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|  | Telescope Project |

Memo

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| To: | Troy Scevers |
| From: | Nathan Wiley |
| Date: | March 22, 2023 |
| Re: | Memo 1 |
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Apologies for the late memo, I realize it won’t be graded, but I wanted to give a report based on the tasks that I completed. The last section of this document is my writing documentation log from WR 350, which is to write 100 words a day about a project (I chose my senior project). It will provide a dated log of tasks that were completed as well as insight to my thought process.

In total, I worked approximately 150 hours this term on the project.

My updated Gantt chart for this term is as follows:



# Documentation Log:

1/9/2023:

For this log, I will be writing about my senior project, which is making a motorized dobsonian telescope. Last term I constructed most of the base for the telescope and ordered the motors, drivers, and power supply. This term I will be finishing the base and physical construction of the telescope, and wiring, programming, and testing it. So far, the project has gone really well, with important tasks being completed according to schedule. I am excited for this term because this is when it all comes together, and I am starting to see the whole project coming together. This week I plan to finally finish the construction of the base and talk to George Drouant (one of my engineering professors) about the wiring between the power supply and motors.

1/10/2023:

I need to make a detailed schedule for this term for my project. Last term I made a good one and stuck to it pretty well and I think it helped me. This term it is more important to stay on track because by the end of this term, I have to have the telescope be functional. Some important tasks that I need to get done soon is to order a belt and pulley system and if I need to, design and print a larger pulley for a 4:1 gear ratio. Last term I learned the basics of Autodesk Inventor and I think I can design something a little more complex like a gear for the pulley.

1/11/2023:

Today we had our first senior project meeting, and it looks like this term will be much more structured than last term which is a relief. All of the assignments and meetings are already laid out on the canvas calendar, so I feel good about that. I turned in some books about telescopes and astronomy that I borrowed from the library. I might need to rent them again because I didn’t read them all the way. I need to learn more about coordinate systems and sidereal time because after I figure out how to move the telescope, I need to know where it needs to point and move too. I found some astronomy videos on YouTube that cover this so I will look at them later today hopefully.

1/12/2023:

I'm excited about this term because I will finally learn what all of the math behind the functionality of the go-to telescope is. I think that the math course I am taking, (applied differential equations 1) will help in the understanding of it as it is more than just trig in 3 dimensions, there is also speed and acceleration of the motors that drive the telescope. Once I understand it all, I will be very proud of myself and I think I'll finally be able to shake off some imposter syndrome. I hope that I can apply all of the math correctly in code, because it won't count for much if I understand it all, but I can't get the telescope to perform the movements.

1/13/2023:

Today I stayed home and got to clean out my car, which is where the main tube and stand of the telescope has been sitting since the end of last term. The mirror was extremely cold and when I brought it inside, it fogged up from the warm air condensing on it. The fog lasted quite a while - over an hour. This is something I need to take note of when trying to use it soon after moving it from cold to warm to cold again. The mirror looks a little dirty too. I need to take it out and clean it soon. I should also think about getting a cap or cover to go over the tube when it is not in use to prevent dust and water from getting on it.

1/14/2023:

I’ve got the raspberry pi, the brains of the project, hooked up to a wireless SSH connection to my PC. I’ve configured it to be able to be programmed by visual studio on my PC so that I can program, build, execute, step through, and debug remotely all on the PC. This will be great going forward as I won’t have to have the Raspberry Pi plugged into the computer whenever I am testing or programming it. I will also be able to send it updates if I find a problem in the future. If it is possible, I want to further extend its compatibility to be able to be programmed and such from a computer that is not on the local connection. That would let me be on my laptop on another LAN and still be able to access it.

1/15/2023:

I started some code to start familiarizing myself with stepper motors. I’ve got a much smaller stepper motor and driver that I was able to connect to the Raspberry Pi and control the movement. It seemed to have a stuttering problem so I hope I will be able to figure out how to use micro stepping correctly soon. If I can do that, I should be able to drive the large stepper motor with 1/256 micro-stepping. This would reduce the jittery feeling significantly and will be good for the final project because it will have to be pointed as a specific point with as much stability as possible. I also hope that I don’t run into too many problems when transferring to the big motors.

