Project Instructions Summer 2023

The purpose of the project is give students more opportunities to model real-life situations using differential equations. It also aims to help students be more prepared for more advanced courses that involve larger projects and research.

Students should work in groups to solve a problem that can be approached using some of the techniques we have introduced in this class.

The project consists of the following parts.

1. Post on the Piazza forum to let your instructor know what project you are working on and who is in your group (if anyone). Also create your group in the People Tab within canvas.
2. Submit a draft of your report to Canvas Assignments. Your work at this stage is graded for completion, see below for details.
3. Engage in an online conference in the Canvas Discussions forum to discuss each others work and offer suggestions for improving your work.
4. Submit your final report. You can incorporate feedback and ideas from the conference.

As with all assessments in this course: all work that is submitted must be your own. Students are expected to follow the GT Honor Code.

Choosing a Project Topic

Students can work on any project that meets the criteria below.

- The project must involve topics covered in MATH 2552.
- The project must incorporate at least one non-linear system of differential equations. You may want to compare different non-linear systems (eg - to compare an **SIR (https://en.wikipedia.org/wiki/Compartmental_models_in_epidemiology)** model with some other model).
- The final report must contain numerical solutions to at least one system of differential equations. There needs to be at least two dependent variables.
- Students must develop code to determine their own solutions to their non-linear system(s). Euler's method is usually sufficient for this project. Students can use spreadsheet software, matlab, python, or other programming language of their choice. It is ok to use online calculators and other software packages (eg - ode45 in matlab or octave) to **check** whether your results are accurate, but for full credit your group **must** develop your own code to approximate your solutions to your system (or systems).
- The final report must contain at least one graph of the solutions to your system that was produced by your numerical routines.

Note that the course has an overview of how to use spreadsheet software to solve a system of equations in the Chapter 8 lecture videos. And students can find information about how to approximate solutions to systems of equations in Section 8.4 of the textbook.

Recommended Topics

The recommended projects below are based on projects from the **Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations (https://www.simiode.org/)** (SIMIODE) community. Students can choose something similar to one of the ideas below, but are encouraged to propose their own ideas.

Please use the list of topics below as a source of ideas, modify the project instructions to meet all the criteria for the project, and pursue your own interests. Creativity is encouraged!

1. Acorns, Rodents, Snakes
   - **www.simiode.org/resources/2505/download (https://www.simiode.org/resources/2505/download/6-21-S-AcornsRodentsSnakes-StudentVersion.pdf)**
2. Exploring SIR Modeling
   - **www.simiode.org/resources/4796/download (https://www.simiode.org/resources/4796/download/6-018-S-ExploringSIRModel-StudentVersion.pdf)**
3. Modelling Evictions
   - **www.simiode.org/resources/4873/download (https://www.simiode.org/resources/4873/download/5-026-S-Evictions-StudentVersion.pdf)**
   - For Part II Question 3 you will need numerical solutions to a non-linear 2D system. It should be ok to use a spreadsheet for this.
   - This project also requires creating 2D phase portraits. WolframAlpha can produce phase portraits.
4. Drone Package Delivery
   - **https://www.simiode.org/resources/5454/download (https://www.simiode.org/resources/5454/download)**
   - This project requires some initial analysis to set up a nonlinear dynamical system.
   - Recommendation: experiment with any non-constant wind speed and determine a relationship between the flight time and the wind speed.
   - *Hint: there is a way to obtain an exact solution for a constant wind speed.*
5. Comet Orbital Dynamics
   - **www.simiode.org/resources/1341/download (https://www.simiode.org/resources/1341/download/3-50-S-CometOrbitalMechanics-StudentVersion.pdf)**
   - This project also requires some initial analysis to set up the dynamical system.
   - Note that this problem involves a relatively more computations and so it likely requires programming. Spreadsheets are not likely sufficient.
   - Note that livecometdata.com is no longer active but there are several other websites you can use to collect comet data, for example: **https://theskylive.com/comets (https://theskylive.com/comets)**
6. Fake News: **https://www.simiode.org/resources/7437 (https://www.simiode.org/resources/7437)**
7. Pandemic Modeling: **https://www.simiode.org/resources/7518 (https://www.simiode.org/resources/7518)**
8. Pullback Cars: **https://www.simiode.org/resources/8453 (https://www.simiode.org/resources/8453)**

Examples of Project Titles from Past Student Projects

Example project titles from recent offers of MATH 2552 are below to help students generate ideas for their topics.

