ECE 1778 Creative Application for Mobile Device

myKnee
Final Report

1995 words
Apper statement 499 words

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1. Introduction

One of the four ligaments in the knee is known as the anterior cruciate ligament (ACL) and is commonly torn during sport or physical activity. In the United States 100,000 people undergo a surgery to reconstruct this ligament annually. The rehabilitation process following this surgery last 6-8 months and it costs $3500-4000 in Canada. Following this major surgery the patient often receives a few pieces of paper from their surgeon detailing their rehabilitation protocol for the next 6-8 months.

One of the major components of the early rehabilitation process, usually carried out by a physical therapist, is measuring and improving knee range of motion (ROM). If the patient does not improve their ROM it will result in the inability to participate in sport and physical activity, difficulty with walking and climbing stairs and possibly the early onset of osteoarthritis (degenerative changes) in the knee.

Our group has designed an app that functions as a mobile goniometer, a device that measures angles similar to a protractor, which can measure knee ROM. We would like to take a focused approach to this app and as such we are targeting it towards patients following ACL reconstruction. As a physical therapist, our apper treats many patients following ACL reconstruction and the ones who do not attain early ROM have a significantly harder recovery following surgery. One of the main reasons patients delay receiving rehabilitation is either because they do not have access to physical therapy, due to location or financial resources, or because they thought they were doing “fine.” By providing patients with this app we are solving two problems:

1) Access to goniometric measurement without the need for a health care provider
2) Information about their knee ROM that alerts the patient that they require further rehabilitation

2. Overall Design

Here is the block diagram of our application:

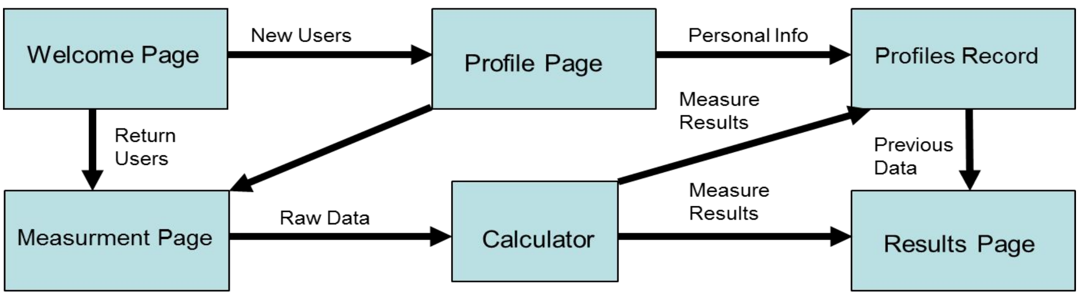

Figure 1.1: Block Diagram

1) "Welcome Page" is the first page which will be seen by users. The welcome page is different based on whether the person is a first time user or a returning user.
2) "Profile Page" is used to collect the basic information about the user. It includes age, gender, date of ACL reconstruction surgery and the knee the surgery was performed on. This information will be sent to the "Profile Record". After users fill out the necessary information they can go to the "Measurement Page" and start to measure their ROM.
3) "Profile Record" consists of information collected by "Profile Page" and measurement results from the "Calculator" related to a user. This information will be saved and used to create recovery benchmarks for user to compare.
4) "Measurement Page" is used to choose a measurement method and start the measurement process. There are two methods to measure ROM in our application: lying on stomach with mobile on the lower leg and lying on back with mobile on the upper leg and the external sensor on the lower leg. In both methods, the measurement raw data will be saved and passed to "Calculator" for future calculation.

