Optimization Mini-Projects
Spring 2022

Learning objectives:

- Application and refinement of key optimization concepts
- Application and refinement of mathematical communication using technical writing and design principles
- Providing and receiving conceptual and design feedback, while also iteratively improving

Stages:

- **Proposal**: Students choose one MP and propose the product and medium(s) they will use. [Time estimate: 1 hour of student's time]. Students submit to Canvas:
  - Selection of MP, proposed medium, and if they need any additional resources.
  - Student initials that they have read and understand all requirements (a, b, …).
  - Instructor provides feedback on proposals where necessary.
- **Draft**: Students begin implementing their proposed project. Progress should include at least 1 major visual and 60% of writing. [Time estimate: 2 hours of student's time]
  - Peers provide partial feedback on drafts: check that every aspect of the target assignment will be satisfied.
- **Final Product**: Students use all feedback and create a final product. [Time estimate: 3+ hours of student's time]
  - Instructor gives full feedback on final products.

Rubric:

Measure	Pts	Level
Conceptual accuracy	**4**	**Advanced:** Showed conceptual accuracy and depth in understanding.
	3	**Proficient:** No major conceptual errors.
	2	**Novice:** Some minor and/or major conceptual errors.
	1	**Beginner:** Fundamental conceptual errors.
Creativity	**4**	**Advanced:** Product is clearly unique and both highly personal and relatable.
	3	**Proficient:** Product is unique.
	2	**Novice:** Several components are similar to other products.
	1	**Beginner:** Major components are plagiarized.
Design of product	**4**	**Advanced:** Design choices were superb in communication of ideas and style.
	3	**Proficient:** Design choices facilitated clear communication of ideas.
	2	**Novice:** Minor design choices interfered with communication of ideas.
	1	**Beginner:** Major design choices interfered with communication of ideas.
Assignment requirements	**4**	**Advanced:** All assignment requirements were met or exceeded.
	3	**Proficient:** All assignment requirements were met.
	2	**Novice:** At least one assignment requirement was not met to satisfaction.
	1	**Beginner:** Multiple assignment requirements were not met to satisfaction.
Peer Feedback	**4**	**Advanced:** Provided substantive and helpful feedback to peers.
	3	**Proficient:** Provided positive and supportive feedback to peers.
	2	**Novice:** Provided little feedback to peers which lacked substance or actionable items.
	1	**Beginner:** Provided inappropriate feedback to peers.

Mini-Project 1 Options: Fundamentals

Pick one of the following:

Beautiful Example: 2D Visualization
Case study, Design principles
Product: Handout, brochure, mini-poster, etc. (1-2 pages, printed)
Medium(s): PowerPoint, Word, Excel, By Hand, or other
Requirements: [Note: Every visual needs 1-3 explanatory sentences]

a) Create an "interesting" LP that has 2 variables, at least 8 constraints (including nonnegativity), and at least 6 extreme points.
b) Compute and display all extreme points. Compute and display three *infeasible* basic solutions.
c) Choose 2 objective functions: one with a unique optimal solution and one with multiple optima. Visualize the objective functions and their associated optimal solutions & optimal values in a comprehensible way.
d) Choose one of the objectives from part (b) and make the LP unbounded by removing some constraints.

Beautiful Example: 3D Visualization
Case study, Design principles
Product: Handout, brochure, mini-poster, etc.
Medium(s): Matlab + PowerPoint/Word (Note: PowerPoint allows you to make documents of any size!)
Requirements: [Note: Every visual needs 1-3 explanatory sentences]
The Matlab function plotregion.m (must be downloaded from Canvas or MathWorks) can be used to plot polytopes from inequality form ($Ax \leq b$).

a) Using the code on the next page as a starting point, modify the A matrix and b vector to create an interesting, new polytope. (Tip: make only a few small changes at a time, then re-run the code to make sure you don't "ruin" the polytope accidentally.)
   Report the final parameters (A and b).
b) Choose 3 of the constraints from the list (8 total in $Ax \leq b$). From this new set of constraints, and compute where the 3 hyperplanes intersect.* Identify which case is true for this solution x:
   i. The inverse of A' does not exist (Matlab will tell you). Why does it not exist?
   ii. The inverse of A' exists and x is an infeasible solution (does not belong to the polytope). How do you know it is infeasible?
   iii. The inverse of A' exists and x is a feasible solution. Identify and label x on your polytope.
c) Repeat (b) for a total of 3 times.

