Undergraduate Research Final Written Report

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Introduction

Examining the symptomatology in rodent models of joint disease can give insight into the characteristics and possible therapeutic strategies for humans suffering from joint diseases, such as osteoarthritis. A mechanism used in Dr. Allen's lab to carry out this kind of research is the EDGAR, or the Experimental Dynamic Gait Arena for Rodents. EDGAR, which consists of an instrumented floor with built-in force platforms, can be used to simultaneously measure both spatiotemporal and dynamic gait parameters. These force platforms collect ground reaction force data when an animal makes contact with the ground. While this innovative system is very successful in providing data that can be analyzed and evaluated, it is also an extremely costly model. Hence, this semester our design team worked on coming up with an alternative to EDGAR– one that would provide similar benefits but at a much cheaper cost.

Planning

The first meeting for this course took place on January 20, 2023. Initially, the first meeting was supposed to occur a week prior on January 13, but due to a scheduling conflict, Dr. Allen decided to push the first meeting back. Prior to this first meeting with Dr. Allen on January 20, 2023, the undergraduate team completed several online safety assignments in order to be authorized to enter and work in the lab. During this first meeting, initial introductions were made as well as expectations for the semester as well as an overall outline of how Dr. Allen wanted the semester to follow. He wanted January to be spent brainstorming, February to be spent narrowing ideas down, getting quotes, and ordering parts, and then March and April to be spent actually building and designing.

Dr. Allen stated that the overall goal of the course was for the undergraduate research team to brainstorm and eventually design a relatively inexpensive but still accurate method of measuring the force the rats and mice being used are exerting. It was important to try to figure out an inexpensive method since the current method the lab was using, albeit fancier and capable of measuring x, y, and z directions, cost thousands of dollars to make and run. For the method the undergraduate team would be in charge of creating, it was only necessary that the model created could measure forces in the x direction. Dr. Allen thought by only requiring x direction, it would make the overall design process simpler and less expensive, especially since none of the undergraduate students had prior experience in this field. Other than forces needing to be measured in the x direction, there were a couple of other requirements. One requirement was about the size of the platform as it was necessary that whatever platform the rodents would be on in order to get a force reading would have to also be big enough where the rodent would have enough space to walk across rather than just stand on. The other requirement was that the force platform that the rodents would walk across would also have to be transparent so that the walking movement can also be viewed from the underside of the platform. Dr. Allen suggested that perhaps plexiglass could be tried as the force platform since it is transparent. Dr. Allen also suggested looking into capacitive touch screens since it could still allow for the transparent platform and can supposedly give force-accurate readings. Dr. Allen said that his group experimented with the idea of using capacitive touch screens but never did proper research to see how it would work and whether or not it could be feasible, so he suggested that the undergraduate team should look into this since it could be an innovative idea if the logistics were to be figured out. Having the flexibility to explore other ways of designing a force platform and the way the force was a shift from the initial course description as initially, the CURE students were going to use the capacitive touch screens to measure the force. After the undergraduate team spent the first 30 minutes of the first-class meeting speaking to Dr. Allen, a tour of the research space was given as well as a safety debrief. The undergraduate team was introduced to the different supplies that they would have access to throughout the design process including many spare part boxes that included glass, plexiglass, and other materials.

For the next two class meetings, brainstorming was done on the different possibilities that could be used to measure the force the rats exert. Initially, the list of ideas that the undergraduate team thought of trying was very long. Initial ideas that were included on the first draft of options to try included building our own force platform using glass and multiple transducers and pedestals, using force plates, building a mini treadmill for rats with IMUs under it, using wearable pressure sensors for the rats, using capacitive touch screens, using load cells, using single tact force sensors and Arduino board, using a MatScan system, using a walking mat system, using floor sensors, using force plates, using pressure sensors, using the image processing system, and using Hallifecter rays. Dr. Allen then wanted this long list of possibilities to be narrowed down to 2-3 most probable methods. To narrow down the options, several factors were considered such as cost, the time it would take to build, the probability of it working, feasibility, durability, skills needed to build/ utilize it, its compatibility with certain software, size, sensitivity, etc. For example, although the building a treadmill for the rodents with IMUs (inertial measurement units) underneath is sounds like an innovative idea and did prove successful in trials with human, since this was only a semester long project and since none of the researchers had prior experience, this idea would not have been probable. After crossing out all the possibilities that seemed too far-fetched given the circumstances, there were eventually two that remained. These were the capacitive touch screen and the Single Tact force sensors which would use an Arduino board and plexiglass as the force platform.

