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| **Teammate FNs:** | Micah | Peter | | | Alex | | Colin |
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| **Section Number:** | 014 | |  | **Team Number:** | | 05 | |

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| **Instructions:**   1. Save this technical brief template file as **M4\_TechBrief\_*sss*\_*tt*.docx** where ***sss*** is your section number (07, 14, or 15) and ***tt*** is your team number (e.g., 03 for team 3).    * Make sure all teammates have copies of all submitted project files at all times. 2. As a team, write sections each week of your technical brief **draft**. Keep all red text in this template in case you need to make edits. Submit each section with the associated Milestone document *each week* to the individual Milestone Dropbox. See each Milestone for *specific* instructions. 3. Your **final** technical brief must be 2 pages, although graphs and/or tables showing results may be included on a 3rd page. Din your **final** brief, delete all red text from this template and this Instructions box just before your final submission. 4. Submit your final **M4\_TechBrief\_*sss*\_*tt*.docx** to the M4 drop box on Bb prior to Class 29.  * Only one submission is required per team. * Only last submission will be graded; make sure all docs are submitted at the same time.  1. Cite your sources in APA format with (1) an in-text citation where referenced in the body of the text **and** (2) a full citation in the Reference section of this Milestone. As a reminder, it would be an example of **Academic Dishonesty** if you don’t include in-text citations and references. |

To: President Frank O. Simpson

From: Section 014, Team 05

RE: FOS Project

Date: Class 31

**Part 1, Introduction**

A. **DUE WITH M1**: In your own words, describe the problem in 2-3 sentences. This should include your team’s consensus on what FOS needs in terms of the deliverable, its function, the criteria for success (indicators of a working solution), and any constraints (what was provided to guide the design solution).

Our task, as we understand it, is to perform a quality analysis on five new thermocouple designs to determine what the Quality Assurance branch of your company can honestly and ethically claim to customers about these new designs, and with our algorithm as an aid, we aim to provide accurate and easily understandable information to QA through graphs and figures along with a detailed explanation, among these being an error analysis to judge how accurate our information and how successful your product truly is. Our work will also play a key role for the company and client financially, as fast-responding thermocouples are typically more expensive than slow-responding ones, which can also be easily deduced from our algorithm. The data we will be given contains 20 time history samples, 10 heating and 10 cooling trials, for each of 5 FOS thermocouple designs. In terms of constraints, they are as follows: the algorithm must appropriately handle ‘noisy’ data from both heating and cooling processes, the algorithm must be fully-automated, the algorithm must be our own original design, the final technical brief for our project must be ready by April 28, 2017.

A. **DUE WITH M2**: Provide an overarching description of your algorithm in 1-2 sentences. This should emphasize the key features included in the algorithm. Be specific.

Our algorithm receives inputs of thermocouple data and calculates the max, min, time step, and tau (denoted as yH, yL, ts, and tau respectively). This algorithm is fully-automated and can handle both heating and cooling thermocouple data.

C1 **DUE WITH M3**: Summarize the process that your team has followed up to this point. Include your reflections on the steps of method generation, development, handling noise, and data analysis. Include both your evidence-based rationales and justifications for decisions you made.

In the beginning, our process for developing our algorithm was as follows: brainstorm techniques for parameter identification, create two unique algorithms using generalized parameter identification methods in the code to accommodate all possible data sets, solidify and improve one algorithm, create an executive function from which the entire operation can be executed, and create a regression program to determine the relationship between tau and the price of the thermocouple. For our original algorithm, the SSEmod for the clean heating calibration data, which produced the most inaccurate result, was 0.70 sec. Through several group meetings, we were able to, as a team, improve our methods for identifying desired parameters using clean data by implementing a moving average to calculate tau. Our SSEmod following the improvements then decreased to 0.64 sec, a significant improvement. The difficulty arose once we began experimenting with ‘noisy’ data. With our original algorithm, the noisy heating data produced a SSEmod of 4.62 sec. To accommodate for the slightly erratic data, we developed two algorithms, one that would essentially smooth the data, eliminating the ‘noise’, and proceed as with clean data and one that would determine the range of data points in which to average the ‘noise’ and make the curve smooth. Through several trials of noisy data, we determined that our smoothing algorithm took much too long to identify the parameters of the data, albeit producing accurate parameter values and a SSEmod of 2.31 sec, but the other algorithm executed more quickly and produced accurate parameter values with a SSEmod of 2.15 sec. From then on, we decided to pursue the algorithm that made use of the moving average, since its method for parameter identification relied heavily on repetitive, simple calculations that the computer could process within a short amount of time.

