Project Milestone 1 – Parameter Identification Brainstorming

Instructions

1. Read this document carefully. You are responsible for following all instructions in this document.
2. Read the Learning Objectives at the end of the document to understand how your work will be graded.
3. Use professional language in all written responses. See EPS01 for guidelines.
4. Submit deliverables to Gradescope for grading. Name your files to match the format in the table below, where *SSS_TT* is your section and team ID (e.g., 001_03 is Section 001, Team 3)

Item	Type	Deliverables
M1 Answer Sheet	Team	M1_AnswerSheet_*SSS_TT*.pdf

See submission requirements on the last page of this answer sheet.

5. Complete the Assignment Header before starting the answer sheet.

Assignment Header

Section and Team ID (SSS_TT):	<019-24>

Team Member Name	**Purdue Career Account Login**
Greg Szymchack	gszymcha
Nathan Thorson	njthorso
Sergio Monge	smonge
Seena Pourzand	spourzan

Role of Each Team Member

In this section, put each team member's name who worked on this milestone. In the Detailed Description of Work, each person on the team should write their own description of how they contributed to this milestone. Be very detailed here. Then in the last column, your team should estimate the percentage of the work that each team member did on this milestone. This column needs to add up to 100%. We know this will vary on any given milestone, but one person in the team should not be doing significantly more than the others throughout the whole project. Use this column as a way for you to make sure your workload is balanced throughout the project.

Team Member Name	**Detailed Description of Work**	**Percent of Work**
Greg Szymchack	Wrote the problem statement, helped with parameter approach of v_0, v_{max}, and K_m and idea generation	25%
Nathan Thorson	Revising and verifying validity of approaches and responses. Assisting in the writing of the problem	25%

	approaches. Assisting in the writing and problem solving of the noisy data problem.	
Sergio Monge	Helped write and improve all approaches and did outside research.	25%
Seena Pourzand	Primarily wrote and revised approaches for v_0, v_{max} and elaborated on the effects of noisy data. Conducted outside research on matlab functions and best pratices for noisy data.	25%

M1 Context

Parameter identification is about determining model parameters from available data. This milestone requires you to think carefully about different potential parameter identification approaches, the process of using/coding those approaches, and the consequences of those choices.

Your assignment is to develop several ideas for fully automated identification of parameters from first-order data of enzyme reactions. You should use evidence-based rationales when evaluating your ideas. In this context, "evidence-based" means you should refer to the graph of the data provided – where the graph is a proxy for actual data, your knowledge of MATLAB, and other trusted sources when evaluating your ideas.

Note: When external sources are used, each must be properly cited with (1) an in-text citation where referenced in the body of the text and (2) a full citation in the appropriate *References* section for each part of this milestone document. Use APA 6th or 7th style.

Part 1: Brainstorm Coding Processes for Parameter Identification

In M0, each team member created an individual problem statement for the project. In Table 1, combine your problem statements into a team problem statement. Remember, a problem statement is a clear, concise, and complete description of a problem to be solved. A problem statement includes information on the need and the user (or a key stakeholder) without reference to a specific solution.

A problem statement is **your interpretation** of the clients' needs or wants.
A good problem statement (PS01 & PS02):

1. Clearly refers to a **client**
2. Clearly states the **need, problem, or the focus** of the project
3. Explains **why** this need/problem/focus is **important** to solve

followed by a list of specifications (PS03)

1. **Criteria** and **reason** for each criteria (needs/wants)
2. **Constraints** and **reason** for each constraint (required/must-haves)

Table 1. Team Problem Statement

Team Problem Statement

Our client NaturalCatalysts, Inc, specifically President Avery D. Lion, has reached out to our engineering team to help with the analysis of five next generation enzymes that have differing rates substrate decay. The reason this is important is because they need to pick a single enzyme to give to Q&H of Greater Lafayette, a cleaning manufacturer, who will mass produce the combination of enzymes to give to the general public. The client has requested that we use the data provided to make of analysis so they can track our input, make clear and understandable graphics to explain our recommendation, minimize error in prediction to have the best possible solution, and that our recommendation is detailed and supported by evidence so the client can see our process. We have several constraints, the first being that this analysis is due by the final engineering class this is because the client wants the analysis before production commences, the final deliverable must be two-pages so that the analysis is detailed but concise, the draft must involve ethical claims because cleaning enzymes are a sensitive subject, and the formulas provided by the company must be used so their engineers can recreate our method.

