WristTrack: A Mobile Healthcare Surveillance System for Wrist Recovery Exercises

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Abstract

Physiotherapy is an important component for injury recovery. Progressive exercises can help in facilitating recovery when executed correctly, but it can cause damaging effects when done wrongly. However, not all patients are able to make it to the hospital every time due to reasons such as post-surgery immobility. This study introduces a self-served physiotherapy system for wrist exercises (i.e., WristTrack), allowing patients to perform wrist conditioning at their own time and place of convenience. The system integrates wearable devices with mobile and web platform, to capture, visualize and provide useful metrics for both doctors and patients to make steady progression in their recovery process.
Keywords: Wrist Injury, Wearable, Physiotherapy, Mobile Device

1. Introduction

Smart Healthcare Service System is a system that aims to provide different stakeholders (e.g., doctors and patients) with a better healthcare service. Smart Healthcare Service System is designed with intelligent management and utilization of their resources to fulfill the needs and goals of users (e.g., doctors and patients) at any point in time [3]. An important trend in Smart Healthcare Service System is to improve health status monitoring [9]. In this paper, we provide a novel approach for innovation of smart service systems through WristTrack.

WristTrack is a mobile healthcare surveillance system for wrist recovery exercises. WristTrack is a novel solution because it integrates the wearable with mobile and web technologies to allow patients and doctors to monitor the progress of the wrist exercise. In this way, it allows 1) patients to observe their actions and receive feedback in real-time, 2) doctors to remotely monitor their patients.

Wrists injuries are common and can cause serious damages to the ligaments when not treated with care. For instance, such injuries can easily be incurred by athletes, through various sports (e.g. tennis, baseball, snowboarding) [10,11], playing instruments (e.g., violin and piano) [14] or even in daily life such as breaking a fall [12]. Physiotherapy and strengthening exercises are used to nurture the wrists into better conditions [9]. Many of such exercises do not require specialized or large equipment. However, physiotherapy exercises need to be done correctly to achieve effectiveness. Damaging effects occur if the exercises are conducted in an improper way. Therefore, it is critical for patients to observe their actions and receive feedbacks if the detected actions are inappropriate.

Despite the need for recovery and strength conditioning, it is not always easy or convenient to travel down to a clinic or hospital for a proper physiotherapy session. This applies commonly to post surgery patients who are weak to travel, handicapped or stroke patients with high inconvenience in travelling [4]. Therefore it is critical for us to design ways that would help these patients to conduct physiotherapy in a proper manner at their own convenience.

With the advancement in technology, wearable devices have been widely applied in the healthcare sector for various purposes like patients' data management and real-time condition surveillance [5]. Along with the proliferation of E-healthcare, patients are becoming more important, better informed and more participative. Hence, they are expected to take a more active role in the management of their wrist injury conditions by engaging in self-management activities [2]. In this study, we introduce WristTrack that helps patients to perform wrist exercises at any place of convenience (i.e., their home), with instant feedbacks for immediate correction. The system is visual and data-driven with metrics to encourage steady progression. The real-time surveillance data will be sent to the respective doctor for reference and diagnostics.

The paper is structured such that we will first explain the research objective and contributions. After which, we will describe the different components and features of the product. Moving on, we will elaborate the technical specifications and algorithms involved for various components. Finally, further research and applications will be discussed where the technology can be expanded.

2. Research Objective and Contributions

This study aims to enrich E-healthcare literature by proposing WristTrack to understand the economic effectiveness of a self-management healthcare. By doing so, this study contributes to the existing literature on self-management healthcare through the instantiation of a mobile healthcare surveillance system. In comparison to a doctor-centric and patient-centric healthcare, WristTrack has been a novel theoretical lens on exploring patient's empowerment from E-healthcare.

This study will also provide practical contributions. Firstly, it provides application developers with ideas regarding the use of Inertial Measurement Unit (IMU) tracking module to perform physiotherapy such as wrist exercises. Secondly, it provides application designers with insights on how mobile applications could be integrated with the IMU tracking module to create visualization for end users to monitor the progress of their exercise. Finally, it provides an integrative platform for doctors and patients to monitor the wrist exercises performed by the patients.

