Final Project Guidelines: MATH 728 – Uncertainty Quantification for Physical and Biological Processes

DUE DATE: 4/28/2025 AT 11:59 PM

Overview: The final project serves as a cumulative assessment of a student's skill development over the course of the semester. As such, the final project should showcase the student's ability to apply concepts related to uncertainty quantification and inverse problems to new avenues. In particular, students should perform some (or all) of the following for the final project (please pick at least 3):

(i) Analyze a computer simulator using local and global sensitivity analysis;
(ii) Compare global sensitivity analysis methods;
(iii) Use sensitivity analysis to fix non-influential parameters;
(iv) Calibrate a computer model to physical observations;
(v) Calibrate a computer model to synthetic, noisy observations;
(vi) Compare weighted and ordinary least squares solutions of multi-output problems;
(vii) Compare frequentist and Bayesian calibrations to noisy observations;
(viii) Construct parameter confidence intervals for a nonlinear model;
(ix) Use MCMC to infer parameter posterior distributions;
(x) Compare MCMC methods (e.g., Metropolis-Hastings versus Hamiltonian Monte Carlo);
(xi) Use frequentist or Bayesian methods for quantifying output uncertainty;
(xii) Examine the effects of different measurement error models;
(xiii) Construct a surrogate model (polynomial chaos, Gaussian processes, machine learning methods) for inferring model parameters;
(xiv) Use active subspaces, principal component analysis, or proper orthogonal decomposition to reduce the dimensionality of an inverse problem;
(xv) Identify model discrepancy between a simulator and data;
(xvi) Identify model discrepancy between a low- and high-fidelity simulator;
(xvii) Compare surrogate models for computing sensitivity metrics;
(xviii) Compare surrogate models for solving frequentist/Bayesian inverse problems; or
(xix) Another topic considered part of the "Uncertainty quantification" or "inverse problem" family.

<u>**Final Project Outline**</u>

The final project will consist of a scientific document (Latex or Word) that follows a typically scientific report. **The final project should be at least four pages**, and include the following sections:

1) Introduction: Describe the problem and why analyzing this model is relevant to science
2) Methods: Describe the mathematical equations and underlying model, describe any mathematical methods being used, and identify any equations or algorithms used for the analysis of the model
3) Results: Present figures <u>**with appropriate font size, line width, labels, and figure captions**</u> describing your results
4) Discussion: Talk about your results, their meaning, and how we should view your results and methods implemented in light of other studies (maybe one or two references to other work).
5) References: Properly cite any papers that describe your problem area or methods.

<u>**Final Project Code**</u>

All code for the final project should be submitted to Dr. Colebank by the above deadline. You may use MATLAB, R, Python, or Julia for your final project. <u>*You may use built in packages, such as UQlab, UQpy, SAlib, OpenTURNS, PyMC, Dakota, or any other packages so long as you cite them and go BEYOND just doing an example from the source developers.*</u> ***You are able to (and encouraged!) to use some of the code/models developed in class, but you must go beyond reproducing a homework problem or class example in the final project.***

<u>**Final Project Grading**</u>

The final project will be graded out of 100. Students are required to communicate with Dr. Colebank prior to the due date to ensure their project is sufficient and reasonable in the amount of time available. In addition, Dr. Colebank will provide assistance in developing or implementing methods with advance notice from the student. The final project will be graded based on the following criteria:

- Appropriate knowledge of UQ methods (30%)
- Correct implementation of UQ methods (20%)
- Proper description of model and methods (10%)
- Appropriate visualization of results, including figures, figure legends, captions, and readable font/line size (30%)
- Project innovation and ability to assimilate knowledge to new problems (10%)