1/16/2023:

I had some issues with the old “Wiring Pi” library which lets you use the pins on the Raspberry Pi. The recommended one to use now is Pi GPIO or PIGPIO. I had quite a few difficulties getting it working as not a lot of people would have it set up like I have. I found one YouTube channel that helped me set it up with Wiring Pi, but the instructions didn’t translate to PIGPIO. I ended up figuring it out on my own by adding remote root login and adding that login info into Visual Studio. It works now with a specific template of the project because there are a bunch of project settings to make it work right.

1/17/2023:

I have my meeting for the project set for tomorrow. I still need to make a schedule for this term. I made a list of things I need to get done, but I haven’t put dates to them yet. It doesn’t feel like I have a ton to do this term, which is probably wrong, so I should be careful with getting too comfortable. Last term I made a schedule in Excel, and it worked very well. I think I will make a similar schedule and do my best to stick to it. We only have 2 memos as opposed to last term's weekly memos, so I think this documentation log will help me keep on track in the absence of the weekly memos.

1/18/2023:

I did my advising meeting today with Troy. He gave me tips on what to make the schedule about and I’ve started filling it out like last term. I am behind already which is a little discouraging, but I’ve been doing good in my classes and extracurriculars, so I don’t want to beat myself up too much for that. Once a lot of these events are over, I will be able to focus more on the telescope. I just hope I can finish it all in time. I’ve talked to a lot of people about the math and software side of things, and they say it will be harder than I think it is. That scares me a bit…

1/19/2023:

I am starting to think about the final look and aesthetics of the telescope. I want to make a large decal to go along the body of the tube to make it a little flashy, but that won't be a priority until the next term probably. Other embellishments I need to add are warning stickers such as "moving parts" or pinch warning near the gears. I found a site that sells high quality waterproof warning stickers for pretty cheap, so I will probably get them once I wrap up the main project.

1/20/2023:

Today's class was a good one. In it we had the exercise about explaining our projects to a partner and making sentences concise. I think this will help my projects documentation and instructions if I make them. I also am trying to get the telescope in a semi functional / presentable state so I can show it off for the club expo on the 25th. I think I can paint and screw in some more pieces to finish it up over this weekend. I need to add the leveling bubbles as well, but I don't think it's as important to get done by then. I am also considering getting a poster printed for the club, but I'm not sure if I can do that in time.

1/21/2023:

I’m preparing a bunch of material and events with my club, so I haven’t had a whole lot of free time to work on the senior project today. But I can write about it! I’m thinking about the belt drive and pulley system, and I’m going to go for a set of GT2 3D printer belts as a first try. I figure if it can control the fine movements of a printer head accurately, it should be able to point a telescope accurately.

1/22/2023:

Today I finally got around to drilling some holes in the base and vertical mounts of the telescope’s base. It has been too cold to paint them though, as it’s recommended to paint between 50- and 90-degrees Fahrenheit. It is supposed to get up to 43 degrees Fahrenheit on Tuesday, so I might paint it then and hope it works ok. The weather forecast is still pretty bad, so I might have to wait until the end of the term for the finishing touches.

1/23/2023:

I want to clean my office soon so I can get a workspace that I feel like I can use. It is pretty cluttered, and all of my parts are still in boxes. I heard that I might be able to get a lab in the CEET building to be able to work on it at school which would be nice. I feel like I can’t get as much work done when I’m at home because I am always watching the kiddo who needs attention and care. Maybe I can arrange to have my mom watch him in Medford so I can hunker down and focus on the project.

1/24/2023:

I cleaned my desk area which improved things quite a bit, but the way my office is laid out, I have another desk that is the “project desk” and it is still a mess. I wish I had a garage to work on this project! That would make all of the parts and machinery a lot easier to store and I wouldn’t have to pull everything out of storage and set up to clean up and store things every time I wanted to work on the project. Also, the telescope itself is so beefy and it takes up so much room, it would help a lot to have a proper place to put it.

