The Perfect Squat Project

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Abstract

The purpose of this project was to make a device that would help the user perform a squat without the need of a personal trainer, and to help prevent injuries. The project started with the Kinect for Microsoft. Simulink software for the Kinect was provided by Microsoft, and that software was modified so that the angles were calculated and feedback was given. The feedback includes a figure in which the text of the knee and hip angles turn from red to green when the right angles are reached. Next was the balance board. Eight load sensors were used. Four of the load sensors are in the balance board and four are not in use to make four complete Wheatstone bridges. A code in Codewarrior was written that reads the signal and sends the data to MATLAB. In MATLAB the center of mass is calculated. A figure displays that center and turns from red to green when the user is balanced. After testing it was found that the Kinect ran slowly because the figure reloaded every time the Simulink model ran. Also, the balance board needed calibration. The Kinect speed problem was partially solved by increasing the refresh rate and the balance board was calibrated so that all the sensors gave close to the same voltage output. Overall the project was a success. This project can sense injuries because they will not be able to perform the squat correctly. Injuries may be prevented because the feedback will guide the user to stay balanced. A lot of knowledge was gained to achieve the objective, and there is room to grow the project further.

Introduction

Performing a squat exercise increases mobility, functionality, and lower body strength. For this project the Kinect for Microsoft measures knee and hip angles while a balance board with load sensors measures balance. Feedback is shown on a computer screen which shows whether or not a perfect squat is being performed. To fully understand how the components work one must first understand how to perform a squat exercise. First, the user's feet are placed shoulder length apart with their toes pointed out. Next, their arms are put out in front them, if they are not carrying any weights. After that both knees and hips are bent. Hips should be at an angle 80 to 140 degrees so that the thighs are almost parallel to the floor. The knees should be at an angle between 90 and 100 degrees. The user should stay balanced throughout the exercise to prevent injury [1]. A balance board measures the center of mass and feedback is also shown for this.

Oakland University IREECE REU Program

This project was done during the Interdisciplinary Research Experience in Electrical and Computer Engineering (IREECE) program as part of the Research Experience for Undergraduates (REU) sponsored by the National Science Foundation (NSF). The program was ten weeks long and in those ten weeks students from many different engineering disciplines completed a project focused on the electrical and computer engineering field. This project was started and completed during this program [2].

Microsoft Kinect Component

The squat exercise project can be separated into two main components: Microsoft Kinect system, and the balance board. The Microsoft Kinect uses MATLAB Simulink to measure and give feedback. Microsoft provided the function that measures and records the locations of each joint in a coordinate plane system. A program was then made to measure the knee and hip angles using the coordinate points. A pop-up window was made to show the user the results. The pop-up consisted of four divisions, left knee, left hip, right knee, and right hip, and the four divisions were labeled as such. When the right angles as described above were achieved the letters would turn green, otherwise the letters would be red. That way, the user would be aware of positive and negative feedback during their squat and adjust accordingly. There was a short delay after this to give some time in-between measurements. After each measurement was made, the angle was calculated, and the corresponding color of captions would change. All of the points were saved and after the squat exercise was finished, a plot of the angles was made.

The whole program for the feedback of the angles was made in MATLAB Simulink. First, the function provided from Microsoft recorded the coordinates of the knee and hip joints. Next, a main function gathered those coordinates and calculated the knee and hip angles. The feedback pop-up was also made in this function. After properties were described, *if statements* determined when the captions would turn from red to green. A short delay occurs after the pop-up initiation part of the function to reduce the number of samples of samples otherwise the sample size would be exceedingly large and is unnecessary for this application. The last part of the function includes a plot of the angles versus time that occurs after the Simulink program is stopped.

Balance Board Component

The balance board consisted of four sets of load sensors (SEN-10245) that are wired to a Dragon 12 Plus development board and uses the software Codewarrior. The load sensors themselves are variable resistors. There are a total of eight of them, and pairs of the load sensors are wired to an instrumental amplifier (INA114AP). This way, even the slightest change would be amplified. When one of the load sensors is pressed the difference in resistance is measured. This made four usable load sensors, one on each corner of the balance board. The board was made out of wood and aluminum. The design was made using a computer added design software package then made to the specifications. The main part of the board is made out of plywood, and the feet that