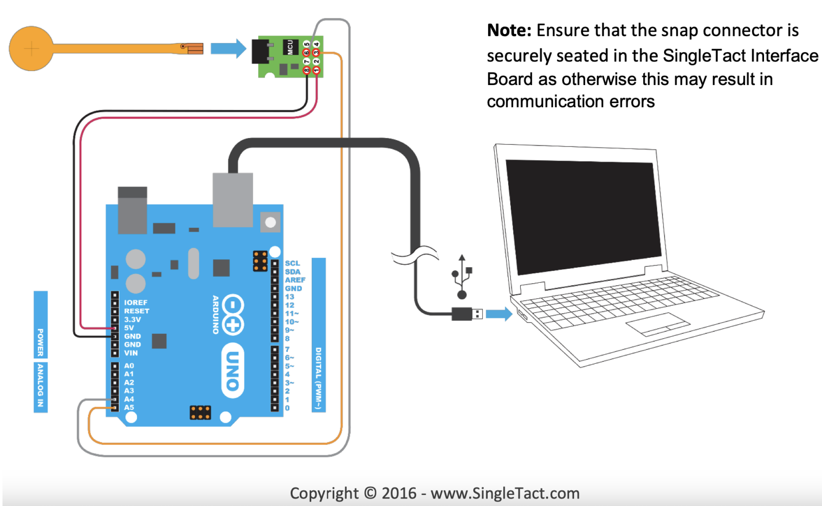
After spending a class listing the critical components of both possibilities as well as ranking their characteristics, it was determined that the main advantages of the sensors with plexiglass was that it had an affordable cost, it would accommodate whatever size was needed, it would be easy to construct, it would be adaptable, it would be compatible with Arduino (no hidden costs in terms of trying to download software), and its sensitivity was within the proper lower limit needed (.25 for 10 N sensors). The main disadvantages of going this route was that no one in the CURE group was familiar with Arduino so it would be necessary to spend time to familiarize with it, that there could be discrepancies between actual and measured forces due to location of foot strikes, that sensors may not be able to distinguish between plexiglass and rat, and that the sensors will not be able to automatically determine where the foot strike is. Conversely, the main advantages of using the capacitive touch screens were that it would be highly sensitive and can determine location of force as well as measure it and it would require no building. However, there were several disadvantages with using the capacitive touch screens. These included that it might be difficult to interface with Arduino and that the sizes available for purchase would not be large enough for the rodent to walk across meaning it would likely become expensive to find a touch screen with the proper size. Because of this, we determined the Single Tact force sensors were the safer route as it hit all the criteria we needed as it could measure forces in the x direction and since the plexiglass that would be used as the force platform would be large enough for rodents to walk across as well as transparent. Additionally, the force sensors would be easier to interface with Arduino than the capacitive touch screen would be and there would likely be less hidden costs associated with using the force sensors compared to the touch screens. We then asked to purchase two calibrated Single Tact force sensors which cost $120 as well as two uncalibrated Single Tact force sensors which cost $25.

Method

Our team initially decided that the best mechanism to explore our research question was to use SingleTact force sensors connected to an Arduino UNO board. The Arduino board could then be connected to a Windows computer with a Windows PC via a USB cable. Considering that these SingleTact sensors are ultra-thin and miniature, they have the capacity to deliver incredible sensitivity, accuracy, and repeatability. Because the sensors are able to detect even the most minute pressures, we thought this would be an effective way to measure the individual forces that a rodent exerts as it walks on a platform. Another benefit to using the SingleTact force sensors was that they are compatible and easy to interface with the Arduino board. This would allow us to see the data captured by the force sensors in real-time and then save that data to the PC in order to further analyze it.

We set up the system by connecting the SingleTact sensor to an FFC connector on the green interface board which was then connected to the Arduino board using four wires, as shown in Figure 1. We then downloaded and installed both the Arduino software and the SingleTact Arduino firmware on the computer. Once these installations were complete, we connected the Arduino to the PC using the provided USB cable. The next step was to configure the Arduino board by opening the Arduino IDE software and uploading the provided SingleTact Demo code. Although programming the Arduino was time-consuming, this process would only need to be completed once before the initial trial. Because the code is then stored after the first trial, subsequent uses of the Arduino would be much quicker and simpler.