3. WristTrack

WristTrack consists of three particular components namely the wearable technology which tracks and captures a user's movements, the mobile application which provides immediate feedback for corrective actions during the exercise and allows a user to refer to his/her own health information records, and a desktop platform for doctors to access their patient's records and provide feedback as shown in Fig. 1. The wearable technology is worn on the wrist of a user. Whatever the user does is reflected on the mobile application and the information is stored on the web that is viewable on the desktop by the user together with the doctors for a detailed analysis. This is in line with the Smart Healthcare Service System to meet the goal of the patient (visualize the progress on the mobile application to ensure that the exercise is done correctly) and the doctor (spend more time analyzing the progress of the patient and performing better diagnostics).

Fig. 1. Components of the Product

3.1. Wearable Sensor

Wearable technologies have been commonly used in healthcare technologies [9]. Our product has improved current wearable technologies by adopting a miniaturized low cost IMU tracking module together with a low resource consumption technology such as Bluetooth Low Energy (BTLE). The wearable sensor consists of a miniaturized ATmega32U4 microcontroller. A small Arduino compatible board is used as the controller, extended with a CC2540 BTLE microprocessor and a 9-axis motion IMU tracking module, based on MPU-9150. It has a build in accelerometer, gyroscope and magnetometer that function over 12C. The IMU tracking module captures the X, Y and Z coordinates of the hand to determine the position. Any turning, vertical and horizontal motion is detected and results in changes of coordinates.

WristTrack allows multiple wearable sensors to be connected to multiple devices. The devices can be configured to handle each wearable sensor separately. This enables users to perform different exercises with both wrists concurrently.

3.2. Mobile Application

The mobile application is an application that is developed using HTML5 technologies which is supported by multiple devices. We have chosen to build our mobile application with HTML5 technologies because it is easily convertible to multiple mobile Operating Systems (OS) such as Objective-C for iOS, Java for Android, C# for Windows Phone, Java for BlackBerry OS, C++ for Symbian [4]. Reports have estimated that by the year 2016, 2.1 billion mobile devices will be equipped with HTML5 supported browsers [1]. The mobile application is developed to perform two goals being visualization and feedback.

Data Visualization

The movement captured by the sensors is displayed in a visual form through a virtual hand, allowing a user to clearly observe how the hand and wrist is moving. The data captured by the sensor such as "degree of rotation" and "angle of bend" is visualized into graphs for easy references in real time. Users can observe these graphs through their mobile phone and make adjustments accordingly. A screen of how the graph looks like is shown in Fig. 2.

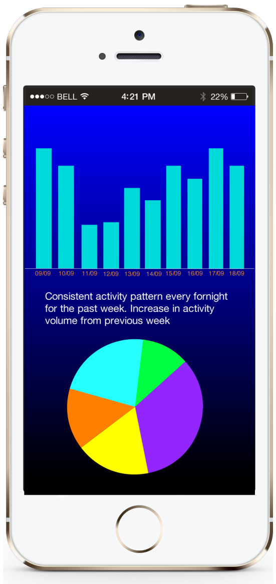

Fig 2: Mobile Screen Capture of the Graph of the Exercises

Information Feedback

Besides data visualization, the mobile application also compares the captured data against a benchmark data proposed by doctors through the desktop (website) platform to determine what a user should improve. For instance, the mobile application provides suggestions such as making a larger motion. In an addition, the captured data is also tallied to a threshold number that represents the maximum number of cycles that the patient can perform at each time. The mobile application alerts a user immediately when he/she enters a dangerous scale (hits the threshold number). This would prevent further injury from over exertion or wrong postures, and pushes a user to stretch as far as it is safe to go. Fig 3 shows an example of the alert that is received by a user.