Optimization in the News
Case study, Modeling, Technical writing
Product: Mini-Research Article (printed, 2-4 pages, professional font, 2-4 sources)
Medium(s): Word, Latex
Requirements:

a) Find 2 news articles related to a local, national, or global issue you care about. Describe the issue broadly in an "Introduction" section, citing these sources. Identify which aspects of the issue can be classified as *decisions*, *constraints*, and *objective(s)*.
b) In a "Data" section, discuss what data should exist about this issue (even if you do not have the data). Define a set of parameters that would be useful for a model.
c) In a "Model" section, define at least two decision variables. Use your list of parameters to define at least two constraints and at least one objective function for this problem.
d) Include a visual aid. For example, either (find) a motivating photograph or (create) a graphical representation of the problem and/or model. Discuss the relevance of the image somewhere in your writing.
e) In an "Analysis" section, answer one of the following questions in-depth with a paragraph:
   a. Does this problem naturally have more than one objective? How do these objectives relate to one another?
   b. Is there any uncertainty in the parameters that you have proposed? If a model took this uncertainty into account, how would the final solution be improved?
f) In a "Bibliography" section, cite all sources.

*How to do this? (1) Take the subset of constraints as $A' x \leq b'$, (2) use Matlab to compute the inverse of A' using the inv() function, and (3) compute $x = (A')^{-1} b'$.

```matlab
%% Example Code
close all
A=[1,1,1;-1,1,1;1,-1,1;1,1,-1;-1,-1,1;-1,1,-1;1,-1,-1;-1,-1,-1];
b=-ones(8,1);
plotregion(A,b);
axis equal
```

Mini-Project 2 Options: Duality

Pick one of the following:

Shadow Price Experimentation	Duality Partial Notes
Coding, Mathematical interpretation, Technical writing **Product:** Mini-Research Article (printed, 2-4 pages, professional font) **Medium(s):** Matlab (required) + Word or Latex **Requirements:** Organize your write-up according to the following sections: a) **Problem setting.** Provide a context for an LP such that the objective function is in terms of profit and the constraints have some realistic interpretation. Construct an LP with at least 4 decision variables and at least 4 inequality constraints (parameters can be random). b) **Dual problem.** Formulate the dual LP, and use Matlab's linprog function to solve both the primal and the dual LP. c) **Hypothesis.** Explain the shadow-price interpretation of the optimal dual variables in terms of your primal problem (given the context you created). Predict how the primal optimal **value** will change when you modify the righthand sides of the constraints. Be precise (use numbers). d) **Experiment 1.** Test the accuracy of your predictions with experiments: modify the righthand side of the first constraint, and evaluate the new primal optimal value. Repeat for each constraint. e) **Experiment 2.** Design a computational experiment to determine the delta for a constraint's RHS (from definition in class), i.e., how far can you increase it such that the shadow price prediction is accurate? f) **Results.** Include (i) a well-designed table to summarize the results of your Experiment 1, explaining whether the results support or refute your hypotheses in part d, and (ii) a well-designed graph to summarize the results of Experiment 2.	*Educational design, Design principles* **Product:** Handout/brochure **Medium(s):** Word, Latex, PowerPoint **Requirements:** Design partially filled note pages specially designed for Dr. P's lectures on duality. Your handout should cover at least two major concepts from duality (e.g., how to compute, weak/strong duality, comp. slackness, shadow price). a) The note pages may include some of Dr. P's visuals, but it *must* include a novel visual aid of your own design. b) Provide a "blank" version for other students to use. c) Include a "completed" version with everything correctly filled. d) Make a bulleted list of the design decisions you made for this document: explain *why* it looks the way it does and *how* it should be used! Discuss at least 4 key decisions. e) Provide me with an editable version, as well.

