MATH 214: INFORMATION ON FINAL GROUP PROJECT

1. Overview

The final project for Math 214 is a group project. Each group will create a poster on some topic related to linear algebra and adjacent mathematics. As Math 214 functions in part as a service course for upper level courses in CS, DS, IOE, and others, this project may emphasize the role linear algebra plays in those courses.

You can form your own group of size 1–7 (2–4 is recommended). Try to form a group through Canvas Discussion or ask the course coordinator for help.

Your group will choose a topic that is suitable as a project in an upper level course, as offered at Michigan. (A side benefit of the project is that you will consider the role of scientific computation in a variety of your potential courses.) For Math 214, you may not replicate a **project** that you have done (or plan to do); rather, we want you to explore the linear algebra aspects more deeply and rigorously than you would in the other class. You **may** replicate the **topic**, provided you go more deeply into the math topics of this course than in the other class.

If you are unsure about choosing a topic, one approach is to raid the websites of upper-level courses you might take (or that a consensus of your group is interested in). Look though topics and projects discussed there. You can regard our Capstone as a chance to understand in advance the mathematics of those topics, with the help of your Math 214 instructor.

After choosing a topic, your group will submit a proposal on Gradescope, and then you will meet with an instructor to discuss the proposal. Sections 2 and 3 below discuss what you should include in your preliminary/final proposal and Section 4 discusses what is expected from your poster and presentation. Finally, all group members should hand in a work summary of how the work was accomplished and by whom, so that we can ensure that the workload was shared equitably. The individual summaries should be submitted at the time of the single group submission of the poster.

Unless special circumstances arise, all group members will receive the same grade on the project. The breakdown for this grade is as follows:

- Preliminary proposal: 2%
- Final (revised) proposal: 8%
- Explanation of Application: 35%
- Explanation of Mathematics: 35%
- Visuals, etc., of poster: 20%

The due dates are as follows:

- **Preliminary proposal due: Friday, March 18, 2022.** This should be viewed as a soft deadline. You may submit a few days later. *However, the earlier you submit, the earlier you will be able to get feedback on the initial proposal.*
- **Final proposal due: Friday, April 1, 2022.**
- **Poster and video due: April 18, 2022**
- **Virtual poster and video fair April 19, 2022**

2. Preliminary Proposal

This should contain the following items, in the following order:

- One paragraph describing the area you wish to study.
- A list of team members and their major field of study/special interests.

The preliminary proposal is meant to make sure you start thinking about topics, and to serve as a starting point for conversation. The more thought you have put into this, the more we can help you design an excellent project. Please make use of our office hours to discuss your proposal at any stage with one or more of our instructors, and modify it as needed to develop it into a full (final) proposal. We are here to help!

Depending on the feedback you get, the final proposal may look different from the preliminary proposal. But the earlier you get started on the process, the more feedback you can get.

3. Final Proposal guidelines

The final proposal should be a revised and expanded version of the preliminary proposal. It should be roughly one to two pages in length, and it should address the following points, preferably in the following order:

- What is the topic?
- Why is the topic interesting outside of mathematics?
- Why is the topic mathematically interesting? What areas of linear algebra (including deliberate non-linear elements) will be involved? You should use some non-trivial aspect of linear algebra in an essential way.
- What data will you use?
- What assumptions are you making? For example, how is your model simplified compared to other models? In particular, are you making assumptions about data or the way users might query the data? Your assumptions, in each case, should compete with an alternative whose merit you are ready to defend, e.g., "We use data for Detroit rather than for all of the U.S. as a start, to be able to conclude on time." Don't include matters irrelevant to the topic, like assuming that MATLAB is implemented correctly on your machine, unless you are ready to defend working with improperly-implemented MATLAB.)
- What resources have you found so far?
- What specific computations will you do? What software will you use to do these computations?
- What background and skills will each team member bring to the project?
- What deadlines has your group set for completing the work? Include a work timeline.
- Who has been delegated to handle which tasks in the timeline?

Some other things to consider follow. Not all of these are applicable to all projects.

- What did you learn; what surprised you?
- What steps did you take to make your project repeatable?
  - Did you use industry-wide benchmark data? If you do something on image processing, say, it's engaging to use your own photo—and there's a place for that in making a presentation. But using benchmark data in addition makes the project more likely to be repeatable.
  - Did you use error bars to claim **less** than a specific number? The wider the error bars, the less you are claiming, so the more repeatable the claim tends to be. While full analysis of error and determination of error bars is beyond this course, something easy you can do to get a rough idea is repeat your prediction say 100 times with different randomness or different data and see what is the range of outcomes you observe.
  - Did you separate training and testing data?
- Algorithmic Fairness: If you use data about people (directly or indirectly), what are the consequences to those people in the choice of algorithm or choice of training data set? Is

everyone affected in a uniform way? What steps did you take or might you take in v2.0 to address any concerns?

- How does math make qualitative predictions? E.g., does the configuation of eigenvalues or the proximity of data to a low-dimensional subspace predict certain long-term client-facing behavior, like "the species thrive"?
- If you use two different algorithms to attack the same problem (e.g., image compression), which algorithm is better on which type of data? Two algorithms, or two variants of a single algorithm, is recommended for this reason. More than two algorithms is **not** recommended. Save something for your next project!

4. Poster guidelines

You have quite a lot of freedom in constructing your poster. It does not need to be professionally printed in this virtual course. However, the poster should be neat, and the text should be typed on a computer. You may handwrite formulas if you wish to avoid using LaTeX or an equation editor in a word processor.

The result of whatever computation(s) you do should be displayed on the poster, and there should be background material explaining the computation. Stress the connection with course material, and be sure to include references somewhere on the poster. The poster should not be a cell phone photo. We prefer PDF made from Microsoft Word or Latex, so we can zoom in. If necessary, for example, to capture handwritten formulas, you can submit several phone photos. Please make sure everything is legible. You are encouraged to get a template for poster creation in your field, and work with it to facilitate your next poster creation.

One or two examples explained clearly in detail generally makes a better poster than many examples explained poorly.

In pre-COVID years, we held a Poster Fair, in which groups presented their poster. In Winter, 2022, you will submit the poster in PDF and a link to a 5- to 10-minute video of your group presenting the poster. For example, you can record a zoom session, if your group cannot all be present together. Optionally, you may also submit any relevant data or code in an appendix or link to repository.

5. Suggested topics

The following topics, among many others, would be suitable for the poster.

(1) Image compression
(2) Image recognition
(3) Techniques for fast matrix multiplication.
(4) Fitting statistical models
(5) Analyzing stability of mechanical systems
(6) Data clustering
(7) Fourier analysis (to analyze frequency, time-shifts in data, and much more)
(8) Expander graphs – their applications and the linear algebra behind their definition
(9) Fractals
(10) Computer graphics
(11) Computer vision
(12) The mathematics of MRI
(13) The mathematics of x-ray crystallography (you can treat the physics as a black box)
(14) Principal component analysis
(15) Instability of Gaussian elimination
(16) Eigenvalues and stability/oscillation of mechanical systems

(17) Eigenvalues and population dynamics
(18) Uses of linear algebra in solving differential equations
(19) Quaternions and three dimensional rotations
(20) Applications of linear programming to game theory

Feel free to bounce ideas on Canvas Discussions and to advertise for partners there, too.