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Work in Progress: Developing Senior Experimental Design Course Projects Involving the Use of a Smartphone

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Introduction

The Mechanical Engineering senior laboratory course at the University of Idaho is a project-based course that focuses on experimental design and requires students to design, perform and analyze their own statistically based experiments. A difficulty that arises each semester, especially in the Fall when there are 40 plus students, is finding enough appropriate experiments that can be designed, ran, and analyzed in the last two-thirds of the semester (the course is one semester) with minimal funds. In the past, we used “canned” projects or Senior Capstone projects; however, the canned projects were not interesting to the students and it is becoming harder to develop short, fast statistical experiments (must use either confidence intervals, factorial ANOVA, or regression) from the capstone projects. With the widespread use of Smartphones and mobile computing devices, we thought using these devices would be an interesting and inexpensive way to develop new projects each semester.

In the Fall 2013 semester, we had two student teams develop experiments to obtain engineering data on human balance using a balance board and their Smartphone with a purchased app. The purpose of the experiments was not to teach students to use Smartphone apps, they can already do that effortlessly, but to have an inexpensive way for them to collect engineering data that they could analyze and make statistical conclusions. We did anticipate using the app to show students ways to collect data in addition to the traditional methods and how to transform the data into something useful for analysis. Overall, what we hoped to accomplish in this pilot semester were developing projects that could apply one of the three statistical designs taught in the course, would result in data related to engineering, could be reused each semester without being exactly the same each time, and, most importantly, students are excited about doing.

This paper will present the process the students took while developing and completing their projects, the observations of the faculty during that process, the lessons learned, and the future of the projects.

Student Experimental Design Development and Testing

It was decided to use a Fitter Rocker balance board (Figure 1) due to the ability to reuse it each semester and the ease of attaching a holder for the Smartphone while testing. We also knew a variety of tests could be performed with minimal time commitment and funds, two very important aspects of the course. Eight students selected the “Stability” project in the Fall 2013 semester even after the class was told that they would be creating this project from scratch. They formed two teams of four students each and were initially tasked with finding an appropriate app (Accelerometer Monitor, Dev: Mobile Tools, Version 1.6, Android IOS) to use (Figure 2) and build a casing to hold the measuring device. Developing an app would have been more time consuming and possibly limited to one Smartphone platform. Therefore, it was decided to purchase an app instead to allow the use of any Smartphone and an app that has been thoroughly tested. Purchasing traditional balance testing equipment, such as force plates, motion capture, and force sensors, to use in the experiments is not possible due to limited funds. In contrast, the purchase of an app on a Smartphone the students already own costs $1 to $5 per team. The experiment can also be repeated each semester without wear and tear on expensive equipment that would eventually need to be replaced. The balance board may need to be replaced every two to three years, which translates to approximately $35 per year; much less expensive than other equipment. Additionally, as apps are becoming more common as tools to collect and analyze data; students should learn how to use them for more than just fun and games.

The seed research questions provided to the students were “what is human balance?” and “can balance be measured and thereby understood?” From these two questions, the students began to research the topic and develop their experiments. Based on previous studies on balance,[1, 2, 3, 4, 5] the students formed their research questions and objectives. Both teams focused on using the results as a possible way to design sports equipment, such as bicycles, for an individual based on their balance profile. This guided their experimental design and selection of independent variables. The faculty members mentored both teams in the development of the experiments, but ultimately the students used the prior studies and their own experiences with the equipment to create the final designs.

Figure 1. Balance board

Figure 2. Accelerometer App

Team 1 decided to test if gender and/or Body Mass Index (BMI) had an effect on time of balance and the frequency; they tested balance in only the side-to-side direction. Team 2 wanted to test the affect of height and direction (side-to-side versus front-to-back) on the amplitude and frequency of an individual’s balance test. To keep the experiments simple, both teams decided to use the 2^2 factorial experimental design they had previously used in a class assignment. Team 1 tested the two levels of gender (male/female) and divided BMI into low and high levels. A low level of BMI was less than 25 and corresponds to a person that is considered normal weight or underweight. Therefore, a high BMI level was any value 25 or over and corresponds to an overweight or obese individual.[6] The team tested three individuals in each category (three females with a low BMI, three with a high BMI, etc.). Each subject completed the test once resulting in 12 total data points for the experiment. Team 2 tested the two levels for direction (side-to-side and front-to-back) and then tested only males with a “normal” BMI at two levels of height. The cutoff height for the low/high levels was the average male height of 69.1 in.[7] A height below this value was considered “low” and anything above was considered “high”. Team

2 collected data from ten individuals in each category of height. Each subject performed both of the tests, resulting in ten samples for each combination (side-to-side and low height, side-to-side and high height, etc.), with a total of 40 data points.