Figure 1



The obstacle our team ran into as we worked on this project was that the Windows PC, we were using, would not recognize the Arduino board. Because of this error message, we were unable to open the Arduino software on the lab computer. Another disadvantage we realized was that the Arduino was only capable of generating a graph of the data from a single sensor on a certain type of computer. However, we wanted to be able to collect data from more than one sensor since the rodent being tested would be walking along the platform, rather than staying still in one spot. Consequently, we had to scrap this idea and turn to another solution.

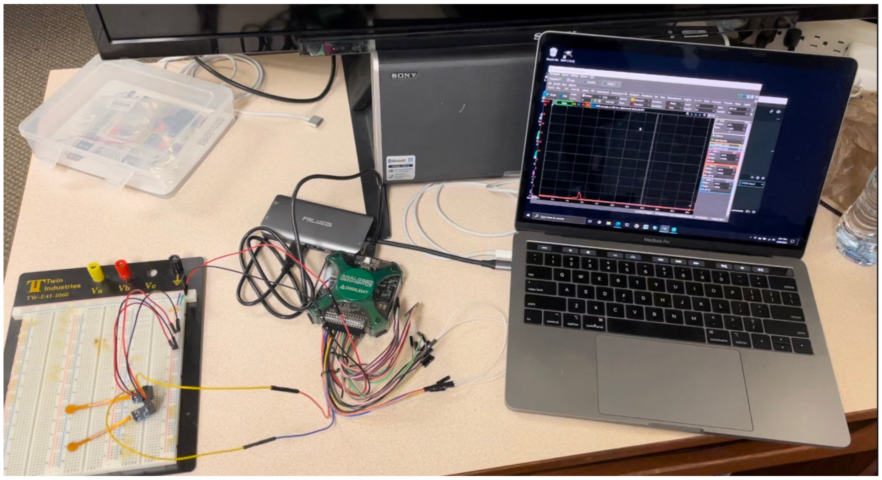
Having not been satisfied with a graphical representation of only one sensor, we went back to step one. We sought to understand how the sensor worked again and went through the user manual. About halfway through, we come across the basic idea that the sensor transmits electrical data, and an oscilloscope is compatible with the sensors. After more research, we see that an oscilloscope can be used to graphically represent electrical inputs and a unit of our choosing. From this, we realized that one of our team members' roommates has a device that had two oscilloscopes built in that would be perfect for syncing two sensors together. This device is a Digilent Analog Discovery 2. This device has many more capabilities, but we only needed the oscilloscopes. We set it up relatively simply where we used a breadboard and 10 total wires. Following basic wiring methods, we set up the wires and ensured everything was connected to the ground and power.

Figure 2

Wire Number	DAD Port	Wire Color	Sensor/Actuator or DAD Port	Comments
1	C1+	Yellow	Sensor1-2	
2	C1– (striped)	White	GND (–)	Use DAD GND wire #3
3	C2+	Yellow	Sensor2-2	
4	C2– (striped)	White	GND (–)	Use DAD GND wire #4
5	V+ (5V)	Red	Board-VCC	
6	Board-VCC	Red	Sensor1-1	
7	Board-VCC	Red	Sensor2-1	
8	GND (–)	Black	Board-GND	
9	Board-GND	Black	Sensor1-8	
10	Board-GND	Black	Sensor2-8	

After downloading the waveforms software that interfaces with the DAD, we were able to use its graphing capabilities using a mathematical formula relating to volts and force. We set up force in Newtons on the y-axis and time in seconds on the x-axis. How this worked, is that it took the electrical input (in volts) and converted it into Newtons which it would then graph. Another aspect of this that was superior to the Arduino was that we were able to sync the sensors together where we would get a total force. It also shows the individual sensors' force readings as well. For example, if we placed an object closer to sensor 1 the total would be 8N but sensor 1 would show about 5N. Now, if we placed the same object closer to sensor 2 the total would still be 8N but sensor 2 would now show 5N. In addition, the code that we were faced with developing for the Arduino method was starting to get very complicated because we wanted to integrate two sensors. With this method, there is no code needed. Another aspect in which this is superior is its calibration. We were able to set it up and program it in a way where it calibrates during each startup. This means that if, during trial one, you just have the bare force sensors, any force you apply will be the force read. If, during trial 2, you set up a plexiglass floor on top of it, it will calibrate and disregard the force of the plexiglass and only read the additional force applied. It is the same concept as the zero button on a scale. It calibrates so that there is no additional math required. After the initial setup, we can adjust the time intervals to whatever we like using the tabs given to us. We can also adjust the Newtons' axis depending on which type of sensor we obtain. To set up for each test, we set up our wires and could use the wiring diagram we made. Then, we would connect it to our computer. Next, we would open up the software and turn the master supply on. It is very important to set everything up before you turn on the master supply because that is when it calibrates itself. After that, it reads the electrical input and displays a force output. We decided that this was the much better method and was the one we should present on our display date. The DAD2 costs 400 dollars. The calibrated SingleTact force sensors cost 125 dollars each. The Dupont wires used for connecting the DAD to the sensors and the breadboard cost 5 dollars. The breadboard itself costs 5 dollars. After that, you just need a working laptop capable of downloading the Waveforms software. In total, the price of this design is going to be about 660 dollars.

