MANE 6710: Numerical Design Optimization

Fall 2024

Prof. Hicken • JEC 5020 • email: *hickej2@rpi.edu*

MANE 6710 Independent Study

Choice decision: due Oct 9 (Wed), 2024
Due Date: Dec 18 (Wed), 2024

Content

You have three choices for the independent study.

(1) An Application of Your Choice: Use optimization to solve a problem of your choice; you may wish to discuss problems with your advisor in order to identify one that would be beneficial to your thesis or project. The problem must satisfy the following criteria.

- The analysis cannot be a simple, closed analytic expression. That is, the analysis must require the solution of linear and/or nonlinear equations. Examples include analyses based on the discretization of ODEs, PDEs, or other simulations.
- There must be at least 2 design variables.

(2) A Deep Neural Network: Implement a deep neural network and a gradient-descent-type method to train it. These software components must satisfy the following requirements.

- The network must have two or more layers, and more than five inputs
- You must demonstrate both the training algorithm (i.e. the gradient-descent method) and the trained network using sample data from an application of your choice.
- **No libraries (e.g. Tensor flow) are allowed for either the network or the gradient-descent algorithm**. You must implement these yourself.
- **Do not reuse code developed for other course projects,** unless you are planning major changes to the software, and you have discussed the chagnes with me.

(3) An Unconstrained Optimization Algorithm: Implement a quasi-Newton optimization algorithm, including a line-search that satisfies the Wolfe (or strong Wolfe) conditions.

- Verify the line-search algorithm using several suitable one-dimensional problems.
- Verify the complete algorithm on one or more multidimensional, unconstrained optimization problems of your choice.
- **You must implement the quasi-Newton method and the line-search algorithms yourself**. No external libraries.

Please inform me of your choice by the date indicated above beside **Choice decision**. If you decide to go with choice (1) above (i.e. application of your choice), then please include a short description of the problem, how you intend to analyze/model it, and the design variables. If you decide to go with choice (2) or (3), then simply indicate the choice on the LMS submission.

Format

You will be assessed based on a report describing your independent study. The report must have the form of an academic paper.

Page limit: minimum 10 pages and maximum 15 pages including figures, tables, references, appendices. You can use a font size as small as 11pt with single line spacing. No title page is necessary, but be sure to write your name on the first page. If your report exceeds this limit you should rethink the way you present the contents: can multiple graphs be presented on the same figure? Can a statement be made more concise?

Figures and Tables

- Ensure that you explain all your results and reference your figures and tables in the text where appropriate. Think about the best way to present your results so that they aid in the understanding of your report. A well thought-out figure or table will make your report clearer.
- Tables vs. text: tables win.
- Graphs vs. tables: graphs usually win. In some cases, you might want to see the digits in a table.
- Make sure you label the axes properly with a readable font, complete with the units used.
- One set of data per plot vs. multiple sets of data per plot: When plotting the same quantity for different parameters, you should show all results in one plot, within reason. Make sure to include legends as necessary.
- When two or more graphs have the same x and y axes, and the data in the graphs are meant to be compared, make sure the graphs have the same ranges on the x and y axes.
- Make sure tables and figures have a descriptive caption and that the caption is in the same page as the figure. Whenever possible, captions should be verbose enough that they can be understood out of the context of the main text. There is no need for a figure title in addition to the caption.
- All figures should be in a vector graphics format or high-resolution bitmaps.
- Refer to figures explicitly in the text. Figures have a purpose and this should be stated when referring to it. e.g., what did that particular plot tell you? Highlight anything worth noting.

Equations

- Explain all variables and symbols.
- If you are short of space, there is no need to repeat equations given in the lectures or in a paper. Just cite it.
- Present equations and computations in a clear and rational manner.
- Use equation typesetting software (such as MS Equation Editor or LaTeX).
- State any assumptions or simplifications made.

Writing Style

- Avoid the passive voice. I know this point is a matter of opinion, and a habit that is hard to kick, but try writing in the active voice and you'll notice that your writing sounds much stronger.

- Avoid "will". E.g. "...drag will increase." vs. "...drag increases." Search for all instances of "will" and see if they are really necessary.
- Which vs. that: Many people use "which" when they should be using "that". Make sure you go "which" hunting before submitting.
- The plural of "minimum" is "minima", maximum/maxima, optimum/optima.
- Wordiness. I see a lot of this. When proof reading, look for a way of eliminating unnecessary words, e.g., "It should be noted..." would sound better as "Note that...". On a similar note, watch our for run-on sentences.
- Spell checking: please check thoroughly before submitting!

LaTeX Tips

Here are a few tips for those of you who are using LaTeXto write your reports.

- To get a properly hyperlinked PDF file, use:

  ```
  \usepackage[bookmarks=true,bookmarksnumbered=true]{hyperref}
  ```

  This makes navigating the PDF much easier.
- Use `/` instead of `\frac` for inline fractions.
- Use proper opening `` ` ` `` → " and closing `' '` → " quotes.
- Protect capital letters in BibTex, e.g.`{N}avier--{S}tokes`.
- Refer to equations as `Equation~\eqref{eq:whatever}`
- Refer to figures and tables as `Figure~\ref{fig:whatever}` and `Table~\ref{fig:whatever}`, respectively.
- In math mode, words and certain abbreviations should be typeset with the regular text font, e.g. `\text{Drag}`, `d_{\text{max}}`.
- Trim all white space around figures and other unnecessary white space.
- Make sure the legend and axis labels are readable.
- If you are having problems with the Matlab PDF export (bounding box problems, usually), export an (eps), then use `epstopdf` to convert, and you get a nice PDF file with proper bounds.
- Be consistent in the bibliography.
- Always use a `~` to keep citations and references together with the word, so that a line break does not separate them, e.g. `Equation~\ref{eq:lift}`.