8/23/18

Today we reviewed the forms required as well as the article assignment's due date. I uploaded my background research paper, proposal, and feasibility study from last year. I began to search for more articles for the article assignment.

8/27/18

Today we received our ACL laptops and listened to the seniors' presentations for the first lab meeting. We also uploaded our presentations for next class.

8/29/18

Today we presented our project proposals for the first lab meeting. Comments on the presentation:

1. Warpage is a major issue in large-scale applications as well as the 3D printing community; therefore, this should be my main reason why I'm doing this project.
2. Label infill types on the presentation
3. Create a separate presentation about the Lee's Disc for Mr. T to work with MATA - needs to be done
4. Add a graph of the Steinhart-Hart equation to the presentation
5. Use the Series 1 Pro printer and make sure it is working
6. Work with Kieran to find if the infill percentage really is the ratio of plastic to air because hexagonal infill is bigger than rectilinear based on pure geometry. We can measure the weights and see if they are actual infill percentages.

8/31/18

Today I searched and found 3 articles for the article assignment on ScienceDirect.

Zhang, J., Wang, X. Z., Yu, W. W., Deng, Y. H. (2017). Numerical investigation of the influence of process conditions on the temperature variation in fused deposition modeling. *Materials & Design, 130,* 59-68. doi:10.1016/j.matdes.2017.05.040

Zheng, X., Wang, L. W., Wang, R. Z., Ge, T. S., Ishugah, T. F. (2014). Thermal conductivity, pore structure and adsorption performance of compact composite silica gel. *International Journal of Heat and Mass Transfer*, *68*, 435-443. doi:10.1016/j.ijheatmasstransfer.2013.09.075

Sombatsompop, N. & Wood, A. K. (1997). Measurement of thermal conductivity of polymers using an improved Lee's Disc apparatus. *Polymer Testing, 16,* 203-222. doi:10.1016/S0142-9418(96)00043-8

9/5/18

Kieran and I started working on fixing the Series 1 Type A machine for our research projects. We don't know what the problem is yet, but there is

A) no spool holder

B) the printer won't create a WiFi network

C) we can't connect to the printer

We built a new temporary spool holder and are working on fixing the printer.

9/7/18

We fixed the printer today. The issue was that the SD card for the printer interface was loose.

To connect to the printer: http://series1-2092.local:5000

9/11/2018

Today, I divided my project into phases. I made a Gantt Chart in Excel depicting the phases.

I also got the Heat textbook from Mr. T for my project. I did some research about the Lees Disc as well.

9/13/18

Today, I read about the Lees' Disc Method and worked on the presentation for it.

9/17/18

Today, I started my work on the Arduino/thermistor circuit. I read about how to create a voltage divider and how to use thermistors with it. I started testing the thermistor with a multimeter, and I wrote some code for the Arduino and got some analog voltage data from the thermistor.

9/19/18

Today, I worked on fixing my Arduino code with the voltage divider. I am getting infinite values for the readings, so the code or the circuit needs to be fixed. I may have to ground something.

I also got the files from the Arduino starter kit CD on Google Drive.

9/21/18

Today, I finished my temperature sensor. The issue was that the thermistor was broken, so I used one from the Arduino starter kit. The sensor works now.

9/25/18

Today, I worked on my ED. I finished the problem statement and worked on the hypothesis. I also created a plan for the Lee's Disc, and found the correct heights for each disc and chamber. The new sample size is 0.5 inches, and the height of the steam chamber has to be 4 inches tall. The radius of each of the discs has to be 4 inches as well, with a thickness of 0.5 inches. I will work with the MATA students, and ask them to build the chamber and the metal discs.

9/29/18

Today, I worked on my ED (the dependent variable section. I need to explain the entire Lees' Disc)

10/1/18

Today, I worked some on the ED some more and got to the Procedure section.

I also found the correct thermistor to buy from Mouser (500 thermistors for approximately $127.50):

https://www.mouser.com/ProductDetail/Amphenol-Advanced-Sensors/TH420J34GDNI?qs=P8zB4ONU6fzOyUXxdGay3g%3D%3D

Amphenol Advanced Sensors, 200K Ohm Glass Encapsulated 25 degrees Celsius NTC Thermistor (TH420J34GDNI)

10/3/18

Today, I worked on my ED and reviewed a senior project board. I started the procedure section.

10/12/18

Looked through previous infill research project prints and continued with the ED procedure and statistics sections.

10/16/18

Today, I worked on the ISEF forms and the statistics section of my ED.