Case Study: IP Duality *Advanced mathematics, Technical reading & writing* **Product:** Mini-Research Article (printed, 2-4 pages, professional font) **Medium(s):** Matlab (required) + Word or Latex **Requirements:** Skim the Hooker 2009 article "IP Duality" included in the Canvas assignment page. *Note that you do not have to understand the full article!* a) Use information from the article to communicate the following idea in your own words: "Unlike LP duality, IP duality is not a singular concept; in fact, multiple notions for IP duals have been proposed, but *none* of them have all the *nice* properties of LP duality!" b) Give a high-level overview of the different types of IP duals and which properties they each have. c) Then give a deep-dive into one of the definitions for an IP dual. Explain it the best way you can! d) Design at least one baby example to help illustrate your understanding. Your example should use some combination of Matlab computations and well-designed visual aids.	**Triobjective Linear Programming** *Coding, Algorithmic design, Design principles* **Product:** Mini-Research Article (printed, 2-4 pages, professional font) **Medium(s):** Matlab (required) + Word or Latex **Requirements:** Dichotomic search uses weighted sum scalarization to solve for the nondominated points of a biobjective LP. Solving weighted sum for three objectives is just as easy, but does dichotomic search generalize so easily? Organize your write-up according to the following sections: a) **Problem setting.** Provide a context for an LP that has three objective functions. Construct an LP with at least 4 decision variables and at least 4 inequality constraints (parameters can be random). b) **Brute force approach**. Implement an organized approach to use different weights for solving the weighted sum scalarization. You should assume your weights sum to one, i.e., $\lambda_1 + \lambda_2 + \lambda_3 = 1$. Use Matlab's linprog to solve each LP. Explain your algorithmic approach. c) **Weight set decomposition**. Visualize the results of your brute force search by plotting points (λ_1, λ_2) that are color-coded based on the image found. The set of weights is called the *weight set*. Explain why when plotting all (λ_1, λ_2) the result is a triangle. Observe: does each colored region (one per image) appear to be convex? d) **Refined search.** How would you refine your brute force approach to be more accurate? Could you algorithmically search for a missing ND image?

Mini-Project 3 Options: Mastery
Pick one of the following:

Research Blog Post	**CAAM Research Network**	**Concept Map**
Case study, Modeling, Technical writing **Product:** Blog post **Medium(s):** Word* or Latex, PowerPoint, etc. **Requirements:** a) Find an optimization research article that presents a *model* for a problem that you find interesting. Write a blog post that could be read by another undergraduate optimization student and satisfies (b)-(d). Include a proper citation for the article and a link to any images you get from online. b) Describe the motivation for the problem/model in your own words, using at least one non-mathematical visual. c) List and explain at least three decision variables. What kind of variables are they, and what lower/upper bounds apply to them? List and explain at least two "simple" constraints and at least one "advanced" constraint. d) Create your own graphic that helps to communicate one mathematical component of the paper to the reader. Optional: If you want your blog post to be published on my Medium page then you must provide (1) a Word document (2) *avoid using any double indices, use only simplified variables,* and (3) *high resolution* images (example: Google images → Tools → Size = Large). You will be highlighted as the "Guest Author" for the article!	*Reading research, Design principles* **Product:** Handout, brochure, mini-poster **Medium(s):** Word, Latex, PowerPoint **Requirements:** Explore and summarize the research topics of CAAM faculty using their websites and Google scholar to access their papers. a) Choose 3 faculty to give a high-level summary (part b) and 1 other faculty to take a deeper dive into their work (part c). For each faculty member, include a photo. b) For 3 faculty: summarize the topics of their research from their department/personal websites. For each, list the titles of 3 papers on topics that interest you. c) For 1 faculty (different from those in part b): summarize the topics of their research from their department/personal websites. Then, choose a paper on a topic that interests you. Present the title of the paper along with one paragraph which describes the application and the optimization/mathematical research question. Then, use a bulleted list to describe some of the key words and methods that are important to the paper (even if they are unfamiliar to you).	*Educational design, Design principles* **Product:** Handout, brochure, mini-poster **Medium(s):** Word, Latex, PowerPoint **Requirements:** a) Construct a "zoomed out" concept map for 10 of the most important concepts in the class. b) Construct a "zoomed in" concept map that focuses on a subgraph of the map from a and add 10 more specific concepts. c) Choose 3 links in each concept map and discuss each in 2-4 sentences. Note: Standard concept maps use labeled nodes to represent concepts, and the edges between the two represent relationships that are described by short descriptions/phrases. Feel free to adapt the formatting.

