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E1.4 – Sensing Meat Analyzing Real Time Thermometer

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Sponsored by Texas State University

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Information

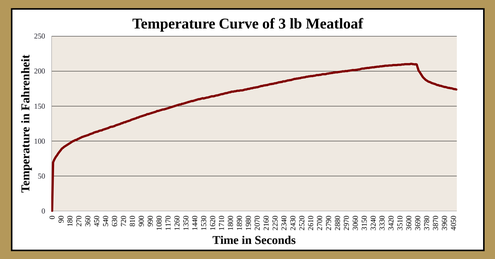
Approach

Goals of the Project include:
- **Design and integrate a predictive algorithm whose accuracy will be verified through the quantitative analysis of chicken and meatloaf heat curves**
- **Integrate hardware and software communication**
- **Develop functional Bluetooth enabled Android application**

Stretch Goals of the project include:
- **Develop an iOS application**
- **Introduce the use of a cloud server to have a centralized location for data collection, which would be used for optimization of the algorithm**

Background Information

Some short comings that original meat thermometers possess is that they do not have predictive capabilities and are typically only able to set off an alarm directly on the apparatus to alert the user that their meal has reached the intended internal temperature. There are even thermometers that sit inside of the oven with the meal and can only be checked by opening the oven, thus disturbing the heating environment. Through our research we have discovered that there are already meat thermometers that allow users to monitor their meat directly on their cellular devices via Bluetooth, but do not have predictive capabilities. We are replacing current meat thermometers by integrating a predictive algorithm into the already established Bluetooth communication achieved by our competitors.



Design of Experiment

Hypothesis:

Variables:
- **Homogeneous**
- **Inhomogeneous**
- **Internal temperature**

Trials:
- **12 meatloaf:**
  6 homogeneous & 6 inhomogeneous
- **10 chicken:**
  5 small (1-4 lbs) & 5 large (4-9 lbs)

Controlled Variables:
- **2 oven pans at different sizes (buy several in bulk)**
- **Same location in oven**
- **Preheat oven for 30 min**
- **Type of oven**
- **Oven temperature**
- **Type of meat**
- **Mass**
- **Surface Area**
- **Isotropic**

Steps:
1. **Prepare meat together, then separate into two separate weights to ensure that they are the same composition**
2. **Ensure same internal temperature of meat**
3. **Document initial internal temperature**
4. **Measure surface area**
5. **Document surface area**
6. **Insert thermocouple into center of meat**
7. **Start recording**
8. **Insert meat on same shelf, roughly the same depth into the oven**
9. **Cook both until the larger weighted meat has reached its goal internal temperature**
10. **Stop recording**
11. **Merge data points into common repository**
12. **Observe and record characteristics**
13. **Rate at which heat is transferred at 10% completion, 20% completion, 40% completion, 60% completion, 90% completion, and 100% completion (if applicable >100% completion)**
14. **Goal temperature of meat in relation to time**
15. **Variance of each heat curve**
16. **Mean of each heat curve**
17. **Oven temperature**

Information

Algorithm Analysis

Newton's Law of Cooling and rolling average:
- **Goal temperature, T_g**
- **Thermal conductivity of the substance, k**
- **Initial temperature, T_i**
- **Ambient temperature of environment, T_a**
- **Change in temperature, Δt**

Step 1: Rolling average

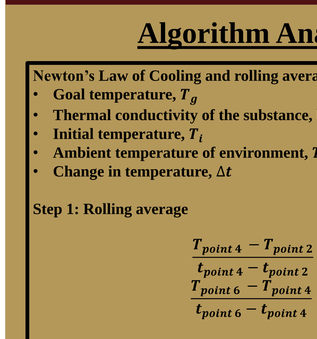
$$\frac{T_{point\,4} - T_{point\,2}}{t_{point\,4} - t_{point\,2}} = a$$
$$\frac{T_{point\,6} - T_{point\,4}}{t_{point\,6} - t_{point\,4}} = b$$

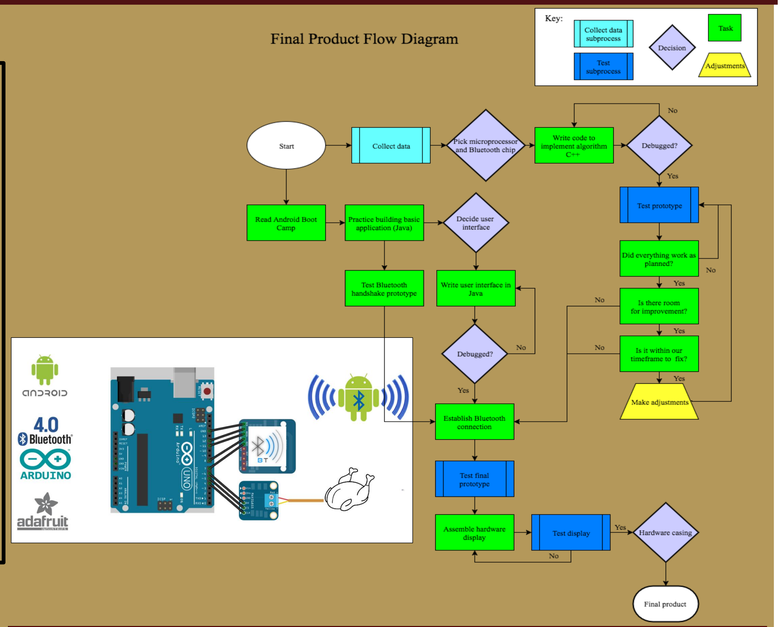
Step 2: System of equations to find the ambient temperature and thermal conductivity