Project changes: 5 trials for each of the infill combinations.

Statistics: I will run a two-factor ANOVA with replication on the data set of thermal conductivity for two factors: infill percentage and infill type. I will use inStat for two mroe data tables coming from the large data set: 5 versions (for each infill percentage) of the infill type on trial thermal conductivity and 3 versions (for each infill type) of the infill percentage on trial thermal conductivity.

Notes from discussion with Mr. T: This year, I will focus on analyzing thermal conductivity changing between infill combinations. I will still collect thermistor data for each of the 75 total discs so that I can do a modeling project next year.

Additionally, I will measure the thermistor data while printing, and while measuring thermal conductivity. It will also be measured in a new part of the project to analyze warpage: Laser-based distance sensors will be used on the object while it is heated using a "heated bed" to see if the object warps, and to see the distribution of temperature with a heated bed.

10/18/18

Today, we worked on improving and editing our statistics section. I talked to Dr. Crowe about my statistics section as well.

10/23/18

Today, Nicole peer reviewed my ED and statistics section. I have to segment my ED some more.

Mrs. Hiltner, the librarian, came to talk to us about the various library databases we have access too. APS is the most important database for my project.

10/25/18

Today, I worked on my stats section of my ED.

10/27/18

Lab meeting day.

The seniors and some of the juniors presented their projects today.

10/31/18

Today, we worked on putting together the drill press and bandsaw and organize some of the tools.

11/2/18

Today, I presented my ED justification presentation and began work on the Lees' Disc CAD model.

11/8/2018

Finished risk assessment form, parent approval form (signed on 11/10), checklist form 1A, and research plan (background + ED).

Working on abstract form

11/12/18

Today, I submitted my ISEF forms, began the acquisition form for the steam generator and PLA, finished CAD model for the steam tank, and began work on the first disc design.

11/14/18

Today, I turned in my acquisition forms and I researched designs for the Lees' Disc.

11/16/18

I got my acquisition forms signed off by Mrs. Chang and Mr. Goff. I finished CADing the rest of the Lee's Disc apparatus. I need to find the dimensions of the Vernier Temperature Probe to make holes in the brass discs.

11/20/18

Today, I finished the CAD model of the Lees' Disc and I made a presentation for a collaboration with Monroe.

11/27/18

Today, I started the CAD model for the basic infill printing design. I am adding the holes to place thermistors. I also found out that the Amphenol thermistors had been back-ordered by 13 weeks, so I found new ones that can serve the same purpose.

Link to new thermistors: https://www.mouser.com/ProductDetail/594-NTCLG100E2203JB

New thermistors' datasheet: https://www.mouser.com/datasheet/2/427/ntclg100-222390.pdf

11/29/18

Today, I sent in the new acquisition form for thermistors. I worked on the CAD model again and edited my presentation for Monroe collaborati

12/3/18

Today, I talked to Mr. Putman about welding the Lees' Disc and set up for presentation on Friday. I made a new design for the ring stand of the Lees' Disc and started the CAD model, started an email for Mr. Putman with the new model and presentation, and changed the Lees' Disc tank apparatus CAD model.

12/5/18

Today, I sent the email to the Monroe Welding teacher. Finished CAD Model of the stand. Fixed the Series 1 Pro printer. Received 4 spool PLA order.

12/6/18

I organized the research room and worked on the Series-1 pro printer.

12/11/18

Today, I received my steam generator and tested it (success!). I also presented to the Monroe welding students at 12:30. They said it is possible to build me the chamber.

12/13/18

Today, I worked on the CAD model for the stand and for the Lees' Disc, moved one of the steam chamber holes lower to account for more air flow. I also began planning out my data collection:

1. start with rectilinear infill because it is easier to insert thermistors and learn how to do the process, print all 5 discs (for the trials)

2. print the hexagonal infills because it gives a better infill to compare to if there is not enough time to do triangular, print all 5 discs

3. run thermal conductivity tests last because if there is a lack of time, I can just drop some of the infill percentages. It also gives the Monroe students time to work on the apparatus

4. If time permits, print and work on triangular infills

12/17/18

Today, I worked on making the parts list to build a better PC for the research room to run the programs we need.

https://pcpartpicker.com/list/LqQLBb

12/19/18

Today, I filled out an acquisition form for Winchester Metals (for the Lees’ Disc).

1/2/2019

Today, I got the order status on my thermistors. They will be in the room by next class. I also sent in the Winchester Metals acquisition form.