Volleyball Rotation IP
Case study, Modeling, Technical writing
Product: Mini-Research Article (printed, 2-4 pages, professional font)
Medium(s): Word or Latex, PowerPoint, etc.
Requirements: Volleyball is a team sport where the rules of a feasible team "lineup" has a rather nice combinatorial structure, which means it may be analyzed with an IP model. Your goal is to model as many aspects for the problem description as possible. I will provide a numbered list of characteristics to describe the rules of (in)feasible solutions (Note: this list may grow as I add to it over time, and even then it may never be "complete"). *You will model an IP but will not solve this model.* The research question is as follows: The most popular rotations in volleyball are 6-2 and 5-1. Are either of these optimal? If given a full team, what assignment of player to position would be optimal? Your research article should be structured as follows:

a) **Background:** Use visual aids to describe the 6 possible *starting positions (SP)*, e.g., positions 1-6, and 4 *playing position (PP)*, e.g., setter, middle, libero, pin hitter. Explain the key difference between 6-2 and 5-1 in your own words.
b) **Decision variables:** Clearly define your decision variables, which must include binary variables, along with necessary indices.
c) **Constraints**: Provide linear constraints which model feasible solutions to the volleyball rotation problem. Constraints should be labeled with the number from the provided list of characteristics for feasible solutions. Note: there likely will not be a one-to-one relationship between constraints and characteristics; sometimes many constraints are necessary for one characteristic, or one constraint handles multiple characteristics, so be extra clear in how you label them. The minimum requirement is 7 characteristics to be modeled, but more is preferred.
d) **Gaps:** If you believe your model is incomplete (e.g., does not handle one characteristic from the list), then clearly identify this gap in your model. Explain how a feasible solution may not satisfy this requirement.
e) **Objective function:** Define an objective function that you believe would help in answering the research question. You should clearly define what parameters you want to use in your objective, and assume that you have access to a professional team, and therefore can ask for *any data that you want*.
f) **Discussion:** Discuss the most challenging aspects of the modeling decisions. Give an accurate estimate of the number of constraints and decision variables are included in your model. Discuss whether your model has symmetry, i.e., if (x, y) is feasible then so is (y, x).

Feasible solution characteristics: For rotations $r = 1..6$:

1. Each player is assigned exactly one SP and PP.
2. Every PP has exactly one player. Every SP has exactly one player.
3. If player A has $SP = i$ in rotation r and is not substituted, then in rotation $r + 1$ they have $SP = i + 1$ (with the obvious exception for $i = 6$, which is followed by 1).
4. A player has SP in front row if and only if the PP is in front row. A player has SP in back row if and only if the PP is in back row.
5. In every rotation, there is exactly one active setter on the court.
6. If the active setter has SP in the back row, then PP = 1. If the active setter has SP in the front row, then PP=2.
7. If a middle has SP in the front row, then their PP=3. (If there are multiple middles in the front row, then at least one has PP=3.)
8. The libero's SP and PP are restricted to back row only.
9. The libero can substitute up to 2 other players, but not at the same time and only when that player is in the back row. (Said another way, the number of distinct people subbed out by the libero is at most 2. The libero is one person so cannot replace two people at one time.)
10. If libero subs out player A, then player A must come back to replace the libero.
11. If a player's position is off the court, then the player cannot be playing ($SP = 0$ implies $PP = 0$); the reverse will depend on your formulation.
12. Players that are off the court should not "contribute" to the objective function. For example, if the libero subs out player A, then the libero should count towards the objective function but player A should *not* (since they are off the court).
13. "Normal" substitutions (not involving the libero, but between two other types of players) are allowed but they are limited to N over all 6 rotations.