housed the sensors were made out of aluminum. The feet were not fixed vertically so that when the user stood on the board, the weight would press down onto the load sensors housed inside. Since each load sensor had a different variable rate, the program included an initial calibration. When the user stepped on the board, the amplified difference was read by the Dragon 12 Plus development board through the analog to digital converter and sent to Codewarrior. After ten readings of the sensors were made, the average was calculated. Those values were then sent to MATLAB. In MATLAB center of mass was calculated. A pop up was made that displays this center of mass in real-time. A general area of acceptation was made, and when the center of mass was in this area, main points on the graph would turn green. If the user went out of this area, the main points would turn red and a warning noise would occur. This gave the user positive and negative feedback for the user to see in real-time. Combining the Kinect and this balance board together gave the user a way to read both their angles and their balance while performing their squat exercise.

There were two parts to the programming of the balance board. First, a code in Codewarrior was made in C language to read the output from the analog to digital converters. An initial code synchronized the rate at which the load sensors would increase. This was done by placing a weight at the very center when the code is initialized. The code would read those initial values and changes the rates accordingly. After, a constant loop started with a moving average code that would constantly take ten samples and average them to increase accuracy and reduce the number of samples of samples. Those averages were sent out to MATLAB. A MATLAB function read the averages then calculated the center of mass. That calculation was echoed back to Codewarrior. The feedback pop-up was then initiated. Properties were described then a plot appeared on the pop-up with gridlines for the center of mass. As part of the function, the center of mass would appear as a dot that changes as the center of mass does. If statements in MATLAB determined when the main points of the figure would turn green or red, and a piece of text in the pop-up would display Balanced or Unbalanced. In Codewarrior an if statement was made so that the speaker on the Dragon 12 Plus board would sound an alarm noise when the user is unbalanced.

Results
Refining the Design
Several design iterations were completed as the components were tested and integrated into a single unit. Initially, the Kinect portion would just calculate the angles then display them on a graph after the exercise was performed. Examples plots of angle versus time are shown below in Figures 1 and 2.
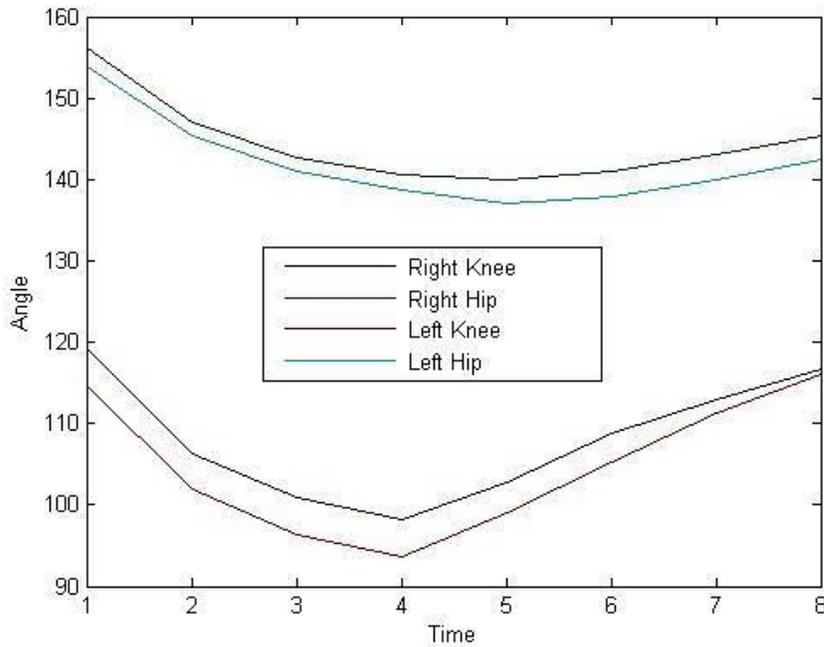
Figure 1 Example of initial testing with Angle (degree) vs. Time (seconds)
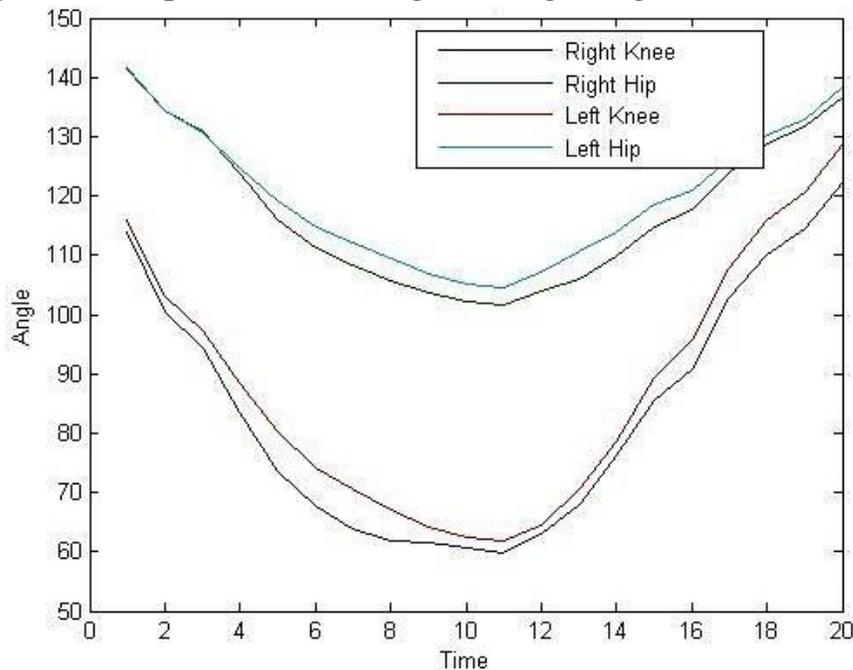