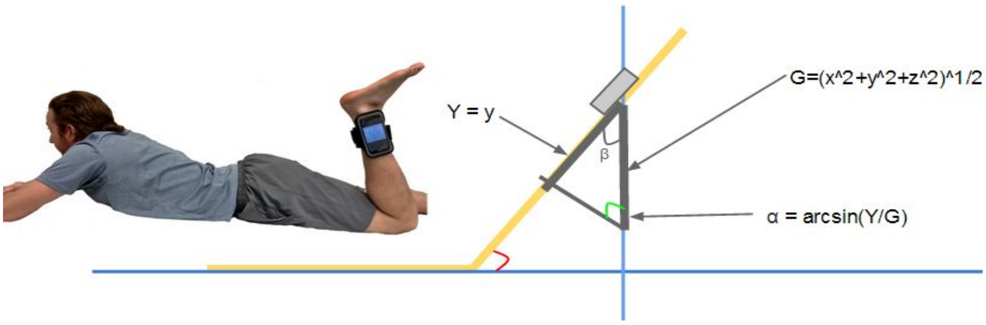

Figure 1.2: Calculation model for "lying on stomach" method

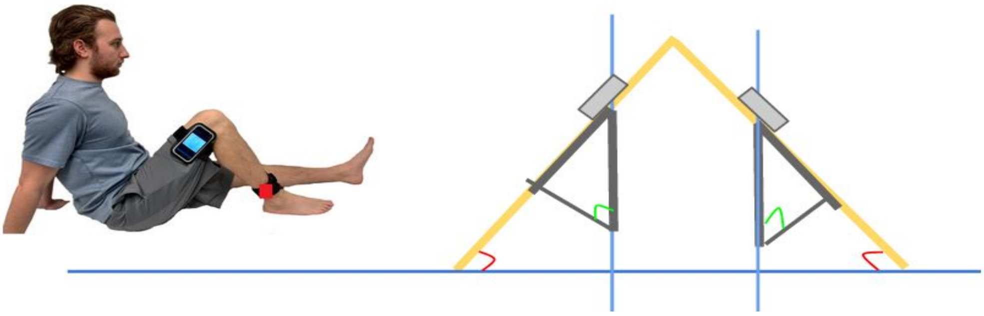

Figure 1.3: Calculation model for "lying on back" method

5) "Calculator" is a logical unit of the application, which takes measurement raw data as input and calculates the knee ROM. The raw data are generated by the gravity sensor of the phone and accelerometer of the external sensor at the x, y and z axis. "Calculator" will filter out the noisy data and use trigonometric functions to get the measurement result. As shown in Figure 1.2, the yellow line represents the patient leg and the smart phone is attached. We can get the gravity value of x, y, z and calculate the gravity. In this case, the range of motion is the same as the red angle, which equals to the green angle, because both of them equals 90 degree

minutes the angle beta. Finally, we can calculate out the green angle by using arcsin(Y/G). In terms of lying-on-back method (shown in Figure 1.3), it is similar with the previous model. In this case, the ROM is the sum of the two red angles, which equal to the sum of two green angles. Both smart phone and the external sensor are used to get these two green angles.

6) "Results Page" displays the measurement results and the benchmark.

3. Statement of functionality

1) Distinguish new users or returning users: the "welcome page" is different for new users and returning users (shown in Figure 2.1 and Figure 2.2). The new users will see the application logo and a button to ask them to enter their profile. The returning user will be able to measure their ROM directly or view their measurement history.
2) Compare with benchmark: once the user has completed their profile (shown in Figure 2.3) the app is able to calculate the benchmark (shown in Figure 2.4) for a specific measurement. In this manner the app can inform the user if they are attaining their necessary ROM.
3) Multiple choices on system settings: there are three interactive methods (button, gesture and clock) and two notification methods (speech and vibrate). Users can turn on or off any method using the settings page (shown in Figure 2.5). Three interactive methods are used to control how to start or end a measurement. Users can choose press the on screen buttons or use the gesture control which involves double clicking anywhere on the screen. They can also choose the clock method, which will start the measurement once the leg is steady for 3 seconds and will stop the measurement once the leg is steady for the next 3 seconds. Two notification methods, voice and vibrate, are used to inform the user when the measurement has started and stopped.