Hint: you should initially assume that you are given a team where players A-B are setters, players C-E are pin hitters, players F-G are middle hitters, and player H is a libero—and that these positions are fixed.

Basics: A standard volleyball team has 7 players: only 6 are allowed on the court at one time, and the 7th is a substitute who switches places with player(s) as the game progresses. This substitution is a critical component of the combinatorial problem, and it must follow many additional rules. The court is divided into 6 regions which are numbered 1-6. These 6 regions will always keep these number labels and will be used to describe both the starting position (SP) and playing position (PP) for every player. For each rotation, each player has *exactly one SP AND exactly one PP*; notably, the SP and PP are often not the same, and one or both will change in the next rotation! The essence of this problem is to *assign or schedule* the SP and PP for each player in every rotation. We commonly refer to the three regions close to the net (positions 2-4) the "front row" and the other regions "back row."

Regions of the Court			
1	6	5	Back row
2	3	4	Front row
NET			
4	3	2	Front row
5	6	1	Back row

Starting positions: Every SP must be filled in every rotation without overlap. As the game progresses (when the opponent serves but loses the point), all players rotate clockwise. Therefore, the player in position #1 serves first (A* in the following example), the player in position #2 (F) serves second, etc. After six rotations, the "schedule" of assigned SPs and PPs just repeat, so planning just the 6 is sufficient. Note: you may want to use a "dummy" SP of 0 to represent a player is not on the court.

SP in Rotation 1		
A*	B	C
F	E	D
NET		

SP in Rotation 2		
F	A*	B
E	D	C
NET		

Playing positions: In each rotation, each player is assigned to one of the court regions as their PP. Notably, their PP does not have to be the same as the SP (after the serve, they simply cross from their SP to their PP). Every PP must be filled in every rotation without overlap. The one rule is that if a player has SP in the front row, then their PP must also be front row, and same for back row. A common example is shown below, where the changes from SP to PP are in bold. Whereas the *SP are dictated by rules*, the *PP are dictated by strategy*, e.g., who is most effective hitting on the left or right side of the net? Note: you may want to use a "dummy" PP of 0 to represent a player is not playing.

SP in Rotation 1		
A*	**B →**	**C ←**
F →	E	**D ←**
NET		

PP in Rotation 1		
A*	**C**	**B**
D	E	**F**
NET		

Players: There are 4 standard players, described below. Hint: you should initially assume that you are given a team where players A-B are setters, players C-E are pin hitters, players F-G are middle hitters, and player H is a libero—and that these positions are fixed. Later, you can relax these assumptions and suppose that there are extra players in each position and/or that you may also assign a position to each player.

- The **setter** is analogous to the quarterback in football or the pitcher in baseball: they are integral to every offensive play of the team. A 5-1 rotation means that a team has exactly 1 setter (which does not change) for the entire match. A 6-2 rotation means that a team has 2 setters which alternate between hitting and setting: whoever is in the backrow is the active setter. A competitive team always has exactly one active setter on a court; any inactive setters would follow the rules of a pin hitter (described next). An active setter is expected to have PP on the right side of the court: so position 1 if they are back row and position 2 if they are front row. You should assume your team has *access to at least 2 setters*.
- **Pin hitters** are the most flexible players, as they play both front and back row. In the front row, they can generally hit in any front position, but they tend to specialize hitting at the left/right side of the net (positions 2 and 4, called the "pins"). In the back row, pin hitters may also play any position. You should assume your team has *access to at least 3 pin hitters*.
- **Middle hitters** "lead the front row" and are crucial to the blocking power of the team. Therefore, when in the front row, they only play in the middle position (3). They are commonly subbed out in the back row, but they can in theory play in any back row position. You should assume your team has *access to at least 2 middles*.
- The **libero** is the "lead of the back row." They are constrained by many extra rules, including they may only play in the back row, cannot hit, etc. Critically, a libero is allowed to substitute for two distinct players! By choosing players that are "opposite" from each other in the rotation (common example: both middles), then the libero can be on the court almost at all times! Notably these libero substitutions are *unlimited.* You should assume your team has *exactly one libero*.