Part 2: Brainstorm Coding Processes for Parameter Identification

Section A: Brainstorm Processes Using Clean Data

The “clean” data used in the in-class activity to identify parameters visually were derived using real experimental data and then applying processes to change the data to fit a nice, clean curve. You will use this clean data as a proxy for actual experimental data for this part of the assignment. Use ideas from your in-class activity to brainstorm the coding processes for multiple (at least 3 or 4) ways to determine each parameter.

Once you have a list of ideas, select the two most promising approaches for each parameter. Think about those approaches in both a conceptual way (describe them in words, flowcharts, and/or sketches) and a practical way (how you will implement it in MATLAB). Write clear steps for identifying each parameter that can be translated into MATLAB code – do not write code. Consider providing a flowchart to clarify your approaches. Use Word’s draw tools or hand sketches to clarify your approach as necessary.

In Tables 2, 3, and 4 below, describe your two approaches for identifying each parameter: v_{0_i}, V_{max}, and K_m. For each,

- briefly and clearly explain your approach using steps. You can also include other items to clarify such as flowchart, pseudocode, or neat sketches;
- provide an evidence-based justification for each approach, keeping in mind that the parameters must be identified in a <u>fully automated</u> way, without any user intervention. Your justifications must make explicit reference to MATLAB functions and coding techniques needed to translate your steps to operational code;
- mark the expected level of difficulty (low, medium, or high) for implementing this approach in MATLAB; then justify in 1-2 sentences your selected level of difficulty, using evidence-based rationales if possible.

In Table 5, cite any references that helped you formulate your approaches. You will need at least one citation for each of Table 2, Table 3, and Table 4; however, you will likely need more than one citation per table. Use APA format. Remember to use in-text citations as well.

Table 2. Two coding approaches to determine v_{0_i}

Approach #1 for Parameter v_{0_i}

Approach (words, flowcharts, sketches)
Steps, in English, not code:
 	
Repeat these steps for each enzyme
1. Firstly, find the initial reaction velocity for each concentration of the enzyme (3.75,7.5, etc)
    a. To find the initial reaction velocity, look at the very beginning of the data (close to time = 0), get the first two data points and find the slope by calculating the change in data over the change in time. (Math Warehouse).
    b. We can easily implement basic MATLAB code to simply take the first two values from a column vector of product concentration values. Then we can take their corresponding values from the time vector. We can then perform basic subtraction and division to get our reaction velocity.
2. Repeat this process for the duplicate tests for the enzyme.
3. Then average these reaction velocities for the corresponding concentrations of substrate.
    a. Ex. Test 1 for Enzyme 1 has an initial velocity of 50 µM/min for the concentration 3.75 µM and the duplicate for the same enzyme and concentration is 70. Average the two and get an average initial reaction velocity of 60 µM/min for a concentration of 3.75 µM for Enzyme 1.

What is your evidence-based justification for your approach? • According to Professor Branco, the v(0) value is the slope of the data when it is at its straightest/most linear. Additionally, the M0 Project Background calls v(0,i) "initial velocity of reaction," effectively meaning it is the rate of the product concentration at the very beginning.   • Averaging out the determined velocities for each of the concentrations can help us get closer to the true value of the initial reaction velocity as the more the data the better. If for some reason the original test for a concentration results in an abnormal reaction velocity, averaging it with the velocity obtained from the duplicate test (that in this example is correct/normal) will help normalize the data so it is more accurate than previously before.
Expected difficulty for coding in MATLAB: __X__low ___ medium ___ high

- Determining the reaction velocity for a specific concentration for a specific enzyme is basic, only involving following the slope formula of y2 – y1/x2 -x1 and plugging in the corresponding values. (Math Warehouse)

Approach #2 for Parameter v_{0_i} (Must be different from Approach #1)

Approach (words, flowcharts, sketches)
Steps, in English, not code:

Repeat these steps for each enzyme

- These instructions are for the example of one enzyme, but we will repeat for all ten.