Figure 2.1: for fist time users

Figure 2.2: for returning users

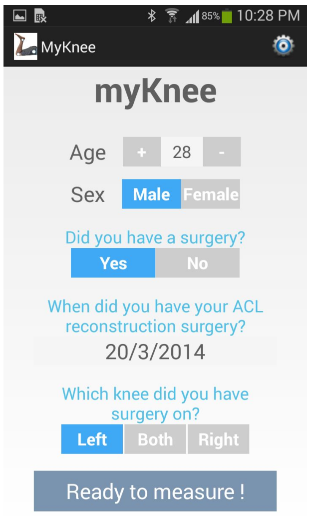

Figure 2.3: User Profile

Figure 2.4: Benchmark page

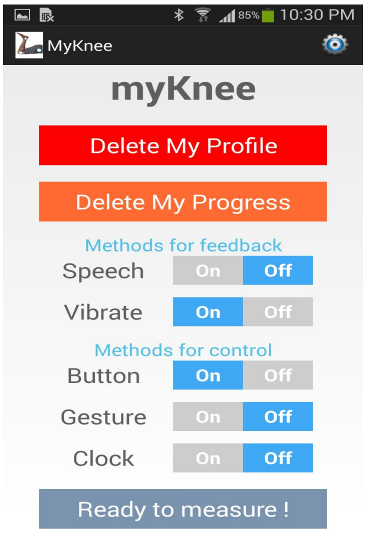

Figure 2.5: Setting Page

Figure 2.6: Measure methods

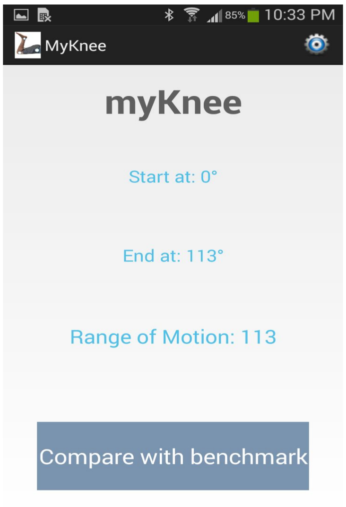

Figure 2.7: ROM result

Figure 2.8: Measurement history

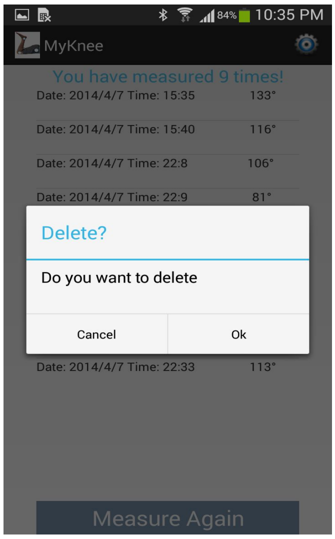

Figure 2.9: Delete single result

4) Two measurement methods: users can choose from two methods (shown in Figure 2.6) to measure their ROM. The "lying on stomach" method requires the user to attach the mobile to the lower leg. By using the gravity sensor of the phone, we can get the relative angles between the leg position and the horizontal line at both start position and end position by using our calculation model. The difference between these two angles is the ROM. The "lying on back" method requires the user to attach the mobile to the upper leg and an external sensor to the lower leg. By using the accelerometer sensor of the external sensor, the angle moved by the lower leg can be transmitted to our application via Bluetooth. The application can calculate ROM by taking into account the angle differences between the mobile and the external sensor. For both method, the final ROM can be shown as Figure 2.7.

5) Measurement history: users can get the whole measurement history (shown in

Figure 2.8) in a list which is ordered by the measurement time. Users can delete any history list by clicking on it and confirm it in the pop-up window (Shown in Figure 2.9).

4. Key Learnings

For the apper:

Prior to our final presentation we met for several hours during which time we practiced our presentation. During this testing we realized some issues with the app that we had previously not encountered. This last session was immensely productive and I learned more in these few hours than I had in all of our previous meetings. We discussed everything from app and sensor issues, to testing and reliability, as well as presentation skills. As well I would have liked to design a better methodology for testing which may have improved validity of the app compared to my measurements.

For the programmers:

Our app requires the use of an external sensor in order to acquire the ROM for one of the two methods. We are using the sensorTag which is inexpensive and seems to have adequate accuracy. However, it uses the bluetooth low energy (BLE) technology which only supports android version 4.3 or higher. This means that our application can only support the newest smart phones and most of the smart phones currently available can not be used. This limitation is contrary to our main goal of patient accessibility to measuring knee ROM. We would like to research other external sensors that support a lower version of android.