C2 **DUE WITH M4**: Continue to summarize the process that your team has followed regarding regression and refinement. Include both your evidence-based rationales and justifications for decisions you made and how the accuracy of your model was enhanced during the process.

As our team worked together, we made some minor adjustments to our code in order to account for outliers that would cause significant inconsistencies within our parameters. The second improvement was to make our code to check the slope of the data and based off the slopes, changed the increment by which the algorithm would test for tau values. This improved our overall tau values by dynamically testing tau values specific to the different slopes of thermocouples. After making these changes, we saw significant improvement in the SSE of our noisy data in both heating and cooling thermocouples. In our original algorithm, the SSE for heating and cooling were 2.15 sec and 3.24 sec respectively. After our changes, the SSE for heating and cooling were 2.10 sec,and 3.23 sec. Although these improvements only improved our SSE by a magnitude of hundredths, they did refine the accuracy of our algorithm.   
**Part 2, Procedure (parameter identification) – DUE WITH M2**

**Describe the steps** of your algorithm in plain English. Provide sample calculations and explanations for steps that may be more difficult to understand or replicate.

To begin, our algorithm accepts a time vector and a temperature vector for the data given. This data is parsed within the executive function so that it may be passed accordingly. Next, the first 100 temperature values of the data are placed in a variable, *tempFirst100*. The time step never occurs during the first 100 data points, so this can be assumed to be an approximate value for the temperature before the time step. This value is just used to initialize the variable called *avgPrior*, which is the average temperature of all the data points before a given data point n. The algorithm then enters a loop that tests every 5th data point to see if the average of the following 50 temperatures (*avgAfter*) is greater than *avgPrior* by 1 degree. To account for both heating and cooling data sets, a variable *avgDiff* is set to equal the difference between *avgPrior* and *AvgAfter*. Once this difference is greater than 1, it can be assumed that the data has rapidly risen or decreased after that data point n, at which time the loop ends and the time of data point n is taken to be the time step. The value of the initial temperature *ymin* is found by taking the average of all the temperatures that are recorded before time step. The final temperature *ymax* is then found by taking the average of the last 50 data points. The code then has an if statement that is true if the data set is cooling instead of heating, and then accordingly changes some factors that will be used to calculate tau and swaps the values of *ymin* and *ymax*. To calculate the value of tau, we first find the temperature at which tau occurs by using the equation *tauTemp* = *(ymax - ymin) \* fac1 + ymin*, with *fac1* being 0.63 if the data is heating and 0.37 if it is cooling. To calculate the actual value of tau, the algorithm finds a time range of values that have temperatures closest to *tauTemp* and then tests values of tau to find the best value. To do this, the algorithm first calculates the slope right after the temperature change using the first 50 data points after the time step. This slope is used to adjust the aforementioned time range so that more data is included with steeper slopes. Then starting with the time value of the first data point in the range, the algorithm uses M3 calibration to get an SSE value for every single value of time in the range with steps of .0005. The algorithm takes the time that corresponds to the lowest SSE value to take as the time for tau.

**Part 3, Results – DUE WITH M3**

**Present results** of applying the algorithm to the specified datasets in the form requested. Results should be formatted for technical presentation; they should not be copied from MATLAB or Excel without cleanup. Consider using tables or graphs to present your results more concisely. Be sure to describe your results clearly.