- Modeling the Effects of Invasive Algal Growth on the Coral Reef Population
  - A helpful source: **https://pubmed.ncbi.nlm.nih.gov/20864137/ (https://pubmed.ncbi.nlm.nih.gov/20864137/)**
- Modeling Chemical Kinetics and Oscillating Chemical Reactions
  - A helpful source: **https://chem.libretexts.org/Courses/New_York_University/CHEM-UA_652%3A_Thermodynamics_and_Kinetics/01%3A_Lectures/1.21%3A_Nonlinear_kinetics_and_oscillating_reactions (https://chem.libretexts.org/Courses/New_York_University/CHEM-UA_652%3A_Thermodynamics_and_Kinetics/01%3A_Lectures/1.21%3A_Nonlinear_kinetics_and_oscillating_reactions)**
- Lanchester's Laws and the Civil War.
  - A helpful source: **https://www.tandfonline.com/doi/full/10.1080/0020739X.2021.2022230 (https://www.tandfonline.com/doi/full/10.1080/0020739X.2021.2022230)**

Instructions for Part I - Team Up and Choose a Topic (5 Points)

This part of the project is meant to help students choose a topic to work on and for groups to created in Canvas.

For the Summer 2023 semester, students can work on their own, or with one or two other people (in a group of two or three people).

Work submitted by a group larger than 3 people will not be graded.

Instructions:

- To select a topic, your group must write a note on our class Piazza forum that states who is in your group and what topic you have chosen. Write a few sentences about what your topic is about.
- Tag your post with the ”project” folder in Piazza.
- Your post should be set as a note (that doesn’t require a response), not as a question.
- One person in each team submits this information.
- All projects are approved automatically, unless the instructor indicates otherwise.
- Students who do not have anyone to work with are encouraged to write a post on Piazza to say they are looking for someone to work with.

Students who do not have anyone to work with, but would like to work with others, are encouraged to write a post on Piazza to say they are looking for others to work with.

The post on our discussion forum will help the instructor make sure that groups are set up correctly.

Instructions for Part II - Project Report Draft (25 Points)

The purpose of the Report draft is to encourage students to not leave work to the last minute, help everyone get the most out of Parts 3 and 4, and give the instructor an opportunity to give feedback on student work.

This part of the project is only graded for completion.

At this stage student work is only graded according to the Well Structured category. See grading rubric below for a definition of well structured.

Students are also encouraged to write a report that is also well executed, well communicated, and essentially correct.

Your instructor may offer feedback or suggestions at this stage.

Only one person per group will need to submit the draft.

Submit your work through a Canvas Assignment.

This part of the project uses TurnitIn: please follow the GT Honor Code and make sure that your work is your own.

Instructions for Part III - Post Draft on Piazza (2 Points)

Students put together a draft of their final report.

- At this stage the report is essentially graded for completion but the draft is used for the online conference.
- Please post a draft of your report on Piazza and tag it with the "Project" folder.
- Only one person per group will need to submit the draft.
- This part of the project is only graded for completion.

Instructions for Part IV - Mini-Conference (18 Points)

Please view other drafts and ask questions. Please also answer questions that students pose.

For this part of the project:

- (9 points) Part A) Please respond to at least **two** report drafts (that are not your own). In each response, please:
  - write something you liked about the draft you read, or something that you learned from reading it.
  - state whether you found the report understandable - and if it wasn't, ask for clarity on an area of the report that you found confusing
  - ask at least one question, or point out at least one way the report might be improved
  - feel free to write more if you have more feedback you would like to give on the report. Please take this as an opportunity to learn from each other and help each other with their projects!
  - each person in your group should do this part.
- (9 points) Part B) you receive full points if all the questions that you were asked about your work were answered, or **at least 2 questions were answered** before the deadline.

Late submissions not accepted.

Instructions for Part V - Submit Final Report (100 Points)

- Submit the report through Canvas.
- The report is graded according to the rubric on the next page.
- Only one person in each group should submit the project in Canvas.