1. Prior to doing any analysis on the data, we will average the respective product concentrations at each substrate (averaging the original and duplicate data). We also need to keep in mind there can be more/less data points for the duplicates so we will average the values for the data which has an equivalent, any other data that does not have a duplicate/original equivalent we will ignore tentatively considering how large the data is so hopefully it should not affect our results too drastically.
2. Then, we will find the initial reaction velocity for each concentration of the enzyme (3.75,7.5, etc.) with our newly created, averaged product concentrations.
    a. To find the initial reaction velocity, look at the very beginning of the data, get the first two data points (from our new averaged product concentration) and find the slope of them over the time difference.
3. We will end up with 10 data pairs of concentrations (3.75, 7.5,….) with corresponding initial reaction velocities(v(0,i)) that we measured based on an average of the original and duplicate product concentration data.

What is your evidence-based justification for your approach?

- Professor Branco spoke about how we can determine the initial reaction velocity of a substrate concentration by look at its respective product concentration vs time graph and finding the slope near zero in class 11B. Additionally, we know from basic mathematics that if we are given a quantity over time, the slope of that quantity at some time is its velocity/rate of change. Furthermore, it is explained to us in the M0 Project Background that to find v(0,i) for a given enzyme at a given substrate concentration, we must find the slope of the line tangent to the curve at the very beginning of the data. Thus, our approach takes inspiration and follows the instructions given from these sources.
- As mentioned earlier, averaging out values, in this case our initial data between original and duplicates, can help have a value that represents and takes into account both datasets. We can better get a sense of what the data centers around and what the data truly is like and make better predictions down the line.

Expected difficulty for coding in MATLAB: __X__ low ___ medium ___ high

Why do you think it will be at the level of difficulty you indicated? • The difficulty of this approach should not be difficult as it effectively the same mathematical process as approach 1 with the only difference being when we average our test/duplicate values. Since the mathematic process is fairly straightforward, simply computing the slope at a certain instance, it should not be very difficult and should be easy to implement in MATLAB.

Table 3. Two coding approaches for determining V_{max}

Approach #1 for Parameter V_{max}
Approach (words, flowcharts, sketches) Steps, in English, not code: **Repeat these steps for each enzyme** 1. In our previous portion we determined the initial reaction velocities for the varying concentration for an enzyme. Now we will have a resulting dataset of substrate concentrations (Ex. 3.75, 7.5 ,15…) and reaction velocities. 2. We can then use the built in MATLAB function max to determine the maximum reaction velocity in our dataset of 10 velocities for the enzyme. This maximum velocity is our V(max).(MathWorks) 3. We will repeat this process for each enzyme.
What is your evidence-based justification for your approach? • When speaking to a TA during breakout rooms, we were told to consider using built in MATLAB functions that can help us determine a maximum value. We as a team determined that the built-in **max** function in MATLAB could help us achieve this as it can easily find the largest value given a dataset. Since we are asked to find V(max), it makes the most sense to find the maximum velocity value from the velocities we calculated earlier. (MathWorks)
Expected difficulty for coding in MATLAB: ___ low ___ medium ___ high Why do you think it will be at the level of difficulty you indicated? • This process should be very easy to accomplish as it simply requires only one function call assuming we have already created our dataset comprised of substrate concentrations and corresponding reaction velocities. We would assign the outputted value of max to a variable likely called vMaxEnzyme(Insert Enzyme Letter).