Figure 2 Another example of initial testing with Angle (degree) vs. Time (seconds)

After the initial testing, it was clear that the feedback of the angles should be shown in real-time. This testing also revealed the accuracy of the Kinect, and proved it to be a useful way to measure the angles. After initial testing of the balance board, it was clear that instead of recording all of the measurements, they should be averaged so that the sample value would be at a reasonable value. This would increase the accuracy. Initial testing has also shown that over time the delay in

reading the coordinates from the Kinect increases. This increasing delay is an improvement that needs to be made for the future. Further testing is needed to see the full accuracy and usefulness of this program.

Improvements for the Future

Considering the project as a concept or prototype, there are a lot of improvements to make. The first purpose for improvement would be the cost for this project. The Kinect itself is very useful in finding the locations of each joint, but since the project only uses it for that reason, a simpler solution could be made. A possible replacement would be an infrared sensor or a webcam. When it comes to the cost of the balance board, a more finalized design would need to be made. The feet could be made out of a cheaper material other than steel, possibly a type of plastic to save on cost and weight. When it comes to the board itself, some improvements should be made. The first improvement would be to make the board out of a more durable and lightweight material other than wood, but that may cause the overall cost of the balance board to increase. Also since each sensor increases its resistance at different weights, a more accurate and sensible load sensor should be used. Improvements could also be made to the MATLAB and Codewarrior codes. For the Kinect the increase in delay overtime should be corrected so that the Kinect can be more accurate and closer to real-time. The balance board has a 400 pound weight limit, which would cause a user with weights to be unable to use it. Load sensors with higher weight limits would correct this problem. Further testing would bring about more improvements that need to be made.

Conclusion

The purpose of the Perfect Squat Project was to be able to measure a squat exercise in real-time. That purpose was achieved. The Kinect for Microsoft measures the knee and hip angles during the squat, while the balance board measures your balance. The Kinect program was done in MATLAB Simulink, while the balance board was done in Codewarrior and MATLAB. This project is a functional prototype and as such many improvements need to be made. In the future more testing needs to be done. Testing for this project would be most beneficial by having Oakland University athletes use the machine and record their results and opinions. To do this an IRB approval to test human subjects in and a possible collaboration with the OU athletics department would be necessary to move forward. Overall, this project shows the possibilities of measuring physical exercises in real-time without the need of a personal trainer.

As a student with little experience before the project, a lot of knowledge was gained in during this process. First, knowledge in C language and MATLAB language programing was gained and became the most useful asset to the project. Second, knowledge in electrical components and wiring was acquired to successfully use the load sensors. The ability to use basic research procedure was obtained in this project. In just ten weeks this project went from idea to an actual usable concept, and the knowledge gained from being able to do hands-on research and

experiencing engineering concepts first hand is something that will set the foundation for the future as an engineer.

Acknowledgements

References

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[2] Leyva, J. (2011) How Deep Should You Squat? Q&A. *BUILTLEAN.* Retrieved From: http://www.builtlean.com/2011/12/12/how-deep-should-you-squat/