- *This part of the project uses TurnitIn: please follow the GT Honor Code and make sure that your work is your own.*

Summer 2023 Deadlines

- Part 1 (P1): 11 pm on Wed Jul 5 2023
- Part 2 (P2): 11 pm on Wed Jul 12 2023
- Part 3 (P3): Post to forum:
  - no earlier than 11 pm on Mon July 10 2023
  - no later than 11 pm Fri July 14 2023
- Part 4 (P4)
  - Part A: Please post questions to peers by 11 pm on Wed July 19 2023
  - Part B: Please complete your responses to your peers by 11 pm on Wed July 26 2023
- Part 5 (P5): Submit final report by 11pm Wed July 26 2023

Please watch Canvas Announcements for any possible extensions or other changes to these deadlines or instructions.

Scoring Rubric Project Summer 2023

The scoring rubric we are using is based on the scoring rubric that is used for the international competition that SIMIODE holds every year.

Overview

The final reports will be scored in a way that involves three categories:

- be well structured,
- be well communicated, and
- be well-executed and essentially correct.

Each report will be scored by both the course instructor and TA(s).

Definitions

Well Structured (25 points)

Your report must have the following components.

- **Mathematical Elements**
  - A system of differential equations containing at least two dependent variables.
  - Code in an appendix or a table produced by Excel (or some other spreadsheet program).
  - At least one graph of the solution produced by your numerical procedure.
- **Format**
  - Please also stay within the word limit of 1000 to 1500 words, **not** including a bibliography, computer code, equations, tables
  - Work needs to be typed.
  - Work is submitted as a single PDF file.
  - Do not include any questions or other text that were given in the project description: describe the problem and what you set out to accomplish in your own words.
- A **title or cover page** with the following.
  - a title of your project, located at the top of the first page or on a separate cover page
  - your name(s), directly below the title
- an **Introduction** section with the following.
  - a brief description of the problem you are working on
  - a brief overview of the approach you take to solve the problem
  - Note: the introduction should be self-contained, meaning that the reader should have a clear understanding of what you are setting out to do by only reading your introduction. Do not assume the reader is familiar with a particular project on, for example, the SIMIODE website.
- an **Analysis** section with the following.
  - results that you found from your approach
  - answers to any questions that are given in the project description
  - explanations on how you obtained your results

- a **Conclusion** section with the following.
  - how your approach to solving to solving your problem was related to the topics we cover in this class
  - a brief summary of your main conclusions in your analysis section
  - describe limitations of their method and/or compare it to other approaches that you could have used
- A **References** section that includes at least one reference.
  - You can cite the textbook and the problem description on the SIMIODE website.
  - Every reference in the paper must have an in-text citation. Please do not include references to the references section that are not cited in the main text!
  - Any software that you used should be identified and either listed in the references section or cited in the body of the text. For example:
    - "results in the above table were obtained using a MATLAB (**https://www.mathworks.com (https://www.mathworks.com)**) script provided in a Appendix 1"
    - "results in Figure 3 were obtained using a python script provided in Appendix 1"
    - "results in Figure 1 were obtained using Microsoft Excel"
- **Appendices**
  - If using Microsoft Excel or other spreadsheet software please include a portion of your spreadsheet as a table as an Appendix.
  - If you wrote your own code please include the code in an Appendix.
- **Websites**
  - Any websites that you used should be listed in the report in the references section or in the essay where they are first mentioned or their results are first used. Examples:
    - *"Results in Figure 1 below were obtained using WolframAlpha (**www.wolframalpha.com (http://www.wolframalpha.com)**)"*
    - *"Desmos (desmos.com) was used to determine the second derivative of h(t)"*
    - *"One of the most popular social media sites, Instagram (http://instagram.com), allows users to share images and videos."*
- It is recommended that any data that is given in the project description be presented in your report: describe the data in your own words.

Well Communicated (25 points)

- Readable: work stands alone (retains context) and is neat and professional.
  - The entire report should use complete sentences.
  - Please do not assume the reader is familiar with the problem you are solving: summarize the problem in your report.
  - Please use a black font throughout the report. It is ok to use a different font color for headers and titles.
  - Please do not include a table of contents. Your report should be short enough that one is not needed.
- Organized: provides a clear logical flow.
- Provides detail, rationale, explanation.
  - When a graph or table is presented, there is some discussion following it that explains relevant details.
  - All variables and parameters in equations are clearly defined.
  - If using a numerical procedure such as the Euler or RK method, the step size is indicated.
- Work is generally free from grammatical errors.
- Mathematical composition, terminology, and notation is correct.