Approach #2 for Parameter V_{max} (Must be different from Approach #1)
Approach (words, flowcharts, sketches) Steps, in English, not code: **Repeat these steps for each enzyme** 1. In our previous portion we determined the initial reaction velocities for the varying concentration for an enzyme. Now we will have a resulting dataset of substrate concentrations (Ex. 3.75, 7.5 ,15…) and reaction velocities. 2. We can utilize a for loop and variable to represent the maximum and use the for loop to loop through each of the 10 velocities, comparing if the current velocity is greater than the current maximum that is stored in our maximum variable. If the current velocity in the loop iteration is greater than the existing maximum variable, set the variable to the current velocity. The maximum variable will initially have a value of zero so that when it is first compared, the first velocity is compared, it becomes the tentative maximum. Once the loop finishes, the maximum value should be stored in the variable. This will be our V(max).
What is your evidence-based justification for your approach? • Since V(max) is simply the largest velocity, using a comparison operator like greater than will help determine which value is the largest aka the maximum.
Expected difficulty for coding in MATLAB: ___ low __X__ medium ___ high Why do you think it will be at the level of difficulty you indicated? • This approach is significantly less convenient than approach 1 considering it is effectively accomplishing the same thing as the max function in MATLAB except we code the process. It utilizes basic looping structures so the level of difficulty is slightly more than approach #1.

Table 4. Two coding approaches for determining K_m

Approach #1 for Parameter K_m
Approach (words, flowcharts, sketches) Steps, in English, not code: **Repeat these steps for each enzyme**

1. In our previous portion we determined the V(max) for our enzyme of choice. According to the Project Background provided in M0, we can algebraically solve for K(m) using the Michaelis-Menten equation. The velocity at any given substrate concentration is the (v(max) * substrate concentration) all divided by the (Km + the substrate concentration). We can rearrange the equation to solve for K(m). (LibreTexts)
   a. $v = \frac{V_{max}[S]}{K_m + [S]}$ ← Michaelis-Menten Equation (LibreTexts)
2. For each of our given data points of velocity for given concentration, we can plug these values into the equation and solve for K(m). We will get a resulting 10 K(m) values for the 10 concentrations & velocity pairs we determined earlier.
3. We then will average these K(M) values to get a final K(m) which should best describe the data.

What is your evidence-based justification for your approach?

- The given Michaelis Menten Equation in the Project Background contains Km, which in this case is our unknown value. By doing basic algebra, we can solve for K(m) since we have values for the rest of the variables in the equation.
- Averaging out the K(m) values to result in one final K(m) is best as it will best encapsulate and represent all of the data in one singular K(m) value.

Expected difficulty for coding in MATLAB: ___ low __X__ medium ___ high
Why do you think it will be at the level of difficulty you indicated?

- Similarly, to other approaches which utilize the equation, mistakes can occur in the formula rearrangement or when handling such amount of calculated data points. If there was a problem or a single point which seems out of place, it would be relatively difficult to find such point.

Approach #2 for Parameter K_m (Must be different from Approach #1)

Repeat these steps for each enzyme

1. In our previous portion we determined the V(max) for our enzyme of choice. According to the Project Background provided in M0, the substrate concentration when the velocity is half of the vmax is equivalent to the K(m) value.
2. To go about finding this, we would need to go about creating a non-linear regression model to describe the data to find all the intermediate values between the data we have experimentally.
3. Once we have the regression model, we can solve backwards by plugging in half the v(max) to find the corresponding substrate concentration which would be equal to K(m)

What is your evidence-based justification for your approach?

- LibreText and the Project Background provide a graph which shows the relationship between ½ Vmax corresponds to K(m). Utilizing this relationship, we determine K(m) using this chemical and mathematical relationship.

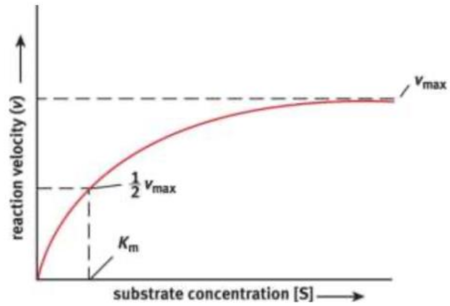

Figure 1: Michaelis-Menten plot

- A Regression Line would help us interpolate values that we do not have precisely such as K(m) as it is unlikely that the corresponding substrate concentration for ½ V(Max) is one our experimentally recorded values (i.e 3.75, 7.5, etc). (Statistics Stack Exchange)

Expected difficulty for coding in MATLAB: ___ low ______ medium __X__ high

Why do you think it will be at the level of difficulty you indicated?