Once the teams decided upon their experimental designs, they worked out a schedule to share the board and collect their data. They then developed a method to convert the raw data into values that could be used in Minitab 16.1 for their statistical analysis. Examples of the data from Team 1 and Team 2 can be seen in Figures 3 and 4, respectively. The only independent variable found to have a statistically significant effect on balance from both experiments was height (p-value = 0.067) for Team 2 at a confidence level of 90%.

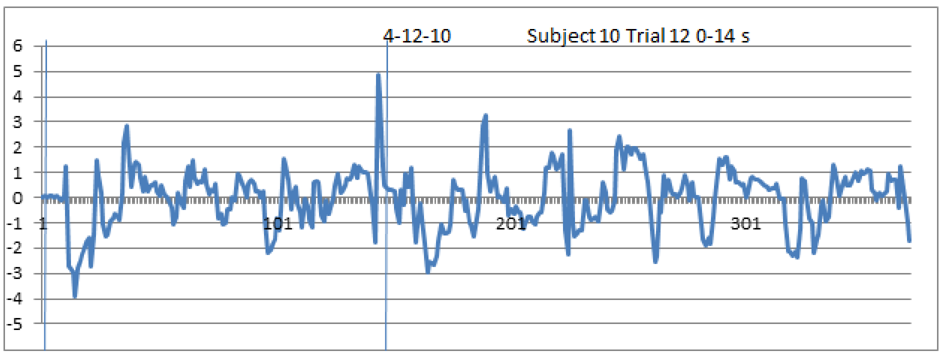

Figure 3. Subject data example from Team 1

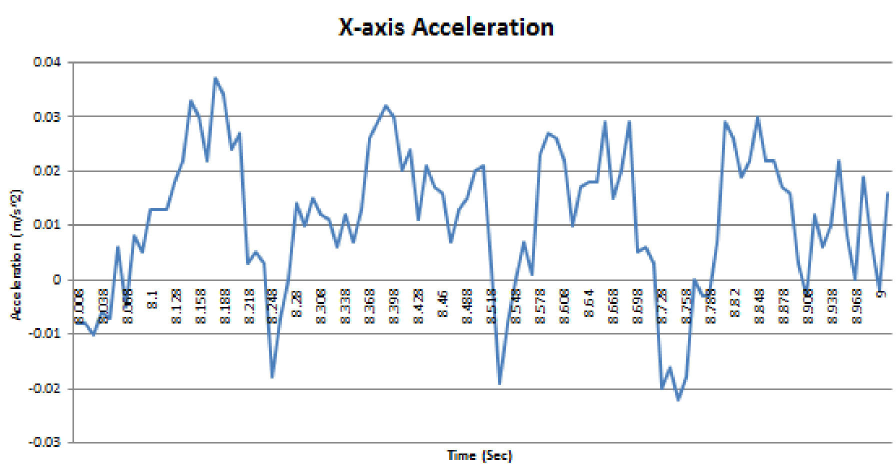

Figure 4. Subject data example from Team 2

Faculty Observations of the Process

During the first meetings with the teams, the faculty members discussed possible research questions for the experiment such as is there a difference between front-to-back and side-to-side balance, does it change over time (i.e., does the mere act of measuring it influence future measurements), and does mild fatigue change balance and if so can it be measured? Some of the considerations we were hoping the students would consider were sampling rates, length of experiment, data recording and transmission, and transforming the data into something useful.

Since this was a new experiment for everyone involved, we left the project very open-ended and let the students develop their own experimental design. Although the students met regularly with the course instructor to make sure their statistical design was sound (it was required), they did not take advantage of the other faculty member to help transform their data after collection. It appeared that the students wanted to do their own thing and not what may have made their projects more applicable and given them better results.

We as faculty hoped that the projects would result in the students finding what a balance profile looks like, discovering how much movement there still is even if the person appears to be balanced, how some factors such as gender, body mass index, and gender may affect balance, and being able to design a successful experiment. The students did develop fairly successful experiments (will be discussed in the next section) and determined that not just one or two factors determine a balance profile, but not to the extent that they could have. It was also evident that although they could use the app successfully in collecting the data, they had trouble with the transformation and knowing how extract the exact data they needed for the analysis. Although we were not completely pleased with the results the students produced, we were pleased with the possibilities we discovered throughout the process. We had used this as a trial-and-error process to develop successful projects for future semesters, and that goal was achieved. However, there are still a few things that should be adjusted and researched further.