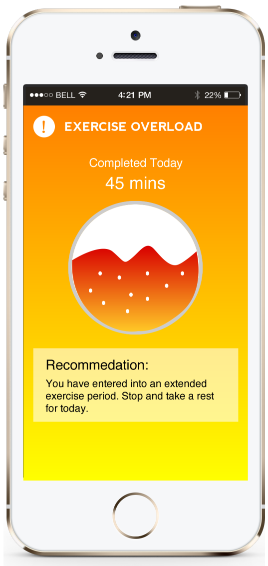

Fig 3: Screen Capture of an Alert

3.3. Desktop Platform (Website)

Administrative Portal

The desktop platform serves as an administrative portal for doctors to fill in the details of the exercises that a user is required to perform. Such details include the angle of rotation in terms of X, Y and Z coordinates (benchmark to be shown on the mobile application) the danger threshold in terms of the angle (when to alert a user) as well as the steps that a user is required to perform. To ensure data accuracy, the doctors input the X, Y and Z coordinate through the same wrist sensor that the user is using.

Exercises Analysis

Besides the administrative portal, the desktop platform also provides the doctors and patients with an analysis of the exercises that has been completed. The analysis includes the angle captured by the sensor and the duration of the exercises performed by the user. This allows the doctor to do a match between the ways in which the exercise is performed with the condition of the user's wrist. Fig 4 shows an example of the dashboard with the analyses of the exercises performed by the user.

Fig 4: Screen Capture of the Exercises done by User on Web

4. Technical Specifications

Fig. 5 provides us with an overview of WristTrack. There are three operational steps in the usage procedure of WristTrack, namely device pairing, sensor calibration and exercises loading, and exercise commencement.