- Results and conclusions are clear. For example:
  - axes in graphs are labeled.
  - appropriate scale is chosen so that relevant details of graph can be seen.

Essentially Correct and Well Executed (50 points)

- Precision: Performs mathematical operations correctly.
- Makes and uses assumptions clearly. For example, if your equations you are using make assumptions about the dynamics you are modeling be sure to indicate those assumptions.
- Uses an appropriate degree of accuracy.
- Draws correct inferences from graphical or numerical data.
- Any computational or algebraic errors are trivial and isolated.
- Correct units are used.
- Applies a strategy that makes sense for the given problem.
- Applies appropriate mathematical concepts and processes.
- Report is succinct and does not offer superfluous material. For example:
  - Any data presented in a table are described in the report. Do not present data that does not add something to your results or conclusions.
  - Multiple graphs and tables do not present the same information. For example, if Figure 1 shows f(t) and Figure 2 shows both f(t) and g(t), then you should probably get rid of Figure 1, unless there are features in Figure 1 that can't be seen in Figure 2.
- Work includes a reality check of the final answer. A reality check can be any combination of the following.
  - a comparison between the results of your code and those found using an online calculator or software package that solves differential equations.
  - A comparison between the behavior of the solution and what one might expect in the real world. For example - if a solution curve reaches a maximum value and then tends to zero, explain why that behavior might be align with what you might anticipate from data measured from an experiment or from collected real-world data.

Course Grades and the Optional Project

Grades

Students who submit any part of the final project will have their final grades calculated using best of the following grade weightings.

	Weight 1	Weight 2	Weight 3	Weight 4
Participation	2%	2%	2%	2%
WeBWorK	4%	4%	4%	4%
Quizzes	14%	14%	14%	14%
Test 1	15%	10%	12%	7%
Test 2	15%	10%	12%	7%
Test 3	15%	10%	12%	7%
Final Exam	35%	50%	32%	47%
Project	0%	0%	12%	12%

Note that:

- The highest of the above weighting formulas (1, 2, 3, or 4) will be used to determine your final grade.
- The first two formulas are exactly what is stated in the syllabus.
- Students who start, but do not finish the group project, will still of course be able to use the best of Weight 1 or Weight 2 for their final grade.

Beyond MATH 2552: Getting Involved in Research

Many of the past students in MATH 2552 have asked about how to get involved in research projects during their undergraduate program. This page is meant to answer some of these frequently asked questions. The information here may be of interest to students who are interested in knowing more about how undergraduate students can get involved in research.

Those students who have found an interest in their topic, and are willing to pursue it beyond the scope of what is required for this course, may be interested in developing their project further so that their work can be shared beyond this course. It is up to students as to whether they would like to do so. There is, of course, no requirement for students to publish or present their work outside of this course. And no course credit would be given to students for exploring such opportunities.

Examples of Student Research Projects on Differential Equations

The **Rose-Hulman Undergraduate Mathematics journal (https://scholar.rose-hulman.edu/rhumj/)** publishes research conducted by and written by high school and undergraduate students. Below are examples of research involving differential equations:

- An example of a paper written and developed by undergraduate students on predator-prey equations: **https://scholar.rose-hulman.edu/rhumj/vol20/iss2/7/ (https://scholar.rose-hulman.edu/rhumj/vol20/iss2/7/)**
- An example of a paper written and developed by high school students, on modeling refugee settlement populations: **https://scholar.rose-hulman.edu/rhumj/vol22/iss2/2/ (https://scholar.rose-hulman.edu/rhumj/vol22/iss2/2/)**

The journal might be receptive to a similar project report written by students who presented an interesting approach to a Modeling Scenario posted in SIMIODE. But you would have to contact the journal for details and review their submission guidelines.

Publications that Accept Reports Written by High School or Undergraduate Students

There are **many** platforms that accept research reports from high school or undergraduate researchers. The Council of Undergraduate Research has a **curated list of journals (https://www.cur.org/engage/undergraduate/journals/listing/)** that publish undergraduate research.

Undergraduate Research at Georgia Tech

The Undergraduate Research Opportunities Program makes it possible for undergraduate students to participate in research, regardless of their major. For more information see **https://math.gatech.edu/undergraduate-research (https://math.gatech.edu/undergraduate-research)**