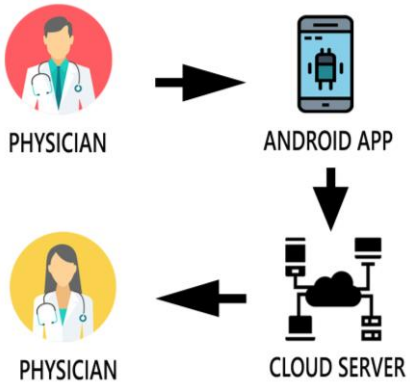

Fig. 6 Physician Referral

Figure 5 and 6 show the system of the project. In the physical rehabilitation system, the wearable device should be attached to the patient's body to detect the movements of the patient. The data will be then transmitted to the android application and send it to the cloud storage. Patients, physicians and therapists can access it by simply logging in to their accounts or signing in. The data will be saved to the cloud storage where the physician can see their record and can now perform the referral method. In the referral system, the physician can view the records of the patient and decide on choosing the best doctor and is also the only one allowed to do the said method.

D. Functionality Testing

Fig. 7 Testing of Device and Application

Figure 7 shows the patient wearing the PocketRehab kit attached to her legs while performing an exercise. Before performing such exercises, the patient must connect the application to the wearable device using Bluetooth. After pairing of devices, patient must select the appropriate details, such as type of exercises, level and the number of repetitions that prescribed by the doctor and the pain encountered before, during and after doing exercises. The device sends information needed to determine the range of motion and the number of repetitions done for each exercise. The results collected from the device can be seen using the application. Patients can see what percentage they have achieved for the range of motion and the number of successes repetitions for each exercise. When daily activity has been performed, the results can be viewed by the physician using the same applications.

After the initial testing of the device and application, the final testing was conducted. It was tested to 5 patients that are free from physical mobilities before deploying it to the patients with mobility issues.

III. RESULTS

TABLE I
OVERALL ACCURACY

Exercise	**Accuracy**				
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Shoulder Flexion	91.67	96.06	84.89	80	64.17
Shoulder Abduction	98.33	88.33	86.67	93.95	100
Inward Rotation	95.5	98.33	90.17	96.2	100
Outward Rotation	98.33	93.89	91.67	95	
Leg Flexion	100	94.17	64.44	92.08	76.67

The overall accuracy based on the deployment result is shown in Table 1 regardless of the repetitions. The data was the average of all the results per exercises gathered by the patients. Shoulder flexion and Leg flexion have lower accuracy at level 5 since the device can read every movement of the patient precisely if the exercises are done slowly. This means that the part of the patient's body, which had a disability, could finally be able to move without pain or the patient's movement become faster than what it should be.

IV. Conclusion

This research provides a technology designed for patients who wish to continue their physical rehabilitation programs at the comfort of their homes, where physician consultation was still feasible. Based on the analysis of the data gathered and results, online therapy and consultation offer multiple benefits: First, it addresses patient's immobility issues by providing an alternative channel to patients and healthcare providers for their consultation activities. Second, it improves the conventional referral method by introducing a standardized physician referral system

V. Recommendation

The study was conducted in a household setting only where the subject tested was persons suffering with different physical mobilities and the other subjects were free from any form of physical mobilities. Due to the pandemic, the proponents were unable to conduct deployment at the hospital and the results could not be verify by the physicians. Secondly, the android application record only one exercise each day. For future researchers, the proponents of this study propose the implementation of the study in a hospital setting to maximize the sample size and to be verified by the physicians, and to improve some features such as multiple exercises a day to enhance the accuracy of the system.

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