- Rearranging an equation algebraically, is by no means an extremely easy task while it is also not extremely difficult. It is a somewhat complicated task that can be prone to small errors that well affect the data in the long run if not done correctly. Having said that, doing non-regression model can be easily messed up, and with no way to cross check our values, we could potentially be calculating a very inaccurate number without realizing it.

Table 5. References Used in Evidence-Based Rationales (Part 2, Section A)

Libretexts. (2020, August 11). Michaelis-Menten kinetics. Retrieved April 07, 2021, from https://chem.libretexts.org/Bookshelves/Biological_Chemistry/Supplemental_Modules_(Biological_Chemistry)/Enzymes/Enzymatic_Kinetics/Michaelis-Menten_Kinetics

MathWarehouse. (n.d.). How to use the formula and calculate slope. Retrieved April 07, 2021, from https://www.mathwarehouse.com/algebra/linear_equation/slope-of-a-line.php

MathWorks. (n/a). Maximum elements of an array - MATLAB. Retrieved April 07, 2021, from https://www.mathworks.com/help/matlab/ref/max.html

Purdue. (2020, October 29). ENGR 132 - Project – Milestone 1B [Video]. YouTube. https://www.youtube.com/watch?v=t54oV_BC--o

Purdue. (2021, March 24). ENGR 132 - Project – Milestone 1A [Video]. YouTube. https://www.youtube.com/watch?v=qG62kX-8hrg

Statistics Stack Exchange, Razan Paul, & Michael R. Chernick. (2014, May 01). How is interpolation related to the concept of regression? -. Retrieved April 07, 2021, from https://stats.stackexchange.com/questions/33659/how-is-interpolation-related-to-the-concept-of-regression

Section B: Evaluate Processes Using Experimental Data

For this project, NaturalCatalysts measured the enzyme performance of 5 next-generation enzymes. For each enzyme, they measured the change in product concentration over time in kinetic-enzyme tests for 10 different substrate concentrations, $[S_i]$. Also, each test was repeated. So, you have a total of 100 tests, 20 for each enzyme. This real experimental data contains measurement noise, an example of which is shown in Figure 1.

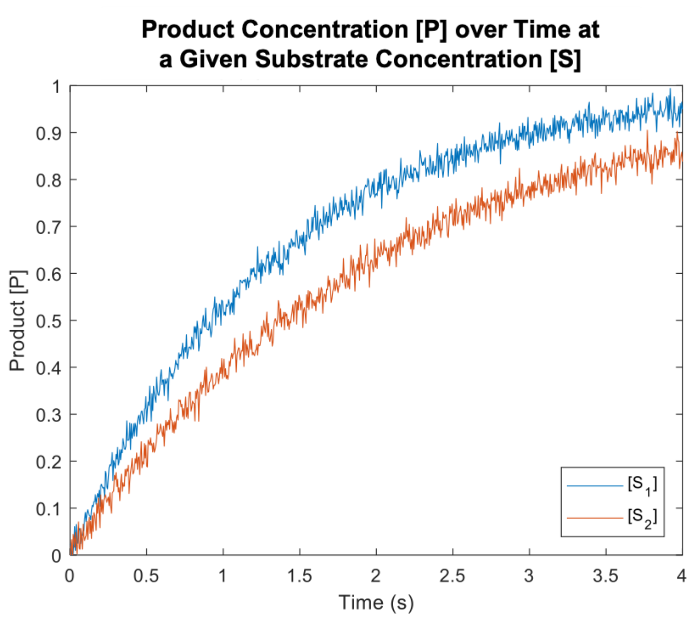

Figure 1. *Two examples of conversion of substrate to product over time during an enzyme reaction with noise present in the data.* ***NOTE****: Title should read "Michaelis-Menten Kinetics denoting velocity (v) as a function of product concentration [P]".*

Experimental noise can come from many different sources, and it always makes parameter identification more challenging. In this part of the assignment, you must re-evaluate your approaches from Part 2, Section A in light of the measurement noise.