1/25/2023:

I really hope I can waterproof this telescope sometime. I am worried that the electronics, hardware, and cardboard tube just won’t be able to hold up to the elements. In Klamath at least, the frost and snow are particularly worrying because the water freezing can wear things much faster by splitting things apart. I think a metal or plastic tube for the telescope would be a worthwhile upgrade, but it would likely be very expensive. I think if I were to redo this project as a personal hobby, I would do a smaller, equatorial or barn door style telescope as they make for better astrophotography setups.

1/26/2023:

I am looking into the Raspberry Pi HQ camera, and I really would like to use it. However, the ribbon cable it comes with is very short, and I’ve seen people have a lot of problems when trying to use one that is longer. It looks like about 2 or 3 feet is the max length for the cable, and I’m not sure if that would be long enough to reach up to the eyepiece if the Raspberry Pi is mounted on the bottom of the turntable. I might have to make an entirely separate module that runs off of a Pi zero perhaps, and it could control a motor to counteract the rotation of the image. One good thing about that is that I already have spare motors from the shipping mishap!

1/27/2023:

Today I had a meeting with the rocketry club, and I gave them an update on the project. I am feeling confident in the design of the telescope, but I am still concerned that the execution will be harder than I thought. I wish I could have gotten a proper proposal for Oregon NASA Space Grant Consortium (OSGC) written up a year ago with multiple disciplines involved, but I didn’t have the chance. This is how the Rocketry club has mainly done projects in the past.

1. Get group together that wants to do a project.
2. Write a proposal to OSGC.
3. Get funding for said project.
4. Do the project as their senior project.

This has gotten a lot of people involved in the club in the past, so I hope doing my project as more of a solo route won’t hurt the club.

1/28/2023:

I had an interview with the MIT Lincoln Laboratory, and we started talking about the project that I’m working on. It sounded like one of the interviewers is working on a tangentially similar project, pointing a laser with 2 axes of freedom. We got to talking about how to calibrate it, and I brought up that I thought about using a 6 Degree of Freedom (DoF) accelerometer to use. We both agreed that it might help, but it would be very difficult to set one with the “less than a degree” precision that I am hoping for. I then brought up that I have seen others use a manual star alignment calibration technique and that seems to be a better approach.

2/1/2023:

I was thinking about that calibration method, and I don’t think that would be as simple as I thought. I didn’t consider the fact that the stars would appear to move in between star measurements. Even if I only used 3 stars, I would still have to manually align them and that would take at least a few minutes, maybe 10. If every 1 minute is 360 degrees / 24 hours \* 60 mins = 0.25 degrees of rotation at the equatorial line per minute. This would be simple enough for stars at that line, but it would get hairier when aiming away from that line. I think if I figure out the movement between any 2 points, I can figure this part out a little easier.

2/2/2023:

I heard about a comet going overhead and I wanted to try to look at it with the big telescope, but it was very cloudy, so I wasn’t about to see anything. I hope I can get it usable by May 5th because there is a lunar eclipse then and I want to try to view it with the telescope. (Hopefully it won’t be cloudy that night too!) Although I’m not sure if it will be visible from here.

2/3/2023:

Today we had our asteroid identification campaign. It uses data from the Pan-STARRS telescope which is a huge permanent installation. One day I hope to be able to use my telescope for similar (less clear) observations.

2/4/2023:

I ordered some parts today! In order to finish the assembly of the telescope, I will need a way to attach the drive for the vertical and horizontal movements. I am still hopeful in the belt and pulley system, and I think it is the way to go on my budget. I ordered the level shifter so my raspberry pi can finally talk to my stepper motor driver, and I also got a bunch of parts for the mechanical assembly. I ordered a set of 5 meters of timing belt along with pulleys. I also ordered a coupling to go from the 8mm shaft of the motor to a 5mm rod to drive the gear of the pulley.

