Algorithms Assignments

Due: as assigned prior to the start of class

Objective: since copying the steps of an algorithm is not an effective use of our limited time in class and since understanding the steps of an algorithm requires more than one reading, you will perform these steps individually, which will allow us to focus on application during class

Assignment: Using the textbook, prepare the following for each algorithm:

- briefly summarize (2-4 sentences) a specific, real problem that can/has been solved with this algorithm - you can find this information in the vignettes/case studies in the book as well in the journal articles provided with the book (available in Canvas)
- identify the specific pieces of information that will be given in the problem which will clue you in that this is the correct algorithm (you may find it helpful to do the next point first), generally to include the following as appropriate:
  - variable characteristics (discrete/continuous, scalar/vector)
  - characteristics/formulation of the constraints
  - nature/formulation of the objective function
- using a bulleted format, write the steps of the algorithm in your own words - rote copying of the algorithm from the book or another source is not acceptable (it does not help you understand the algorithm)
- bring your completed work to class - your professor will review it before class starts

Requirements:

- a paper copy of your work is to be presented to the instructor before class; the format is at your discretion, but it should be intentional not haphazard
- this is an individual assignment; you may not copy from each other or show each other your work; however, you may discuss algorithm with each other and ask each other specific questions about the problems/algorithms (but you must write your own versions)

Failure to complete an algorithms assignment will constitute a failure to be prepared for class, and you will be asked to leave (this will count as a personal absence). Productive professional meetings require that participants prepare as necessary prior to the start of the meeting. This requirement will help you build important professional skills.

Optimization with Spreadsheets - 20 points

Due: January 20, 2023

Objective: develop the skill to efficiently and professionally set up an optimization problem in Excel with the goal of being able to share/print the page and clearly communicate the problem and the solution; develop skills that will be helpful in solving the case study problems

Assignment: Work the following problems from Chapter 21: 21-1, 21-2, 21-4, 21-5

Upload a pdf for each problem (to represent the "printed" report of your solution) and a single Excel file (with each problem presented/solved on a separate tab) to the Canvas assignment.

You will be graded on the accuracy of your answer as well as the professionalism and clarity of your presentation in the Excel file as well as the "printouts." (Pay attention to how your pages "print.")

This is an individual assignment. You may not copy from each other or show someone your working solution. However, you may discuss the problems with each other and ask someone specific questions about the problems or the Excel solver. We will use the CpS 110 guidelines for giving help - you may ask someone to help you debug, but you must do all the typing/clicking on your solution. You should cite the help that you received (who and how they helped you).

Theoretical/Computational Development - 50 points each

Due: February 22, 2023/April 7, 2023

Objective: develop a deeper understanding of either the theoretical argument or the computational method for the algorithm based on your professional interests

Assignment: Find a partner (with permission there may be a group of three or a group of one). Plan to choose a different partner for the second assignment. Select an algorithm that has been studied at this point and determine if you are going to do a theoretical or computational investigation. Each group should get it's group composition, algorithm, and investigation approach approved at least two weeks prior to the assignment due date.

- For the theoretical investigation: clearly present the algorithm along with an explanation as to why the algorithm generates an improved solution in each algorithm
  - how do the steps in the algorithm move you towards improvement?
  - can we argue that the algorithm will eventually converge to an optimal answer? is it a local or global optimum?
- For the computational investigation:
  - choose the language in which you are going to implement the algorithm (python and R are recommended, others may be acceptable)
  - write well-documented code that uses the algorithm to generate an optimal solution
  - make sure the required inputs are clearly stated and "easy" for a user to input
  - make sure the solution is clearly presented (including a graphical solution would be appropriate for the algorithms in Chs 9-10)
  - test your code on a sample problem (one that we already know the answer to, but is not too easy)

Requirements:

- For the theoretical investigation:
  - typewritten is not required, but clear, neat, and professional presentation is required
  - submit the clearly articulated discussion of the algorithm addressing the questions presented
- For the computational investigation:
  - submit a copy of your commented code (which should make it clear how the user is to input the problem)
  - submit the test problem that you used
  - submit the input/output of your test problem showing the solution and how you are presenting it to the user
- For either, turn in your solution in class on the day assigned.