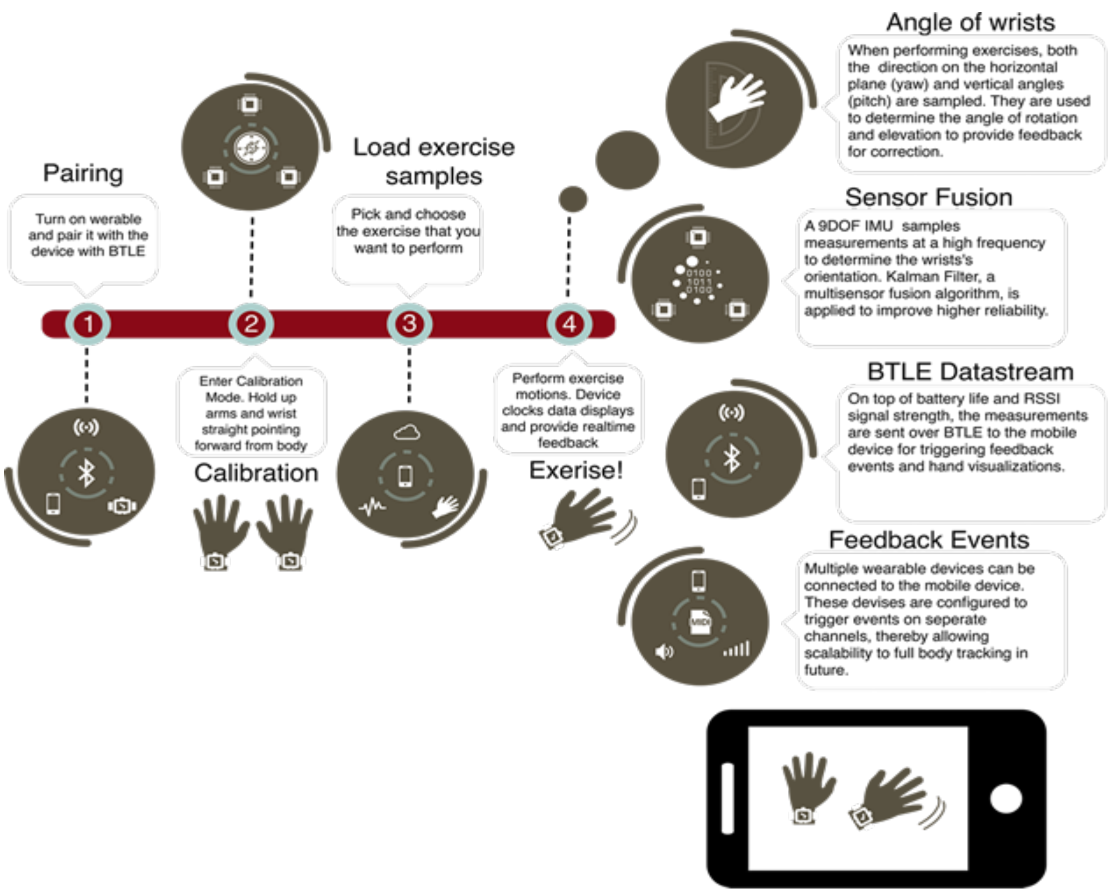

Fig 5: Overall Architecture of WristTrack

4.1. Device Pairing

During the pairing stage, the user is required to turn on the wearable sensor as well as the Bluetooth feature on the device itself. The device in this case could be a smartphone or a tablet that is equipped with Bluetooth technology.

4.2. Sensor Calibration and Exercises Loading

Before the exercise begins, the sensors need to be calibrated. At this stage, what the user is required to do is to put on the sensor and hold up his/her arms straight pointing towards the device. This device could be any device that is equipped with Bluetooth feature such as a mobile phone, tablet or even a laptop. The accelerometer and gyroscope is set to its initial state and calibrated together with the mobile application. After the sensors have been calibrated, the user can begin to choose the exercise to perform and start exercising as shown in Fig. 6.

Fig 6: Screen Capture of Exercises

4.3. Exercise Commencement

When the user starts exercising, the directions on the horizontal plane (Yaw) and the vertical angles (Pitch) are sampled. They are used to determine the angle of rotation and elevation to provide feedbacks for correction. These feedbacks are transmitted to the device using Bluetooth Low Energy (BTLE) datastream. This device could be any device that is equipped with Bluetooth feature such as a mobile phone, tablet or even a laptop. We have chosen to transmit the data using BTLE because it consumes a lower amount of energy providing a higher sample rate [16].

Each time the accelerometer and gyroscope captures a data, Kalman filtering is applied to the measurements to remove the noises. Kalman filtering is an important feature that is commonly used for noise minimization. We have chosen to use Kalman filtering because it minimizes the variance of the estimation error [13]. This filtering is done based on the kinematic state of the sensor that includes the position, velocity and the acceleration measurement of the sensor. Kalman filtering removes noise based on two criteria: how close the captured data is to the real data and how fast it follows the data change. It is "an optimal combination between the time propagated estimate from a previous time instant and the measurement at the present instant". This optimal combination is dependent on the error variance of both the prior estimate and the current measurement" [9].

It is applied as six separate linear filters for each acceleration and rotation component respectively. To ensure the accuracy of detecting changes in Kinematic State, we have made use of a technique known as dead reckoning. Dead Reckoning takes into account the acceleration that is measured by the IMU sensor to locate the estimated velocity and identify the new position. One of the reasons why we chose to use dead reckoning technique is because that it is independent of external beacons [13]. The usage of external beacons might incur extra cost and unnecessary weight to WristTrack itself.

5. Conclusion

The objective of this paper is to design a mobile healthcare surveillance system (i.e., WristTrack) for patients to perform physiotherapy at home, meanwhile doctors are able to analyze the data captured and provide further diagnostics for patients. This not only allows patients to perform the physiotherapy exercises at their own pace, but more importantly it allows patients to do it in a proper manner. The patients are able to review the captured data and correct any wrong actions.

WristTrack can be enhanced by expanding the sensors from the wrist to other parts of the body such as knee. Knee injury is another common alternative that future researchers should look into. Furthermore, it can also be catered to sports schools where instructors can use this technology to train the athletes and correct their postures.

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