$$a = -k(T_i - T_a)$$
$$b = -k(T_i - T_a)$$

Step 3: Newton's Law of Cooling

$$T_g = T_a + (T_i - T_a) * e^{-k\Delta t}$$
$$\Delta t = \left(-\frac{1}{k}\right) * ln\left(\frac{T_g - T_a}{T_{i,n} - T_a}\right)$$





Conclusion

Through this analysis we were able to observe the percent difference in which the "predictive" aspect of the formulae produced compared to the actual time at which the substance reached the intended internal temperature. The results were astounding, for the large homogeneous meatloaf data we found that the equation produced a prediction within 5% of the actual completion time within the first 4 minutes as long as the data points used for the rolling average had at least one data point in between them and produced consistent predicted values under 5% after roughly 19 minutes. The small homogeneous meatloaf produced a value within 5% within the first 5 minutes and produced consistent predictive values under 5% after roughly 21 minutes. Please refer to the slideshow of our analysis for an in depth quantitative view. This is a bright beginning our analysis and we hope to see better results as we tailor our design.

Newton's Law of Cooling 3lb Meatloaf Analysis

		Steps 1 & 2				Step 3									
						One in between each point			Steps 1 & 2				Two in between each point		
Time	Temperature (F)	a	b	Ta	k	Time predicted with initial temp as most recent data point before T1 in the rolling average	Time predicted + time at sample	Percent Difference	a	b	Ta	k	Time predicted with initial temp as most recent data point before T1 in the rolling average	Time predicted + time at sample	Percent Difference
0.00	69.57														
10.00	72.81	0.30	0.21	88.94	0.02	#NUM!	#NUM!		0.28	0.20	99.22	0.01	#NUM!	#NUM!	
20.00	75.56	0.25	0.21	100.67	0.01	#NUM!	#NUM!		0.23	0.20	124.58	0.00	#NUM!	#NUM!	
30.00	77.86	0.21	0.21	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		0.21	0.18	119.92	0.00	#NUM!	#NUM!	
40.00	79.70	0.21	0.18	114.49	0.01	#NUM!	#NUM!		0.20	0.18	151.35	0.00	#NUM!	#NUM!	
50.00	82.00	0.21	0.18	116.32	0.01	#NUM!	#NUM!		0.20	0.15	105.14	0.01	#NUM!	#NUM!	
60.00	83.84	0.18	0.18	831.09	0.00	446.40	506.40	66.24	0.18	0.14	103.61	0.01	#NUM!	#NUM!	#NUM!
70.00	85.68	0.18	0.14	98.25	0.02	#NUM!	#NUM!		0.18	0.11	97.02	0.01	#NUM!	#NUM!	
80.00	87.51	0.18	0.11	95.44	0.03	#NUM!	#NUM!		0.15	0.11	100.96	0.01	#NUM!	#NUM!	
90.00	89.33	0.14	0.11	104.15	0.01	#NUM!	#NUM!		0.14	0.09	99.82	0.01	#NUM!	#NUM!	
100.00	90.25	0.11	0.09	100.94	0.01	#NUM!	#NUM!		0.11	0.09	111.27	0.00	#NUM!	#NUM!	
110.00	91.62	0.11	0.09	101.41	0.01	#NUM!	#NUM!		0.11	0.09	112.18	0.00	#NUM!	#NUM!	
120.00	92.53	0.09	0.09	278.89	0.00	917.85	1037.85	30.81	0.09	0.09	########	0.00	749.99	869.99	42.00
130.00	93.45	0.09	0.09	-91.08	0.00	638.38	768.38	48.77	0.09	0.09	########	0.00	739.04	869.04	42.06
140.00	94.35	0.09	0.09	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		0.09	0.09	509.32	0.00	795.16	935.16	
150.00	95.27	0.09	0.09	281.62	0.00	871.89	1021.89	31.87	0.09	0.09	########	0.00	719.73	869.73	42.02
160.00	96.19	0.09	0.09	2334894935656003.00	0.00	711.80	871.80	41.88	0.09	0.08	111.27	0.01	#NUM!	#NUM!	#NUM!
170.00	97.09	0.09	0.09	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		0.09	0.08	113.29	0.01	#NUM!	#NUM!	
180.00	98.01	0.09	0.07	104.43	0.02	#NUM!	#NUM!		0.09	0.06	105.24	0.01	#NUM!	#NUM!	
190.00	98.91	0.09	0.07	105.35	0.02	#NUM!	#NUM!		0.08	0.06	109.44	0.01	#NUM!	#NUM!	
200.00	99.82	0.07	0.07	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		0.08	0.06	110.07	0.01	#NUM!	#NUM!	
210.00	100.27	0.07	0.05	103.82	0.03	#NUM!	#NUM!		0.06	0.06	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
220.00	101.19	0.07	0.07	-1322061871222286.00	0.00	872.94	1092.94	27.14	0.06	0.08	92.93	-0.01	268.07	488.07	67.46
230.00	101.64	0.05	0.07	99.46	-0.02	207.81	437.81	70.81	0.06	0.06	########	0.00	970.44	1200.44	19.97
240.00	102.09	0.07	0.07	205.61	0.00	1235.93	1475.93	1.60	0.06	0.08	94.30	-0.01	265.57	505.57	66.30
250.00	103.01	0.07	0.07	-1322061871222285.00	0.00	846.77	1096.77	26.88	0.08	0.06	113.52	0.01	#NUM!	#NUM!	#NUM!
260.00	103.46	0.07	0.07	1.76	0.00	678.71	938.71	37.42	0.06	0.06	286.63	0.00	1125.96	1385.96	7.60
270.00	104.36	0.07	0.07	207.43	0.00	1177.31	1447.31	3.51	0.08	0.05	109.18	0.01	#NUM!	#NUM!	
280.00	104.83	0.07	0.05	108.36	0.03	#NUM!	#NUM!		0.06	0.05	111.70	0.01	#NUM!	#NUM!	
290.00	105.73	0.07	0.05	109.05	0.02	#NUM!	#NUM!		0.06	0.05	112.33	0.01	#NUM!	#NUM!	
300.00	106.18	0.05	0.05	60.73	0.00	807.03	1107.03	26.20	0.05	0.04	209.70	0.00	1683.00	1983.00	32.20
310.00	106.63	0.05	0.04	153.00	0.00	#NUM!	#NUM!		0.05	0.04	210.15	0.00	1662.45	1972.45	
320.00	107.10	0.05	0.04	153.45	0.00	#NUM!	#NUM!		0.05	0.06	102.47	-0.01	239.59	559.59	
330.00	107.55	0.04	0.05	57222207030011.00	0.00	1175.72	1505.72	0.38	0.04	0.06	103.20	-0.01	231.92	561.92	62.54
340.00	108.00	0.04	0.07	105.82	-0.02	201.33	541.33	63.91	0.04	0.06	103.65	-0.01	231.24	571.24	61.92
350.00	108.45	0.05	0.07	106.27	-0.02	200.84	550.84	63.28	0.06	0.05	115.06	0.01	#NUM!	#NUM!	#NUM!