After running our algorithm for 5 sets of 20 trials of thermocouple data, 10 heating and 10 cooling, we generated the figures below. Qualitatively, table 1 (below) shows how each thermocouple model compares in terms of the mean values for tau. As you can see, FOS-5 has a much larger mean tau value than FOS-1, meaning it takes thermocouple model FOS-5 to heat up or cool down. The average sum of the squares of error of our calculations (SSEmod) can be seen in the third column of table 1. These values are very low, which means our algorithm is successful and our calculations are reliable. Figure 1 (below) depicts the price of a given thermocouple model as a function of the thermocouple model’s tau value. Clearly, the model shows an exponential relationship between price and tau. That is to say, as the value of tau becomes smaller for a given thermocouple model, the price of the thermocouple increases exponentially. This explains why thermocouple model FOS-5 with an average tau value of 1.82 is much less expensive than FOS-1 with a mean tau value of 0.18. These results are supported by the value of the coefficient of determination of our model (R^2) shown in table (below). With an R^2 value of 0.97, our model very accurately represents the relationship between tau and the price of a thermocouple, given that as R^2 comes closer to 1, the model is a better representation of the relationship of the data.

**Part 4, Interpretation – DUE WITH M4**

In no more than 2 paragraphs, address the two questions of primary interest to FOS:

● How can you characterize the error in this process? Please comment on the quality of the experiments themselves, and also on your parameter identification algorithm. Use evidence to support your case, including specific data from your analysis and outside references as appropriate.

● What can FOS honestly say about our products in terms of their performance, pricing, and manufacturing consistency?

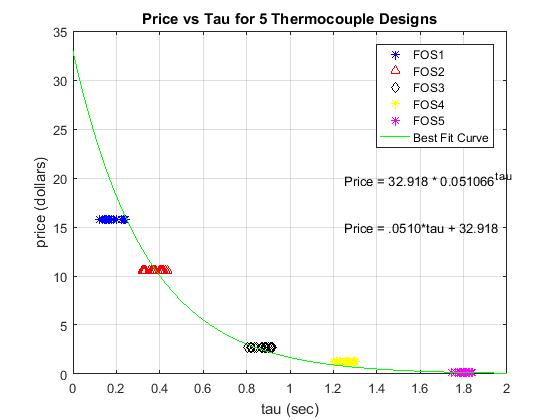
The error throughout these thermocouples were pretty consistent, taking into consideration the standard deviation of tau, which differed at most by 0.01 sec for each thermocouple design and with an average of 0.035 sec. Despite significant outliers in the recorded data, the experiments appeared to be high quality. Our parameter identification showed to be strong although our algorithm did have issues with noisy data finding yL. This is shown in the evidence of our data. Our algorithm in the noisy heating thermocouple predicted ts, yL, yH, and tau to be 1.84 sec, -1.51 °C, 98.04 °C, and 1.36 sec respectively. The actual values reported were 1.84 sec, -.96 °C, 98.75 °C, and 1.35 sec. respectively. For noisy data, our algorithm produced a smaller SSEmod for both heating and cooling data, insinuating that the actual parameter values provided were not entirely accurate, which may have caused the results of our algorithm to be slightly skewed.

As the value of tau decreased, representing the response time of the thermocouple, we found, using our algorithm, that the price of the thermocouple increased exponentially. This supports the logic of the pricing for First-Order Systems, Inc. thermocouple designs. The manufacturing process, according to our algorithm, is very consistent, considering the maximum difference in standard deviation was 0.01 sec. In short, the performance and manufacturing consistency of First-Order Systems, Inc. supports ethical pricing for its thermocouple designs.

**Table 1**

|  |  |  |  |
| --- | --- | --- | --- |
| Model Number | τ Characteristics | | Mean SSEmod |
| Mean | Standard Deviation |
| FOS-1 | 0.1835 sec | 0.0387 sec | 2.2349 sec |
| FOS-2 | 0.3822 sec | 0.0375 sec | 1.3596 sec |
| FOS-3 | 0.8672 sec | 0.0387 sec | 1.0509 sec |
| FOS-4 | 1.2591 sec | 0.0312 sec | 1.0238 sec |
| FOS-5 | 1.7996 sec | 0.0288 sec | 1.2160 sec |

**Figure 1**



**Table 2**

|  |  |
| --- | --- |
| Parameter | Value |
| SSE | 0.9349 |
| SST | 34.5307 |
| r2 | 0.9729 |

**Part 5, References – DUE WITH M4**

If you have any references, list them here in APA format.

<List references in APA format>

**REFERENCES (written in APA format – see Word>reference>manage sources>new tab)**

List all your References.

|  |
| --- |
| Example (reference for an internet source):  Author Last, X. (year). Title xxxx xxx xxxx. Retrieved from http://www.url.xxx/xxxx/xxxx |
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