2/5/2023:

I need to start mounting the motors to the telescope itself. I have 4 metal brackets that can hold the motor in place against the wood, I still need to figure out the position though. I am worried that if I make a belt by splicing, it will get caught in the gears and won’t drive properly. It would be beneficial to me to sketch it all out with dimensions so I can figure out how much the belt will rotate around for 1 rotation of the large gear. If the large gear can make 1 full rotation without the belt joint hitting either gear, that would be ideal.

2/6/2023:

Today I drilled some holes in the turntable base for the motor mounts. I will need to find a good size of hole to drill into the side panel so the motor’s shaft can reach the outside of the plate. It needs to be sturdy enough to hold the belt’s tension so I might have to 3D print some kind of bearing holder or something.

2/7/2023:

It’s feeling like it’s all coming together! It’s exciting, but I hope I’m able to finish programming it before it’s too late. I’m not sure how I’m doing as far as progression goes compared to the other seniors, but I think I’m doing ok. Most of my grade will be from the work agreement and I said I would have a lot of the software side of things done. I really should have put more tasks in the hardware side.

2/8/2023:

I should be getting my timing belts, pulleys, couplings, rods, and level shifters today. I want to get a lot of work done within the next few weeks. I am supposed to have a demo-able project by the 28th, so it is really crunch time and I sure hope I can put it all together in time. I think I will work on the layout of all the parts today and sketch up a wiring diagram. I wanted to run the wiring diagram by George for approval before I hook everything up, but I’m starting to run out of time, so I think I might just trust my own judgment. (Which hopefully won’t come back to bite me!)

2/9/2023

I’ve made a wiring diagram, and everything looks right. I can’t see any issues with shorting or overvoltage in the design. Luckily, the wiring isn’t too complex since it is just connecting two motors and their drivers to power and logic controls. I still need to find a suitable housing for the electronics. I found some boxes on amazon that are waterproof and have a transparent lid. I think that would look great and would make it more easily serviced.

2/10/2023

Today I designed a 3D file for a pulley gear for the motors to rotate. I downloaded a file for Autodesk Inventor that allows you to enter a custom number of teeth for the pulley and it generates a drawing for it. I used this to create and modify a 40 tooth GT2 pulley gear. I ran through the options of a 1:2, 1:3, and 1:4 ratio to find the largest ratio I could use with a belt tensioner and a belt “splicer” joint connecting the two ends of the belt to form a loop. Since the joiner can’t go on the gears, I have to find the number of times I can rotate without the joiner hitting one of the gears. I calculated that the 1:2 gear ratio is the largest I can do for the horizontal axis. I could go with a 1:4 for the vertical, but then I would have to account for that difference in software. I would like to keep a single function for controlling the two motors, so it simplifies things on my end.

2/11/2023

I found out that the pulley generator I used was for belts with 3mm pitch and my belt has 2mm pitch. So, the gear that I printed won’t even fit the belt at all. I redesigned it and found a file that works for 2mm pitch belts. I printed 2 pulley gears at the same time, so I don’t have to wait for 8 hours to get one. I will print these starting now and they will continue printing overnight so they will be ready when I wake up.

2/12/2023

The two pulleys finished printing this morning and they turned out great! The important part is that they fit the belt I am using. I am worried that they will slip because the PLA plastic is very slippery. I am working on mounting the motors and I realize I need something to hold a bearing for the horizontal mount.

2/13/2023

I went to Home Depot today and bought a few supplies in order to hook everything up. I bought 2ft. of 14-gauge wire, electrical tape, and some solder. I ran into some old co-workers too (I used to work there) which was nice. I plan on wiring everything together soon, so I needed the supplies, and I figured I might as well go today.