I will have to use 2 Arduinos because each board only has 5 analog pins and I am using 10. I began slicing the next hexagonal disc.

1/4/19

I got my thermistors and I tried testing the code that I made earlier. It works, but I'm going to have to use 2 Arduinos. I also am still looking for the proper thermistor coefficients for the ones that I have.

I also need to remake the CAD model for my disc design. Each disc should have a bottom half of thermistors and channels leading outwards, and then the top half would be printed with a regular infill. I will probably print 0.1 inches from the bottom normally, 0.15 inches with channels and compartments for the thermistors, and then print 0.25 inches of normal infill. I wanted to change it so that I could just heat up the entire disc after I measure it, but Mr. T told me that its better to do it while printing because no data has been collected for this before and because the warpage really only occurs during the printing process.

1/7/18

There is no research class today (it's a B day) but I still did some work on the thermistors.

This is the exact thermistor model I bought: NTCLG100E2203JB (link). I finally found the datasheet for it, which has important values for me to use (link). Using the data sheet, I found that the resistance value at the standard 25 degrees Celsius reference temperature was 20kOhms, with a tolerance of +-5%, and a B25/85 value of 3977. With these, as well as other data sheets with other reference temperatures, I was able to construct a curve with the resistance vs. temperature data (attached) from -55.0 C to 200 C, and was finally able to find the Steinhart-Hart thermistor coefficients. I was also able to check with a program called My Vishay Curve computation spreadsheet. The thermistor coefficient values are: A = 0.003354016, B = 0.0002569850, C = 0.000002620131, and D = 0.00000006.383091

I modified the Steinhart-Hart equation and was able to use these coefficients to create a better curve for my thermistors, and I programmed it in Arduino to test in class.

1/8/2019

Today, I was able to fix the program to actually give temperature values. I also made the program work for two thermistors, and I'm working on connecting more to the board.

1/10/19

Today, I redesigned my CAD for the discs to have a single layer (.1 inch thick) in the middle for the thermistors to be placed horizontally. This makes it much easier to CAD and it makes more sense because there is more actual infill and no holes being made compared to the old design with compartments and channels. I need to work on the new design next class.

1/16/19

(2 hour delay, less time)

Today, I fixed the Dremel printer, worked on the Series 1 pro printer, and worked on my CAD model.

I had a lab meeting with Mr. T as well, and now I have to talk to the Mr. Linsicome and check if his printer is big enough to support my print because the Series 1 doesn't work. (as of yet)

1/22/19

We set up the tools and equipment that care in today. I finished the final disc template but I can’t print it because the Series 1 is broken (clogged extruded). Kieran is going to bring an accupuncture needle because it is the right diameter to unclog the nozzle. We tried fusing the PLA, cold pole tests, and nylon fusing. We even used a soldering iron to warm up the extruder.

1/24/18

Today, I unloaded some more tools and helped organize the bags. Mr. T discussed the new bag organization (we have to sign out a tool bag if we're going to use it, no more taking just 1 screwdriver or something). It has a lot of tools (especially electrical).

I also worked on the 3D printer. Next class, Kieran is going to bring an acupuncture needle to fix it, but we found a better one to buy (the Rais3d pro2 for $4000, it has an 12x12x11.8 inch bed and a dual extruder. I also helped Kieran with the mark 10 press and trying to get a load-extension graph for a Young's modulus calculation.

My metal also came in. Mr. Putman emailed me, and I went in to talk with him before lunch about the final design.

1/28/19

Today, I rewired and taped down my thermistor setup. I added tabs to the Serial output format so I can easily copy it to Excel. I let my program run all throughout class, leaving 1 thermistor in my laptop bag, 1 on Kieran's laptop charger, and 2 out in the open. I graphed the distribution on Excel. The data was pretty accurate, and the graph is adequate for me to use to show the distribution for this year's analysis of my data. I also worked on the Series1 printer and we found that the problem was caused by the extruder's thermistor wires not being connected. The hot end clip doesn't have any of the crimp pieces, so we had to recrimp them. However, we decided to do something else next class: take another extruder (that HAS the crimps and the clip all working), cut the wire, and solder it to the wires of the extruder that we already have. I also marked my first brass discs at 90 degrees on the edges for me to drill 0.75 inch deep 0.315 inch diameter holes for me to put in 1 inch bolts so that I can hang the disc up. Mr. T and I bolted a vice into the table so that I could drill next class. Goals for next time (1/28/19): Make a midterm presentation and present (basically the entire first-day presentation of problem, hypothesis, variables, materials, method, data so far (essentially the thermistor distribution that I have), and where I have to go (Monroe is going to work on the aluminum disc and finish it soon, T ordered a printer with a big enough bed so that I can finally print) Work I still have to do: Drill holes into the brass disc for bolts AND the temperature probes Assemble the Lee's Disc Apparatus when Monroe finishes Start printing.