Other

Pokemon IP *Modeling, Technical writing* **Product:** Mini-Research Article (printed, 2-4 pages, professional font) **Medium(s):** Matlab (required) + Word or Latex **Requirements:** The Pokemon game is designed with 18 elemental types (e.g., fire, water), each of which has a numeric multiplier against other types. For example, 1 (normal effective), 2 (super effective), 0.5 (not very effective) and 0 (not effective). Note that the matrix of multipliers is NOT symmetric! g) Propose a research question which may be solved by an IP that uses this multiplier data as parameters. Example 1: *Which type combination of two (or three) types is the "most powerful"?* Example 2: *If a new elemental type were added to the list, which would make the system more "balanced"?* h) Explain a complete IP model which attempts to answer your research question. (For example 2, your model must include restrictions on the multipliers, e.g., at most N_i of each type of multiplier, where you choose N_i.) i) Explain why you chose the objective function that your model uses. Give some examples of feasible solutions and their objective values. j) Use Matlab to solve the IP model. Report not only optimal solution and values but also "computational metrics", e.g., how long intlinprog took to solve the problem. k) Provide a visual representation of the solution to your research question.	**Helpful Handouts** *Educational design, Design principles* **Product:** Handout/brochure **Medium(s):** Word, Latex, PowerPoint **Requirements:** Come up with 3 pages specially designed for optimization notes or problems. For example, use small multiples to facilitate drawing multiple LP feasible sets, multiobjective image sets, branch and bound, or networks. d) Provide a "blank" version for anyone to use. e) Make a bulleted list of the design decisions you made for this document: explain *why* it looks the way it does and *how* it should be used! Discuss at least 4 key decisions. f) Use your pages to illustrate at least two beautiful examples (one for a concept and one for a computation).

YouTube Tutorial Review *Educational design* **Product:** Handout/brochure (printed) **Medium(s):** Word, Latex (printed) **Requirements:** a) Find 4 videos about linear programming to watch from YouTube. Report the title of the video, along with the channel, date posted, and length of the video. Report the length of each video in minutes (minimum of 60 minutes total). b) Rate each video out of 5 stars based communication, visuals, and two other criteria that are important to you. c) For each video, come up with 3 questions & answers for students watching to check their understanding from what the video covered.	**Sample Test Problems** *Educational design, Problem solving* **Product:** Handout (2-4 pages, printed) **Medium(s):** Word, Latex, By Hand **Requirements:** a) Create 8 test problems including complete solutions that satisfy (b)-(d). Up to four questions may be collected from other sources as long as you *cite* them! b) At least one modeling question – if it is collected from elsewhere, then *cite it* and edit the context to make it your own! c) At least three *concept* questions and at least three *calculation* questions.

	At least one question that requires a visual aid (e.g., an LP feasible set), which you should also provide. The visual aid does NOT need to be created in Latex!!