Multicriteria Optimization Assignment - 20 points

Due: April 21, 2021

I recommend using Excel for all but the algebraic portions of the assignment (#6 and 7). Present all work professionally (handwritten portions are acceptable). This is an individual assignment.

Consider

$$\min \left[f_1(x) = e^x,\ f_2(x) = \begin{cases} \frac{1}{1+x} & x < 5 \\ (x-5)^2 + \frac{1}{6} & x \geq 5 \end{cases} \right]$$

$$\text{subject to } \ 0 \leq x \leq 10,\ x \in \mathbb{R}$$

(this biobjective optimization problem is adapted from problem 2.11 in *Multicriteria Optimization* by Matthias Ehrgott, 2^{nd} Edition, 2005, Springer)

1. Write $f_2(x)$ as a single expression that can be entered into Excel. You will need to use an indicator function, denoted $1_A(x) = \begin{cases} 1 & \text{if } x \in A \\ 0 & \text{else} \end{cases}$.

   $$f_2(x) = \left(\frac{1}{1+x}\right) 1_{x<5}(x) + \left((x-5)^2 + \frac{1}{6}\right) 1_{x \geq 5}$$

   You may want to consider the use of the `if` function in Excel.

2. Construct the Pareto curve (in the objective space).

3. Graphically identify all the non-dominated points.

4. Based on your graphs, find he set of all efficient solutions.

5. Does this problem have properly efficient solutions? Why or why not?

6. Algebraically state the conditions for a point to be a properly efficient (in the Kuhn Tucker sense) solution.

7. Compute all properly efficient points including the corresponding λ and μ.

8. Formulate the weighted sum scalarization problem. Solve your formulation using the weights,

   $$w_1 = 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 03.8, 0.9, 1 \quad \text{and} \quad w_2 = 1 - w_1$$

   (use Excel's nonlinear solver for each single-objective problem). Graph the Pareto curve of your 10 solutions.

9. Formulate both of the ϵ-constraint method problems for solving the biobjective problem where both f_1 and f_2 are relaxed. Solve your formulations using

   $$\epsilon = (0.01, 0.01), (0.5, 0.1), (1, 0.2), (10, 0.5), (100, 1), (1000, 5), \text{ and } (25000, 30)$$

   (use Excel's nonlinear solver for each single-objective problem - you should have 14 problems to solve). Graph the Pareto curve of your 10 solutions.

Case Studies - 100 points each

Ch 9, 10, and 21 Case Study	Due: February 13, 2023
Ch 12, 13 Case Study	Due: March 31, 2023
Ch 20 Case Study	Due: April 14, 2023

Objective: To improve your ability to take a problem from start to finish, to develop your technical/-computation skills, to develop your teamwork/collaborative skills, and to improve your technical/professional writing skills. It is my goal that with each case study you write and read you will mature in your ability to communicate problems and their solutions to people who need that information. In light of this goal, it would be reasonable to assume that grading on your communication will become less forgiving with each case study.

Audience: These case studies will have two audiences that you must address. The first is the mathematically savvy, therefore you must include sufficient mathematical detail to convince them that your problem formulation and solution are correct (material to support this may be included in appendices). The second audience is the appropriate administrative or business manager, therefore you must include descriptive paragraphs that summarize the problem being solved, explain what your solution is, and discuss how they should use it in non-technical language.

Assignment: For 9/10/21 and 12/13 units, the class will be split into two teams (each team will have a Teams channel to store/share work), and a team-lead will be selected. For Chapter 20, students will work individually (in lieu of a chapter test).