5. Contribution by Group Members

As the apper, Nirtal helped with the user interface of the app. He was responsible for providing and editing the pictures for the app. Nirtal also researched the benchmark measures for range of motion based on age as well as following ACL reconstruction. Nirtal also performed 60 clinical trials with seven subjects to assess the validity of myKnee compared to his own measurements with a goniometer. The results of this testing are presented in the final presentation. Nirtal also helped with the final presentation slides and writing the final report.

As the programmer, Xia has designed and coded all layout related xml files to make sure that the User Interface are the same as the apper's mockups. He also built the whole framework for the project to make sure all pages can be transmitted correctly and smoothly. He designed and coded the user profile page and setting page by accessing through a small icon on the toolbar. He designed and coded two interactive methods: button and gesture. He did a great deal of research on interactive methods especially on gesture and voice control. As a result, he found that voice control should not be involved in our application. He also added the speech function to inform users to start or end a measurement. He added the benchmark functions as well. Xia helped to make design decisions, debug and prepare all of the presentations and reports.

As the other programmer, Xiaolei has designed and coded the calculation model for both measurement methods. He did lots of research on both embedded and external sensors. He also built the functions to connect and get data from sensorTag through bluetooth. He added SQLite database into the project. He designed and coded the other interactive method which was the clock. He added the vibrate function to inform users to start or end a measurement. Xiaolei helped to make design decisions, debug, and prepare all of the presentations and reports.

6. Apper Projects

As a physical therapist and a master`s student in public health my interest is in the area of accessibility to rehabilitation and removing barriers that exist that limit access. This app is an extension of my professional and academic goals to allow patients to be able to access an aspect of rehabilitation in a simple and efficient way that does not require the expertise of a health care provider. The main achievement of this app in the field of physical therapy is its' ability to provide patients with an objective and accessible way for them to measure and track their knee flexion range of motion. Currently this is done by a physical therapist but can now also be done using myKnee. There are aspects of post operative rehabilitation that can not be carried out by the individual and for these components the patient needs to follow up with a physical therapist. Measuring ROM is not one of these aspects since it is a technical skill that can now be measured by the use of a mobile device. With this app the patient can accurately report back to their physical therapist their progress and track it themselves to know when they are falling behind on their ROM goals. The fact that the app can provide the user with normal values based on their surgical date and indicate if they are falling behind would help them determine if they need further rehabilitation to regain ROM. For patients who indicate they have not had surgery the app would also provide them normal ROM values based on their age entered in the opening profile page. In the future this app will also provide the patient with suggestions to increase their ROM if it is below the benchmark measures that are provided by the app.

These benchmarks within the app are based on peer-reviewed journal articles. In reviewing these articles it became apparent that normal value research has not been done for the knee since about 1991. The largest sample including 500 subjects and more recent work has had normal values based on as few as 12 subjects. This app has the ability to change research in the field of physical therapy by allowing multiple practitioners to use the app and obtain age appropriate normal values. The app can also collect data based on how much ROM a patient attains following surgery to determine normal values that are even more specific than the ones currently available in the literature. This app has the potential of changing how research is performed in the field of physical therapy. Research is usually done within one lab or clinic and conveyed to researchers and practitioners in all settings. Now with the use of a mobile app we can perform multi-center research and improve applicability to other researchers and clinicians. This type of research has the potential of improving patient related outcomes in the future by conducting research that is applicable to a larger patient population.

7. Future Work

The future work for this app will include further testing to determine the reliability and validity of the app as compared to goniometric measurements performed by a physical therapist. Our group would also like to perform usability testing with the app with actual patients who have had an ACL reconstruction.

Another extension of this app would be to allow patients that have had other knee related surgeries to use the app to measure their ROM and provide them with evidence based benchmarks for their ROM. Once we have established these features for the knee we would like to expand the app to measure ROM at other joints such as the elbow and hip .

The app will also provide patients with methods of increasing their ROM if they are below their benchmark. This will be incorporated with a few simple pictures of exercises which will be presented to the patient if their ROM values are lower than the established benchmarks provided by the app. We are planning to release the app with the above added features by June 2014.

A future research goal is to use the app to collect data from patients and other clinicians to establish normal values for knee ROM. By using mobile devices to collect research data from multiple sources we have the potential to revolutionize the way clinical research can be done in physical therapy.