Lesson Plan Design *Educational design* **Product:** Lesson plan + video of highlights **Medium(s):** Word + Video recording (YouTube, Zoom, etc.) **Requirements:** l) Choose a challenging topic of the class. Outline a lesson plan for a single lecture (~50-minutes) to present that topic with appropriate context. m) Provide at least 4 definitions related to the course topic; for two definitions, provide a useful visual. n) Create at least one engaging activity or one dynamic visualization. As appropriate, provide sources and appropriate directions. Record a video of the “highlights reel.” In the video, present (b) the two definitions with your visuals (b) and how you incorporate (c) into the lesson. Video should be at least 5 minutes.	**Research Blog Post** *Case study, Modeling, Research* **Product:** Blog post **Medium(s):** Word for text, PowerPoint, etc. **Requirements:** e) Find an optimization research article that presents a model for a problem that you find interesting. Write a blog post that could be read by another undergraduate optimization student and satisfies (b)-(d). Include a proper citation for the article and a link to any images you get from online. f) Describe the motivation for the problem/model in your own words, using at least one non-mathematical visual. g) List and explain at least three decision variables. What kind of variables are they, and what lower/upper bounds apply to them? List and explain at least two “simple” constraints and at least one “advanced” constraint. h) Create your own graphic that helps to communicate one mathematical component of the paper to the reader.
Concept Map *Educational design, design principles* **Product:** Handout, brochure, mini-poster **Medium(s):** Word, Latex, PowerPoint **Requirements:** d) Construct a “zoomed out” concept map for the most important concepts in the class. e) Construct a “zoomed in” concept map that focuses on more specific details for a subgraph of the previous concept map. f) Choose 3 links in these concept maps, and discuss each in a short paragraph. [Note: Standard concept maps use labeled nodes to represent concepts, and the edges between the two represent relationships that are described by short descriptions/phrases. Feel free to adapt the formatting.]	**Helpful Note Pages** *Educational design, design principles* **Product:** Handout/brochure **Medium(s):** Word, Latex, PowerPoint **Requirements:** g) Come up with pages specially designed for optimization notes or problems. For example, use small multiples to facilitate drawing multiple LP feasible sets, simplex tableaus, or networks. Provide a “blank” version for others to use. h) Make a bulleted list of the design decisions you made for this document: explain *why* it looks the way it does and *how* it should be used! Discuss at least 4 key decisions. i) Use your pages to illustrate at least two beautiful examples (one for a concept and one for a computation).

Beautiful Examples *Case study, Design principles* **Product:** Handout, brochure, mini-poster, etc. **Medium(s):** PowerPoint, Word, Excel, or any of choice (Note: PowerPoint allows you to make documents of any size!) **Requirements:** g) Construct a primal LP feasible set defined with 3 variables and 3 inequality constraints (excluding nonnegativity). Compute and display all extreme points. h) Choose 2 objective functions: one with a unique optimal solution and one with multiple optima. Plot the biobjective image set in objective space. Identify all efficient solutions and nondominated images. i) Compute a dual for one of these objectives. Write its LP formulation and represent it visually in the same manner as (a). Illustrate complementary slackness with this primal/dual.	**Practice Problem Rehearsal** *Problem solving, Scripting, Technical writing* **Product:** Handout **Medium(s):** Latex (required) **Requirements:** a) Choose 10 unassigned problems from Chapter 6 (duality) to solve completely. b) Write up the solutions in Latex with clear and accurate explanations. c) Include at least two helpful visual aids.
Design Module for Dashboard *Educational design, design principles, coding* **Product:** Code + Description **Medium(s):** Matlab, Python, or R **Requirements:** e) Choose one of the following topics: duality, multiobjective LPs, robust LPs, or stochastic LPs. f) Design the components of a new interactive module for the dashboard. Sketch out the module, including text, buttons, sliders, etc. g) Describe the purpose and function of the module in writing. Describe what each button, slider, etc. should do. Come up with at least two thoughtful questions to prompt the user (one concept and one calculation) and provide your own answer to those questions. h) Use code to generate a beta version of your module's graphical visualization. Values from the interactive features (e.g., buttons or sliders) can be fixed and instead focus on the graph's design. Use appropriate labels, legends, and color scales. You will be provided with relevant libraries and small functional examples. For example: R + ggplot2, …	**Optimization Solver** *Coding* **Product:** Matlab code + Description **Medium(s):** Matlab (previous experience with Python required) **Requirements:** a) Build an IP/LP model in python to be solved by Gurobi solver. The model should contain at least 6 variables, and at least 6 constraints (not counting sign constraints). b) For a fixed objective function, solve the model with continuous variables and discrete variables. Compare the optimal solutions and the objective values. c) For a fixed objective function, experiment with removing one or more constraints. Show when the model becomes unbounded. Your write-up should include the model for (a) as well as the results of analysis for (b) and (c). The code should also be partitioned into parts a/b/c and be commented to be read by someone else.