2/5/19

Today, we had our midterm research presentations. I also worked on a presentation so that the AOS engineering research class can get new 3D printers with Jean-Paul. We will be presenting next class.

2/7/19

Today, we watched two presentations and worked some more on a presentation for more 3D printers. We researched different printers and I talked to Mr. Linsicome and I found out about the Taz 6, the Mark 2, and the CR-10 that he has. He recommended the CR-10 for our requirements of a high build space.

2/11/19

Today, I worked on the PC for a while and then went to Mr. Putman to see the status on the steam chamber (he was busy but I got a look at it and its almost done).

2/13/19

Today, I fixed the PC in the back and got my Arduino program running on it. I also marked and started drilling my brass discs by hand, but the drill bit would always slip out of the hole and was difficult to mark and use. Mr. T used the drill press with a 0.5 inch stop and my 5/16 inch drill bit to make 2 of the holes, and he said he would work on the other 2 after class.

2/15/19

Started class by drilling the other 2 holes in the brass disc. I asked Nicole to show me how to get a thread in the holes, so Nicole taught me how to tap the hole with the right thread:

1. Check the chart to see what size tap https://www.lincolnmachine.com/tap_drill_chart.html

2. Add fluid into the hole

3. Put the tap into the tool and turn until it is even and inside the hole a little

4. Make 1/4 of a turn, then make 1/2 of a turn back. Repeat until the hole is the right size

I threaded one of the discs, but I didn't get to find the right size bolt.

I need to get the Series 1 to work later. I also will make a 3 week plan later today

2/18/19

I came in today at around 12:30 and left at 2:30. JP and Ayush had told me that they had fixed the Series 1, so I plugged it in and tried to connect with the Toshiba but found that the same problem was back (thermistor/extruder hot end was broken with error code 0, max temp reached). I then decided to work on the Lees' Disc and I made each of the holes in the first disc deeper and threaded them using the tap. I found only 4 bolts that work with the drill bit we have, so I decided that I would have to use a smaller drill bit size for the next disc. I measured some of the bolts that we have and used the tap drill chart to find the right bit, but didn't drill anything. Instead, I used the 15mm wrench to tighten the bolts into the first disc.

I decided to change the design of the holder for the apparatus; instead of 2 ring stands and a metal part between them, I decided that I will simply build a wooden "box" to enclose it. I was in the storage room and I saw a similar box, so I searched for wood that was thick enough and not being used by anyone. I placed the disc on top of the wood to mark the top of the "box," and I left a 2 inch buffer on both sides (meaning I will cut a piece with length 12 inches since my disc is 4 inches in radius). I marked this part of the wood but didn't have time to cut it. I also decided that I would use the remaining wood to make the "walls" for the box.

Tasks for Wednesday:

- Check if Monroe finished the chamber, bring it to the room
- Cut the top of the enclosure
- Drill 4 holes to insert a hook so I can use metal chain to hang up the discs
- Drill holes on the edges for attaching the sides of the enclosure
- Cut the sides (if there is still time)

Remaining tasks in this subsection (after Wednesday):

- Put the enclosure together
- Drill and thread the second disc
- Hang the discs up with the tank and generator

2/22/19

Today, Mr. T and Kieran cut my wood pieces so that I can build my enclosure. I also found the right size tap for my bolts (5/16) and drilled the right holes into the other disc. I didn't get to make the fifth hole but I am ready to tap next class and start putting the enclosure together.

2/26/19

Today, I threaded two of the holes in my disc with the 5/16 tap. I also talked to Mr. Putman about the design and he showed me the holes he had drilled and the aluminum plates that he would put on the tank, and he said he would weld it and tell me when he is finished. Sala stole my wood so I had to recut my enclosure pieces, and then I drilled into them and attached one side to the ceiling.

2/28/19

Finished enclosure today. Mr. T cut some flat aluminum bars to use as cross braces for the back, with one long piece crossing the whole back and 2 smaller ones in the opposite direction. I have to add the hooks next class and thread the second disc so I can hang everything up. Mr. T also said they are working on the printer situation.