Figure 3



Conclusion

This project involved a variety of concepts and products that were foreign to all of us. In the beginning of the semester, we had to put our heads together, brainstorm, and research potential solutions to the question at hand. Some of our ideas proved to be a little far-fetched, both due to prices, the duration of the project, and level of expertise required for some of our ideas. Two examples exhibit these obstacles perfectly. First, the idea of building our own force platform using glass, multiple transducers and pedestals was one that would have provided far fewer satisfying results at the end of the semester. Building a force platform would have taken a great deal of time and would have been way outside of our budget. Additionally, we would have needed to learn certain skills that could have involved soldering or electrical engineering, to name a few. Second, we thought about building a mini treadmill with inertial measurement units underneath it. This also would have been expensive and the idea itself came from a research study which involved humans, not rodents. Scaling a treadmill for humans down to an appropriate size for the rodents would have been more involved than necessary. This is not to say these two ideas wouldn't be effective or worth producing, however. After brainstorming and producing several effective solutions, we decided the best option would be to stick with one of our cheaper and easier ideas: using an Arduino board and force sensors placed underneath a sort of plexiglass platform to get our force readings.

In the process of pursuing this solution, we learned fairly basic skills within the Arduino software as well as the process of connecting wires using a breadboard. None of us had ever used either of these devices before, so there was a bit of a learning curve and obstacles to overcome. Even with these skills, the software proved to be quite the challenge. We struggled for a large part of the semester with getting the computer and Arduino Uno board to recognize the calibrated Single Tact sensors.

It is safe to say that trial and error was a major theme for the majority of the semester. Throughout the process of focusing on one idea throughout the semester, we made plenty of mistakes and hit a number of dead ends. Our time in the lab consisted of testing one route of connecting wires, for example, and then diverting to a different application if we found that our initial methods were ineffective. It is through these mistakes and use of inefficient methods that we were able to move on as a team and learn to work more efficiently. As time went on, we utilized techniques that would save us time and warrant more satisfying results.

Over the last few months, all of us honed and employed skills that we've used in the past in different courses and group projects. The four most significant of these skills include collaborating, communication, critical thinking, and flexibility. Through our brainstorming at the beginning of this project, we communicated and collaborated. We listened to one another's suggestions and took them into consideration; we collaborated by doing research on the same topic and sharing our findings to pick out the most useful pieces of information. Our critical thinking and problem-solving skills were arguably the most employed. In trying to understand why the computer refused to recognize the sensors, we had to consider a variety of angles. Were the wires connected improperly? Is something wrong with the computer? Would another computer warrant different results? These are all questions we asked ourselves in the process of attempting to solve the problem? Finally, flexibility was a skill that came about at the very end of our time together. After focusing on building a plexiglass platform using calibrated force sensors and an Arduino board, we switched gears, ditched the Arduino, and discovered a much easier route to display our force readings. The Digilent Analog Discovery 2 (DAD) was just what we needed to solve the issue. The DAD was a much simpler device that required no coding, unlike the Arduino, and used an app to display a graphical representation of the forces exhibited upon the sensors.

In our first semester of undergraduate research, we learned that, sometimes, research and design can lead you down a path of working on a single idea for months, or even years, until you and/or your team decides the design is ineffective and you move onto the next solution. Yes, this process can be frustrating, but finding a design solution that works perfectly for the research question at hand is satisfying, to say the least. In our opinion, this design with the DAD and sensors is something worth pursuing and the procedure is cost effective and simple enough that the product can be elevated. Finding the right platform for the sensors to lay upon, pinpointing a way to hold the sensors down so that we can get accurate readings, and ensuring the sensors are sensitive enough to capture a reading as the rodents' paws hit the platform are just three examples of how this design can be altered to foster most effective results.