1 Description of Final Project

The goal of the final project is to demonstrate a thorough understanding of a topic beyond the material covered in the course. The project will consist of a written report (worth 30% of the final grade), and a 15 minute oral presentation for the group, held during the last week of class (worth 5% of the final grade).

1.1 Choose a topic

Below is a list of topics that you can choose from for your project. Additionally you can choose a topic related to your area of research. The main goal is to apply the tools you have learned in this class to an advanced topic, and in particular, *pick something that is of interest to you*!

1.1.1 Suggested topics

1. Iterative solvers
   (a) Krylov Methods. These is about fast matrix solvers in general, and is currently state of the art for large sparse systems. Investigate the main ideas, and consider GMRES or BiCGSTAB.
   (b) Geometric or algebraic multigrid methods. These are methods designed to speed up the convergence, iterative solvers. See "A Multigrid Tutorial", Briggs, Henson and McCormick for an introduction.
2. Finding solutions to non-linear systems of equations.
   (e.g. Quasi Newton's Method, DFP, BFGS, Broyden, etc.).
3. Distributed computing. Implement your own or apply a parallelized software package using MPI or GPGPU such as PETSc, hypre, ScaLAPACK or SuperLU to solve a large (sparse) linear system.[1]
4. Numerical methods to solve Poisson's equation (fast summation treecode algorithms or finite difference approximations).

[1] Distributed computing is only recommended for those with a lot of computing experience.

5. Numerical methods to solve chemical rate equations (stiff integrators).
6. Multiderivative quadrature rules or multiderivative interpolation.
7. Compression of image or music (wavelets).
8. Newton fractals: generating fractal patterns using Newton's method. See, for example Steven Strogatz's article: "Finding your roots", New York Times, 2010.
9. Spectral methods for parabolic differential equations. This project will require discrete Fourier transforms, as well as the application of an ODE solver to the resulting method of lines formulation.
10. Present results from a survey paper.
    (a) "Nineteen Dubious Ways to Compute the Exponential of a Matrix, Twenty-Five Years Later." You can probably guess what the title refers to.
    (b) "Numerical integration of periodic functions: a few examples". This paper, by Weideman, discusses precisely what the title says. The results are used often in Fourier analysis and numerical computations that deal with Fourier series.
11. A project of your choosing! Be creative, check in with me, and most importantly, **find something that interests you**!

1.2 Choose a group

Depending on the scope of the topic, and number of interested classmates, groups will range from 1 to 3 members. Ideally, I would like to see groups of 2, so that each person is able to contribute a fair amount to the total project.

1.3 One page summary

Tell me in one page or less who is in your group, what your topic is, and give a brief outline of what work you have done, and intend to do. It is also helpful to assign specific tasks to group members at this time. This is a research report, and so I would like to see some references. This should be completed and sent to me by **Friday, October 18th.**

1.4 Oral presentation

Part of your final project will include an oral presentation. You will have a total of 20 minutes, with 5 of the 20 minutes allocated for questions and answers. With electronic slides (either LaTeX or PowerPoint), you should present the background for your problem, the main idea behind the algorithm you worked, on and your numerical results. A good rule is to take at minimum one to two minutes per slide, so you should have **at most you should have 15 slides.** Rehearse your presentation and be ready to answer questions from your fellow classmates (and me!). The presentations will be scheduled during the the last week of class, **Monday December 2nd** through **Friday, December 6th.**

1.5 Project report

The report should be 12-15 pages (excluding references, and codes; including figures, tables), 12 point font and double spaced. You are encouraged to use LaTeXto type up your report, although this is not necessary. Observe standard scientific journal syntax; in particular, key equations should be inline, i.e., they should be on their own line, and numbered, so that they may be referred to within the text. The final copy is due on the day of the final exam period, **Friday December 14th.**

A proper scientific paper should have the following section headings:

(a) **Abstract.** a short summary that concisely states what the reader will find in your paper. This should be limited to a total of 100 words.

(b) **Introduction.** Give your topic some context. Why is it important to you? Why is it important to the audience (me, or perhaps mechanical engineers, chemists etc.)? Give some historical background if applicable. Make sure to clearly state the problem, as well as the objectives of the project.

(c) **A literature review.** This includes a short synopsis (no more than two pages) of any relevant articles and how they relate to the work you did. This often constitutes the historical background.

(d) **Description of the numerical method.** This section could be as long as it needs to be to give a complete description, with the understanding that there should be at least two pages of figures and results, detailing the algorithm, and demonstrating that it works as intended.

(e) **Conclusions/Discussion**. Here, maybe a page or two. Reiterate and highlight the points that you hit upon in the introduction. Make sure that the abstract also closely follows your findings, summarized here.

(f) **References** You should cite the course text, but it cannot be your only. The team should find and read other reference material on the topic of interest, both from books and in original journal articles on their topic. Be sure to cite these works in the body of your paper where relevant. Adhere to proper MLA, APA, etc. style for citing references.

(g) **Codes/Appendices** The code that you implement should be included in an appendix. The code must be well commented so that I may correlate parts of the write-up with the important parts of your code.

2 Grading and Deadlines

Here is a brief summary of important dates:

- **October 14th:** One page project abstract.
- **Monday December 2nd - Friday December 6th:** Final Presentations
- **Thursday December 12th:** Final report due by noon. Note: this is later than what is written on the syllabus.