3/4/19

I threaded both discs and added the bolts. I added hooks to the top of the wood enclosure, and since we couldn't find metal chain, Kieran and I came up with a solution of using nylon filament to hold the discs up. We cut 27 inch nylon pieces to hang up the bottom disc, and then soldered the end together. This solution worked well but is a little off in the adjustment, so I can use a level and just loosen/tighten one of the four hooks to make the disc horizontal. I need to cut more nylon pieces of length 25 inches for the disc closer to the aluminum chamber.

3/6/19

today we ran the lee's disc with 1 brass disc. everything heated up correctly and we reached a brass disc temperature of 75 deg. the Arduino wasn't connecting to my computer, so I had to use Kieran's.

3/8/19

Today we set up the second brass disc with zipties and ran the whole apparatus. Now we are waiting for the 3D printer. T says to learn the screw gauge, the entire lee's disc method, and then use my apparatus with materials like cardboard and wood.

We also decided to concrete the steam generator hose/pipe into the tank because it won't't be for anything else. We stuck duct tape on the thermistor so it wouldn't get covered with the water.

3/12/19

I drilled the second thermistor hole in the disc. I called gcreate and researched the prusa printers to find the educational discount.

gCreate order:

send email to info@gcreate.com about what school and what we're ordering, how we order (check? card?) and they will work with you for a discount
Heated bed plate add-on: https://shop.gcreate.com/products/16-x-16-heated-build-plate-and-digital-controller

gMat printer xt+ thing with dual extruder: https://shop.gcreate.com/products/the-gmax-1-5-xt-16x16x21-the-next-big-thing-in-3d-printing?variant=32666052550

Shipping in about two days if we order today, they will send it out tomorrow

Prusa: no educational discount. Lead time is 1-2 weeks though for the Prusa I3 MK3S. https://shop.prusa3d.com/en/3d-printers/180-original-prusa-i3-mk3-kit.html

3/14/19

Today, I went to Mr. Ajima to laser-cut a wooden 8inch disc for me to measure thermal conductivity for the March 21st LCPS maker fair. He told me to ask Mr. T to do it tomorrow when he's cutting his 1/2 inch plywood, and Mr. T agreed. Also, the nylon strings on the Lees' Disc broke and the apparatus collapsed. I cut binding wire to the right length so that I can solder it next class to use. I also fixed the Arduino program to run both thermistors so that I can get a steady state reading. It works on the Toshiba.

3/18/20

Today, I worked on fixing the Lees' Disc apparatus for the maker fair and tried different ways of putting it together, like having the discs on the top, but these didn't work (the tank's bottom haS to touch the discs for perfect contact and transfer). I also need to use cables and cable connectors for the final design, but for the maker faire, I'm just going to use binding wire.

3/20/19

I fixed the Lees' Disc today for Thursday's maker fair. I used binding wire. I also ran the apparatus with plywood, but was unable to finish the test because the temperature would not stop changing. I exported the data to a .txt and I used the python Matplotlib library to graph it.

3/22/19

Today, we cleaned the lab and reorganized a lot of the tools.

3/26/19

Today, we ordered the gCreate printer (expected to come next class).

3/28/19

Today, I checked the package room at the beginning of research with Kieran for the printer. it wasn't there.

This quarter, I finished my Lees' Disc apparatus and tested it (it works). I also decided to change this year to only hexagonal infills due to the lack of time. I also researched printers and made a presentation to get a good gCreate gMax printer. I also got to present my Lees Disc at the maker faire. I also made the thermistor setup better, and it actually works for measuring temperature distribution via 5 thermistors.

I failed to start my prints because we didn't get the printer yet.

4/5/19

Today, we set up the gCreate printer and I sliced the template disc to 20% infill and grid. I will begin the print next class.

4/5/19

Today, I started my first print! (20%, grid)

10% grid takes 7 hours

20% grid takes 10 hours

30% grid takes 12 hours

40% grid takes 14 hours

50% grid takes 17 hours

4/9/19

The last print worked well for the entire print. Today, I started the same print again so that I can insert the thermistors this time. I came in during math to put the thermistors in; however, when I tried connecting the printer to the computer, the printer aborted the print. I have to start the print again next class.

4/11/19

Today, I set up the heated bed and started the print again with a pause so that I could come back to put in the thermistors when the channel layer was ready. We also went to the balloon launch today.