Discussion of the Process and Future Use of the Project

The students included their opinions of what went wrong in their experiments as part of their final reports. Some of their suggestions were to include more factors, increase the number of subjects, be more restrictive in the testing process (e.g., make sure it is exactly the same for each subject), increase the levels of the factors (e.g., not just low and high BMI), improve the sampling rate and extraction of data, and improve the testing platform (e.g., one that is more stable). These findings from the students reinforced to the faculty that the projects did indeed teach the students what was intended even if there were issues with the end results. All the goals of the pilot semester were met: the students applied one of the three statistical methods and designed appropriate experiments; they collected engineering data using a non-traditional method through their Smartphone and acceleration app; two teams used the same equipment but developed two completely different experiments that could easily be repeated without duplicating the exact same results or minutely tweaked to create additional experiments; the students were engaged and invested in the projects throughout the process.

Overall, the students were very pleased with their experiences with the project. They stated that it “improved [their] design outlook” and they enjoyed that the project allowed them to “experience a full project through all the design stages.” The two teams also expressed that the project helped with their scheduling skills because the two teams had to share the board. They had to test when they were scheduled or they may not get the chance again for a few days. Although the results did not show significant results, the teams mentioned that it was “interesting to see how different people balanced and to figure out why they had better balance than others.” These responses indicate that the project was a success in terms of student interest, learning the experimental design process, and trying to understand how different factors affect balance.

The faculty member teaching the course had a unique insight into the projects as she had regular meetings with both teams and was actually a subject in one of the experiments. None of the comments and observations made by the students was a surprise to her, and was pleased that the students recognized the short-comings of their experiments yet felt that they learned a great deal from the process. Since there have been senior capstone related projects in the past that do not receive the same student feedback, we believe that this project will continue to be appropriate for the course and keep the students interested. It will also allow for a minimum of two projects each semester, which will reduce the burden of finding suitable projects greatly. The use of the Smartphone and app also showed that we could create additional projects with different apps, further decreasing the number of outside projects needed. This project showed that although students may know how to use various apps, they do not necessarily know what to do with the data that is collected. Implementing projects that involve the use of mobile technology will not only "update" the course but teach students that apps can be useful tools in engineering.

Although we attained results that met all our goals, there are still improvements that can be made to make the experience for both the students and faculty better. First, there should be more structure in the initial problem statement, especially if we want to create three or four unique projects each semester. This would be as simple as including a question to be answered in the project description. Examples are those that the faculty initially expected from the students: How does fatigue affect balance? Does balance change over time? Is there a difference between front-to-back and side-to-side balance? With these preliminary questions, the students would have a direction for what they are measuring and need to figure out how. A second improvement would be to further stress the importance of controlling variables that you are not directly measuring. This would include the way each subject performs the test, how the data is recorded, etc. It is not expected that a perfect experiment will be run and not controlling some things actually teaches the students the importance of doing so, but these were items that the students in the pilot semester specifically mentioned. Making sure future students try to control at least one of these variables would illustrate how you need a structured plan and still demonstrate how environmental factors can affect your results. The last main improvements are concerned with collecting the data with the app and transforming it for further use.

Probably the biggest problem that was observed by both the students and the faculty members was collecting the correct data with the app and how to transform it for analysis. This is still being examined. Since the students did not take advantage of the faculty member that had the expertise in this area, they had trouble first deciding exactly how to collect the "right" data and then how to select and use the data they collected. Since a Smartphone can collect data through accelerometers and gyroscopes, the students needed to first recognize what was being measured while the person was balancing and which would be best for their analysis. They then needed to understand the profiles of that data and recognize the events represented (e.g., when the balance board hit the ground). The students took all of this on themselves during this pilot semester and the data they collected was actually not as useful as they originally thought. This means that we will need to collect more data with the balance board before we can include appropriate ways to transform the data. The faculty will be working on this aspect during the Spring semester so that the projects will be ready in Fall 2014.

Conclusion

We believe that the use of Smartphones and mobile computing devices will provide us multiple projects in the foreseeable future with a little more structure and research on how to transform the data. This will reduce the stress of finding new projects each semester with minimal funds. It will also allow students to gain experience with a new engineering tool: apps. The results of this pilot semester indicate that simple projects with just a balance board and Smartphone can teach engineering students the process of designing and analyzing a statistical experiment.

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