Information

Overview/Description

The SMART Thermometer will have the ability to monitor the internal temperature of food in real-time, while fusing the power of a cooking prediction algorithm and the convenience of a Bluetooth-enabled Android application, to eliminate the need of having to examine one's meal manually.

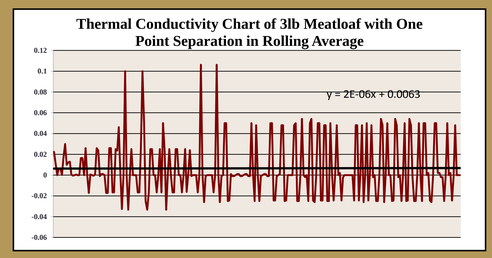
Problem Statement

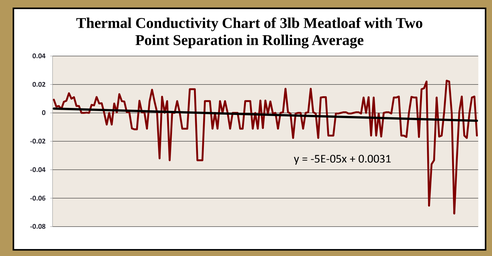
The problem:
- **Cooking a perfect meal is never easy**
- **Time is a valuable thing**
- **Why not know roughly when your meal will reach the FDA approved safe temperature?**
- **Improper estimation of food temperature leads to ruined meals**
- **Disturbance of cooking environment extends cooking time**

Why is this important?
- **It is a very marketable product**
- **Promotes food safety by preventing risk of foodborne illness**
- **Reduces stress when hosting meals**
- **Gives users the convenience of monitoring their meal efficiently and allows better time management**

Planned Work

In order to produce a predictive thermometer we need to achieve the design of a microprocessor board, specifically an Arduino Uno, to be able to record temperature data points using a k-type thermocouple, which is then going to use Bluetooth to push the algorithms predicted time and current temperature to an Android phone. The phone will display the information and allow the user to set notifications for the cooking session. We plan to build a functional thermometer that is able to perform all of the listed actions above. Below in Figure 1 you will find a system level diagram of our project, blocks highlighted in yellow will be designed and coded for this project by team members. In Figure 2 we have also displayed an in-depth wiring diagram of how we plan to set up the system, following the block diagram with the microprocessor as the central component.





Acknowledgements

We would like to thank our professor Dr. Compeau for facilitating our brainstorming sessions, allowing us to openly discuss any concerns or new findings we have come across, and for helping us learn about life after graduation.