I came back in the afternoon to put in the thermistors. What I learned:

1. it takes about 2 hours to put them in correctly

2. I need to use glue or some adhesive to put the thermistors in

3. puTTY can log the data for me

4. I need to make sure I have very long cables so that the printer can move the bed around while the Arduino stays in place

5. I can let it print for a bit and then manually pause it to start putting the thermistors in so that the print head goes to the corner and the bed comes out

6. two of the thermistors are not connected properly inside of the print, so they give inaccurate values (>385 degrees C while the others are only at 50).

Ultimately, the print resumed and the entire thing worked. Mr. T came in Saturday to unplug the Arduino so it would stop collecting data. I'm writing a python script to read in the csv file and find when the temperature values stopped changing and cut every row after that out so that I can clean up the dataset.

4/22/19

Today, I got the csv file from puTTY and began visualizing it using python.

The next print (20%) was not sticking to the bed all class so I used glue

4/26/19

Today, I fixed the gCreate printer by adding all the settings for the live Z adjust and the Z offset. I also had to store the settings so that they won't be wiped after the printer was turned off. Using the babystep Z setting, I started the print and lowered the extruder until it was close enough to the bed so that the filament would stick.

Printer settings:

Extruder: 200 deg. Celcius

Bed: 80 deg. Celcius in the 8x8 zone

Probe z-offset: -2.5

I also talked with Mr. T about data analysis, and eventually, I have to make a powerpoint explaining the logic behind a machine learning algorithm in Tensorflow 2.0 + Keras for the thermistor data analysis. I need to figure out which features and parts of the dataset to use, as well as which type of algorithm (quantitative regression vs. clustering vs. classification). If I were to use regression, I would have to predict temperature values at different points. If I used clustering, I would have to make the model cluster into the thermistor groups but I may have to integrate it with a neural network by pre-training the network with the labelled data. If I used classification, I would use the sigmoid function to predict whether there is warpage or not based on the thing. However, these are rough ideas and not the actual models or algorithms I will be using.

I could also calculate the gradient/slope between each temperature value in a certain second. This would involve plotting the points in 3 dimensions, with the x and y positions of the thermistor on the disc and the vertical (z) axis being the temperature at a certain second. This would mean that for each second, all the points would be at different positions and heights, and if the time was changed, the heights would change while the position remains constant. Using this, I could calculate the distance between the points or do some other mathematical function to find the temperature difference with respect to distance (the gradient) and would be able to analyze this for every point from every other point. I could then compare the gradient or the slope values to see temperature distribution. This could easily be modeled and calculated in python, but I will ask Mr. T before starting to write the script.

I ran an ANOVA on the first set of thermistor data and found that the temperature values were statistically significant with a p-value of 0 (this means that there actually is a temperature distribution).

Additionally, using an advanced data analysis such as these (especially the machine learning algorithms) would help my project's credibility and analysis significantly. I need to talk to Dr. Crowe soon so that I can change my project back into the Materials Science category, and although I will be competing with electrospinner/nano people, my data analysis would help my project. It is also a better fit in Materials Science (-Mr. T).

I'm coming in tomorrow (Saturday, April 27th) so I can put in the thermistors for the 20% lines print and collect more data. If I have time, I will create the cooling curve for the Lees' Disc and then start testing the discs (not likely due to time, I will probably get the cooling curve done if I work fast on the Arduino/thermistors and I don't run into many problems).

4/27/19

Came in on Saturday to put in the thermistors for the second print. I color coded the wires and made the Arduino better so that all I have to do is unplug the disc and I can reuse the Arduino each time. I also created a cooling curve for the Lees' Disc so that I could calculate thermal conductivity, and I finally calculate the first thermal conductivity value. (attached is cooling curve + thermal conductivity files).

4/30/19

I've been working on the math behind the temperature gradient analysis so that I can understand the temperature distribution. My python script calculated gradients between all the points (like 1 to 2, 1 to 3...). This is what I'm planning on doing:

If we plot the x and y positions of the thermistors as functions of time t, they would be constant for all values of t. However, I then added a temperature axis that changes with t. This means that at each time t, x(t) and y(t) are constant but T(t) is changing -- so the points are getting relatively taller and shorter than each other as time progresses, showing it getting hotter and cooler in different areas. Using these heights, I can calculate the temperature gradient between two points by finding dT/dt (change in temperature over the 2-dimensional distance between two points). However, this only gives me the gradients and doesn't let me see temperature distribution. Instead, I need a way to quantify temperature distribution. One way that I could do this is by analyzing midpoints: if we imagine 4 points in our 3D space, each at the same temperature (so they are all at the same height), then we can construct a linear plane with these 4 points. If we take the midpoint of these four points, this point would represent the "center of temperature" for these four positions. Because the temperatures are equal, there is a 0 net temperature distribution. If one point suddenly got hotter, then the new midpoint of the points, including the hotter one, would represent the new "center of temperature" for the new time t. If we compare the new center to the old center (when the temperatures are all the same), the vector from the old center to the new center would show the magnitude of the temperature change as well as the angle of temperature flow (only the angle on the xy plane would matter). This would give us some way to actually quantify temperature distribution. To do this, I need to find out how to get the center of "mass" where the mass is my temperatures, and I can use the physics formulas for center of mass and parallel axis theorem and stuff to figure it out.