2/15/2023

Today I finally wired all of the components together. The main thing was connecting the power cord plug to the power supply. I had to get that thick 14-gauge wire in order to not burn the connection that I was hooking up because of the high power draw. First, I cut the 14 AWG wire to short lengths and got a pair of wire strippers to create a nice connection. Then I wrapped the wire around the plug’s connections and soldered them together. I did a “tug” test to make sure they had a good connection. Then I plugged it into the wall and got a multimeter to test the output. I got good measurements and since the power supply has a variable voltage, I was able to adjust the output voltage and measure it with the digital multimeter in the lab to confirm the onboard 7 segment display was accurate (which it was). After that I hooked up the positive and negative output terminals of the power supply to the VCC and GND of the stepper motor drivers. This is what gives the motors enough juice to run properly. I packed everything up and took it home where I finished connecting the 5V logic levels of the stepper driver to the level shifter

2/16/2023

This morning I hooked up the level shifter to the 3.3V Raspberry Pi end and started measuring voltages with a handheld digital multimeter. My measurements should be 3.3V for the input and 5V for the output of the level shifter, but I was reading 3.3V input and 2.5V output. I’m not sure what happened. I ran out of time to work on it because I had to get to class, so I will continue to work on it probably later tonight or tomorrow.

2/18/2023

I turned in my draft report for the project. I didn’t really change too much, but mostly added and updated things in it.

2/21/2023.

Next week is the design review presentation and I am really hoping I can get it in shape in time.

2/22/2023

My level shifters aren’t working how I thought they would, I might have to find an alternative. They aren’t shifting the 3.3 to 5V, it doesn’t make much sense. I am following the documentation of the chip perfectly.

2/23/2023

I found someone that used 2222NPN transistors to use 3.3v to drive the logic between 5V and gnd to the driver. I have some laying around so I might try that. -Update I tried it and it works great! No need for the logic level converters anymore! I will need to solder this cause it’s pretty loosey goosey on the breadboard.

2/25/2023

I hooked up all the motors and pulleys and it works! My code is really basic right now, it only moves back and forth, but soon I will add some way to control it. The belt seems pretty spongy and it isn’t as tight as I’d hoped. It seems to be slipping pretty often. I think the pulleys are too small so they can’t get much mechanical advantage to turn the heavy scope. It is easy to move when it’s balanced, but it has a lot of mass, so switching directions makes the belt slip.

2/26/2023

I’m considering using this chain I have from a VEX robotics kit. It’s high strength plastic, and it is said to hold 50 lbs. I don’t have any large gears right now, but I might be able to print some. I know I’ve done that in the past and it worked pretty good. The CAD files are on VEX’s website so I could download them and modify them to fit my mounting hole for the base and rocker wheel.

2/27/2023

A picture containing outdoor, sky, car, snow

Description automatically generatedGot into car accident.

3/9/2023

I 3D printed a wheel for the chain drive, and it seems to have turned out ok. The chain kind of pops off of it, but with enough tension, I think it should hold fine. Definitely won’t have the slippage issue.

3/10/2023

My printer got all gunked up and I can’t seem to get it clean enough. Every print turn into a glob of melted plastic now. I asked a friend who has a 3D printer to print off the last gear for me so hopefully I can finish in time.

3/13/2023

I got everything together, now to start working on the code! I think I am going to start on the sidereal time code because it seems pretty important to the whole operation of the telescope.

I got a GMT / UTC clock working but I’m having problems with the conversion to sidereal time.

3/15/2023

I fixed a problem in my Julian date function, now it correctly outputs the “continuous count of days and fractions since noon Universal Time on January 1, 4713 BC”. Also, I made all of my functions static so I don’t have to instantiate an actual instance of the class to use the utility functions. I added a few functions to calculate the Earth Rotation Angle (ERA) and they seem to agree with each other. One is much faster though, so I will probably go with that one.

3/16/2023

I finally got my local sidereal time working and it’s accurate! I’m so happy that it precisely matches what stellarium shows. This should make things easier and more accurate going forward. I started working on and completed my Alt/Az calculation function too! Now if I know my location and know a star or object's location in the sky, I can calculate where I need to point the telescope! I still need to connect that location to a function that actually moves the telescope however, but for now this is great progress.

3/17/2023

I painted the side of the telescope mount and put some finishing touches on it. I also ordered my electronic housing which should come in soon. It will be able to comfortably hold all of my electronics and keep them safe from water. My work agreement meeting is today so I will probably be done working on it for the term.