For each of the approaches you described in Table 2:

- explain in a few sentences how the approach might fail in the presence of noise. As appropriate, include sketches to clarify your explanation.
- modify your approach to account for the presence of noise in the reaction data. Use flowcharts and sketches to clarify your steps as necessary.
- re-assess the difficulty of coding this approach in MATLAB for analysis of noisy data and then justify in a few sentences your selected level of difficulty using evidence-based rationales (remember, your parameter identification must be <u>fully automated</u>). Again, your justifications must make explicit reference to MATLAB functions and coding techniques needed to translate your steps to operational code.

In Table 8, cite any references that helped you formulate your approaches. <u>You will need at least one citation for Table 6. Table 7 will likely also need citations</u>. However, you will likely need more citations in this section than the minimum listed here. You are allowed to re-use the citations from Part 2a in this section, provided they make sense. Use APA format. Remember to use in-text citations as well.

Table 6. Evaluate the effect of noisy data on coding approaches

Evaluate Approach #1 for Parameter v_{0_i} (Refer to Approach #1 from Table 2)
How could this approach fail in the presence of noise? Because of the variance in data due to noise, when taking the initial reaction velocity of some data, the volatility of data could cause us to calculate an initial reaction velocity that is negative because how the data is noisy when in reality the reaction velocity would be positive.
Modify this approach to account for noise. Steps, in English, not code: 1. MATLAB has a built-in function called Smooth and Filter, both are designed to reduce noisy data that is outputted by data filters but in this case, we can utilize them to reduce the volatility and extreme variability among groups of data. (MathWorks) 2. Another possible method of smoothing our data is creating a non-linear regression model to model our data and use the model to determine values that might be need for calculations (MATLAB Central) 3. Once smoothed, we can use our new smoothed data and perform the initially proposed calculations in our approaches.

What is your evidence-based justification for your approach? After doing some research our team found out that other MATLAB users used the built-in functions to handle this type of data in similar projects with noisy data. Smooth, filter, and regression lines were recommended by users to help reduce noise. (MATLAB Central Forum Post)
Expected difficulty for coding in MATLAB: ___ low __X__ medium ___ high Why do you think it will be at the level of difficulty you indicated? Learning about the appropriate way to apply these built-in functions could prove to be difficult, however this should be the hardest part about this approach.
Evaluate Approach #2 for Parameter v_{0_i} (Refer to Approach #2 from Table 2)
How could this approach fail in the presence of noise? As mentioned before, due to noise, some of our averaged values could be far from the actual ones, meaning that it is necessary to consider how could this affect our accuracy in our final values.
Modify this approach to account for noise. Steps, in English, not code: Due to the fact both of our approaches are fairly similar, the same steps used for Approach #1, could be used and when doing so, get a smoothed data set.
What is your evidence-based justification for your approach? MATLAB Documentation for the smooth and filter functions describe using the functions to help reduce noisy data and make more accurate predictions when utilizing data. For these reasons we believe these functions can be of use to us because MathWorks has provided a variety of examples in the guide reducing noisy data. Additionally, a MATLAB forum post regarding dealing with noisy data was answered by a MATLAB forum admin recommending the user to utilize regression models to represent the data when working with Noisy data. See References for the specific webpages. (MathWorks & MATLAB Central)
Expected difficulty for coding in MATLAB: ___ low _X__ medium ___ high Why do you think it will be at the level of difficulty you indicated?

Creating accurate regression models is an intermediary skill in MATLAB and requires a certain level of precision and skill to do correctly as compared to basic tasks such as element wise operations and creating vectors. However, utilizing built in MATLAB functions like smooth, filter, and others would not be as difficult as making a regression model.