Morning: puTTY didn't log for the 2nd print. I had to do it again.

Class: I ran the Lees Disc but the second disc didn't heat up at all. this was because I used black PLA, which could have changed the thermal properties. I started over with the gray filament. I also went through some of the math for the gradient analysis and found some papers on it, but I decided to just use midpoints for now because it is way too complicated. I might use the Fourier Heat Equation later. I figured out how to calculate the center of temperature between 4 points, but I need to find out if I should repeat this along all combinations of 4 points or find a way to construct a plane between all 8 points and then find the temperature center (which is probably a better idea).

5/1/19

no class

Today, I did lot of research on algorithms and models for me to understand my data.
Explanation of the problem:

I have categorical data (infill percent), and for each level of the categorical variable, I have another dataset. Each of these datasets is composed of temperature values over time at multiple positions. (each column is a position, each row is 1 second, each cell is a temperature value). I need to have a model that can understand the patterns between the columns of data (a pattern of what we know as "heat flow" - a single temperature value will eventually cause the next temperature value to raise soon) and the rows (what we know as time progressing). This means that the model has to be a combination of a multivariate time series analysis and something else that I don't know yet. Additionally, after it recognizes the patterns within the dataset, it needs to understand the relationship between these patterns and the specific infill percent, or my categorical variable. This means that there are nested variables for my model.

I did research on CrossValidation, StackOverflow, and some papers online. Notes from them:

- On StackOverflow, someone had a problem of nested variables and another user told them that to solve this, multilevel optimization (wikipedia) needs to be used. This seems extremely complicated so I decided I would look at this later.

- I asked my own question on CrossValidation because apparently nobody else has had to deal with data like this before.

- I finally found an extremely useful article: Temperature Distribution Measurement Using the Guassian Process Regression Method. I'm currently reading through the proposed methodology right now and trying to understand what they did. However, the entire article is useful. In the introduction, they describe the nature of the data that is typically collected using conventional methods, which is scattered temperature values -- EXACTLY WHAT I HAVE. Then in section 2, where they begin the proposal, they describe other techniques that are being used in the field right now. They start off by saying that " 3D temperature distribution predictions from the limited number of the measurement data can be formulized to be a tensor completion (TC) problem." I have no idea what tensor completion is but after more research I partially understood what a tensor is. They later state that there are numerous drawbacks to the TC problem method of finding unknown temperature distributions, and they stated that there was a simpler way. "We find that if the mapping of the measurement point positions and the corresponding temperature values are abstracted, the temperature distribution at other positions in a 3D measurement area can be predicted." They gave 5 major steps in order to predict unknown temperature distribution values, which I have currently been following without knowing (which is great):

Step 1. In accordance with practical demands, a 3D measurement area is appropriately determined. - this means my 3d print

Step 2. Acquire finite temperature measurement data using one of conventional measurement technologies. - this means my thermistors

Step 3. The raw measurement data is refined by an appropriate method to ameliorate the data quality. - not sure what this is yet but its probably cleaning the data set

Step 4. Abstract the mapping between the temperature value and the measurement position according to the finite measured temperature values. - this is the weird stuff

Step 5. Use the mapping abstracted in Step to predict 3D temperature distributions at other locations in a measurement area. - predictions

In section 3, they begin to talk about their proposed model. At the beginning, they state that "A variety of methods are available for the estimation of the mapping function," and then list various models, including multivariate linear/nonlinear regression, robust estimation, and even neural networks. After reading this, I went to their references for using artificial neural networks as I'm most familiar with them and would like to use them. I found a long book on using neural networks for science (attached). I may have to learn about using them to build mapping functions, but I certainly can. They did state later in the article, "Owing to the superior fitness capacity, the ANN technique has found wide applications in different areas. In real-world applications, how to select a suitable network structure is full of challenges," which is true. For this reason, they decided to use the Gaussian process regression (GPR) method. I'm still reading on how it works. I've attached this main article too.