Each team is to form 2-3 subteams (one for each case study that will need to be submitted) taking into consideration different team members strengths and skills (mathematical formulation, computational skills, and writing). The subteam members are to collaborate together to develop and draft a solution that that has been read and revised by each member of the subteam. It will then be submitted for reading/revision by the members of a different subteam and the original subteam will revise based on their feedback.

Each team is to have a meeting once a week (either in person or on Teams) to report on the week's progress. Assign one member of the team to take meeting minutes and post them in your Teams channel. They will be used to assess the project management component of the assignment and should contain the following sections.

- Time/date of the team meeting and who was present. The minutes from the first meeting should also include which people are working on which case study. A Team member should also be selected to take/update the minutes.
- Stating what tasks were accomplished by each team member that week. (You may wish to have team members supply this information in advance.)
- Identifying individual goals for each subteam/person for the week based on the project schedule. Prior to the first team meeting, the team-lead should propose a project completion schedule, which will be revised/approved during the first meeting.

- Reporting on how/if previous goals were met.
- Identifying problems encountered that week and how they could be avoided in the future.
- Recording who submitted revisions and who read/revised each week.

CatMe will also be used to provide peer evaluations periodically throughout the semester and will earn a completion grade.

Case studies not available in your textbook are available on the course website.

- 9.1 Shipping Wood to Market
  (use sensitivity analysis for the last portion)
- 10.2 Aiding Allies
- 21.1 Prudent Provision for Pensions *
- 12.2 Assigning Art
- 13.2 International Investments *
- 20.3 Planning Planers
- 20.4 Pricing under Pressure *

* good for those interested in actuarial topics

Each project will require you to complete the same stages, 1) problem investigation, development, and formulation, 2) solution development/execution, and 3) writing the report (plan on this taking at least 30% of your time investment for the project).

Each Case Study's grade will be based on effective communication (both English/grammar/writing and in the math), accuracy of your model and solution, clarity of the presentation of the problem and the proposed solution based on the following rubric. Your overall grade for each of the two group case studies will be a weighted average of all the case studies your team presents, 80% from the study you primarily worked on and 20% from the study(ies) of the rest of your team.

Be sure that each written submission includes enough information for your professor to evaluate all of the following directly from the written report. Accuracy of your work (including the problem formulation and the solution presented) is assumed in the following rubric. A lack of accuracy will negatively impact your grade.

Communication (30%)

- Executive summary – clearly and concisely written stand-alone summary that is appropriate for someone who reads nothing else
- Problem statement – clearly defines the problem and its business context (should include an introduction)
- Use of figures/tables/equations – clearly constructed, labeled (use table/figure captions and just numbering for equations), and discussed/referenced
  No figure/table/equation should be presented without commentary focusing the reader on how they can understand/interpret what they will see in the figure/table/equation (so commentary should start before the figure/etc. is presented and explicitly reference it).

- Interpretation of model results – relates the results of the modeling process to the problem statement
- Audience – sections tailored to the audience as described in the project statement
- Presentation of variables/models - clearly defined and well integrated into document with sufficient commentary
- Overall presentation - the report and solution files are professionally presented

Problem Formulation and Development (35%)

- Mathematical description of the problem – summary of problem needing a solution
- Selection of variables - define the correct decisions that need to be made
- Mathematical model formulation - correctly **and efficiently** captures relationships to solve the problem
- Correct solution method/technique selected - the method chosen to solve the problem is effective

Solution (25%)

- Presentation and justification of the solution – relates recommended decisions to the business problem and the available data
- Description of the solution – describes the solution in appropriate terms for the stated audiences
- Correctness - presented numerical solution is correct
- Code/solution file – well organized/commented, neatly presented, successfully runs and produces output presented in the report

Project Management and Collaboration (10%)

- Project completion schedule - breaks the project down into stages with a deadline for each stage
- Meeting project deadlines - indicates if team deadlines were met
- Effective team collaboration as evidenced through team meeting minutes
- Recognition of how to improve - documents any problems encountered in the "management" of completing the project with commentary on how to improve

** Grading rubric based on the SOA Exam PA published rubric.