Consider how the noise and the updated approaches to v_{0_i} could affect your approach to finding V_{max} (from Table 3) or K_m (from Table 4). Explain any modifications needed, or explain why no modifications are needed.

Table 7. Modifications and justifications to V_{max} or K_m approaches

Updates to V_{max} approaches
We will utilize MATLAB's smooth or filter functions to smooth the variations within our datasets and then perform the same calculations we would have normally on those edited datasets. Depending on the situation, we can also utilize MATLAB's rmoutliers function to remove any larger outliers that might potentially skew our average in the event that smoothing our data is not enough. Furthermore, we can utilize creating a regression model of our data for each enzyme. This could additionally help us determine intermediate values that we do not have within in our provided data while also served to eliminate the noise in the data.
Updates to K_m approaches
Refer to the Updates to V_{max} approaches as the same process specified should additionally solve any issues in our approach for K_m.

In Table 8, cite any references that helped you formulate your approaches. Use APA format. Remember to use in-text citations as well.

Table 8. References Used in Evidence-Based Rationales (Part 2, Section B)

MathWorks. (n/a). Signal Smoothing - MATLAB. Retrieved April 07, 2021, from https://www.mathworks.com/help/signal/ug/signal-smoothing.html

MathWorks. (n/a). Detect and Remove Outliers in Data - MATLAB. Retrieved April 07, 2021, from https://www.mathworks.com/help/matlab/ref/rmoutliers.html

MathWorks. (n/a). Smooth Response Data - MATLAB. Retrieved April 07, 2021, from https://www.mathworks.com/help/curvefit/smooth.html

MATALAB Central. (n/a). What is the best way to smooth and compute the derivatives of noisy data? Retrieved April 07, 2021, from https://www.mathworks.com/matlabcentral/answers/450562-what-is-the-best-way-to-smooth-and-compute-the-derivatives-of-noisy-data

How to Submit

1. Rename this answer sheet to be **M1_AnswerSheet_*SSS*_*TT*.docx** where ***SSS*** is your section number (e.g., 001 for section 001) and ***TT*** is your team number (e.g., 07 for team 7).
2. Save the answer sheet as one PDF named M1_***SSS*_*TT*.pdf**.
3. Select one person to submit the PDF for the team. That person should
   a. Log into Gradescope and submit **M1_AnswerSheet_*SSS*_*TT*.pdf** to the **M1** assignment.
   b. Select all team members for the group assignment.
   c. Double-check that all team members are assigned to the submission.
4. Each team member should confirm that they are part of the submission and that all parts of the answer sheet were properly tagged.
5. After submission, distribute the submitted files to all team members. *Ensure all members of the team have copies of the submitted files.*

Learning Objectives

Idea Fluency (IF)

Generate ideas fluently. Take risks when necessary.

IF01. Generate a wide range of solutions including ideas not readily obvious or combinations of ideas in new ways.

IF03. Generate testable prototypes (including process steps) for a set of potential solutions.

Evidence-Based Decision Making (EB)

Use evidence to develop and optimize solution. Evaluate solutions, test and optimize chosen solution based on evidence.

EB01. Test prototypes and analyze results to inform comparison of alternative solutions.

EB06. Clearly articulate reasons for answers when making decisions or evaluating alternative solutions.

Solution Quality (SQ)

Design final solution to be of high technical quality. Design final solution to meet client and user needs.

SQ01. Use accurate, scientific, mathematical, and/or technical concepts, units, and/or data in solutions.

Information Literacy (IL)

Seek, find, use and document appropriate and trustworthy information sources.

IL04. Include citations within the text (in-text citations) that show how the references at the end of the text are used as evidence to support decisions.

IL05. Format reference list of used sources that is traceable to original sources (APA or MLA are recommended)

Engineering Professional Skills

PC05. Fully address all parts of assignment by following instructions and completing all work.

EPS01. Use professional written and oral communication.