For my gradient analysis, I updated my code/file structure and uploaded to the GitHub repository. I also created a pickle file of all the gradients so that I wouldn't have to keep calculating them. Pickle is basically for data serialization, like JSON, but optimized for python. I also realized that I made an error of using 3 dimensional distance to calculate gradient even though I really only have 2 positional dimensions. This realization could make it easier for me to calculate midpoints as well because I only have to deal with the 2D distance.

For calculating the midpoint of multiple points, I did some research and realized that I was basically looking for how to calculate the centroid of a point cloud/cluster in 3 dimensions. It is actually really simple as this stack overflow example shows. The most common method is literally taking the mean of the coordinates in each dimension and using those. However, the user who answered showed that using the median is much better for finding the centroid that is closer to the "cluster." For a more accurate calculation, another user described convex hull peeling. This is when a set of points that can be connected by line segments (just like all of mine when plotted as x(t), y(t), T(t) for 3D) is described as set X, and the smallest set of points in the convex set (which is the set of points that intersects every line into a line segment) is returned as a "hull". Convex hull peeling is when every point on the hull - not inside - is removed. This is because those points are essentially outliers, and if this process is repeated multiple times, all outliers are essentially removed and a much more accurate estimate of the center of a set of points is found. I might use this later, but for now, I am just going to use the simple mean calculation because it is the most common and most used method to find the centroid in 3D space. However, after trying this, I realized that the centroids do not actually change -- the x and y positions are always the same, so I'm just getting values of not a number and 0 for my distance and angle. I'll try improving this soon. All code has been uploaded to GitHub.

5/2/19

put in thermistors for 20% print today, logging to file "20pLines"

New color-coded organization for the thermistor wires:

1: white

2: red

3: green

4: yellow

5: blue

6: purple

7: gray

8: gold

5/6/19

Today, I finished creating the regular ANN network. My mean squared error was only 3.04, but I think I need to use a CNN because each row of data is dependent on another row.

5/8/19

After evaluation of everything that I'm doing, I finally decided that I won't use a CNN. There is not enough time to build the entire neural network and train it, and the complications and concepts that I have to learn for this to happen are too much. I will do this next year after collecting more data.

5/10/19

Today, I started my print for 30%. I also put in the thermistors later in the day. I also worked the math through my gradient analysis, but I need to talk to Mr. T about the correct procedure for understanding this data.

5/20/19

I decided not to even do the 40% infill after it failed today. It's more important for me to have a 10%, 20%, and 30% dataset where all numbers are correct, so I reprinted the 10% disc.

I also finished writing my python code for calculating all the gradients. This is what it does:

Temperature is a scalar function - T(x,y) - where every value is a real number value with no direction. I know 8 points for my temperature function at every time t, so that there is a new function at every time T but the same x,y pairs are defined.

Now, if we imagine that by plotting all the points on an X Y plane, each value has a "weight" or "mass" - the temperature. For any object, we can then calculate the center of mass by finding the weighted mean of all of the masses in terms of X and Y components. However, for temperature, this is only true if the temperatures are linear. Since Q = kA dT/dt at steady-state, the rate of temperature change is directly proportional to the rate of heat flow when at steady-state. Because every time has a separate scalar function, that means at **every specific time t, the system is at a steady-state**. Over time, then, the "center of mass" or "center of temperature" will be changing and can be calculated because it is a steady state. When all temperatures are 0 (all masses are 0), the center of all the X Y points gives a point for "perfect equilibrium" where there is no temperature distribution. We can then take the sum of all T * distance from equilibrium point / distance from equilibrium point, for every time, to find the average temperature. We can then use a weighted mean for position in X and position in Y to get a center point such that we know the X, Y, and average temperature for every time t.

Then, we can see that the net temperature movement and direction for the system from the main equilibrium and time t = 0 is going to be represented by a vector from the original center point to the new center. This vector can be calculated by calculating the temperature gradient, since the derivative of a scalar field will give a vector field. Using the partial derivative of T in terms of X and the partial derivative in terms of Y, the component vector and angle can be calculated for every time t to see the direction and magnitude of the fastest rate of temperature flow for the system to go to the steady-state temperature.

I printed data of all my twenty % infill data, and then I tried running an ANOVA test along all of the three groups. However, I have to wait because the 10% infill is still printing.

5/22/19

Link to GitHub with all my files:

https://github.com/pranavaddepalli/AOSResearch2019