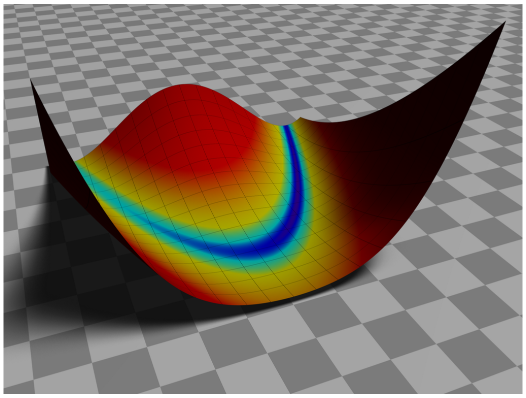
Introduction

Lecture 1



ME EN 575
Andrew Ning
aning@byu.edu

Outline

Syllabus

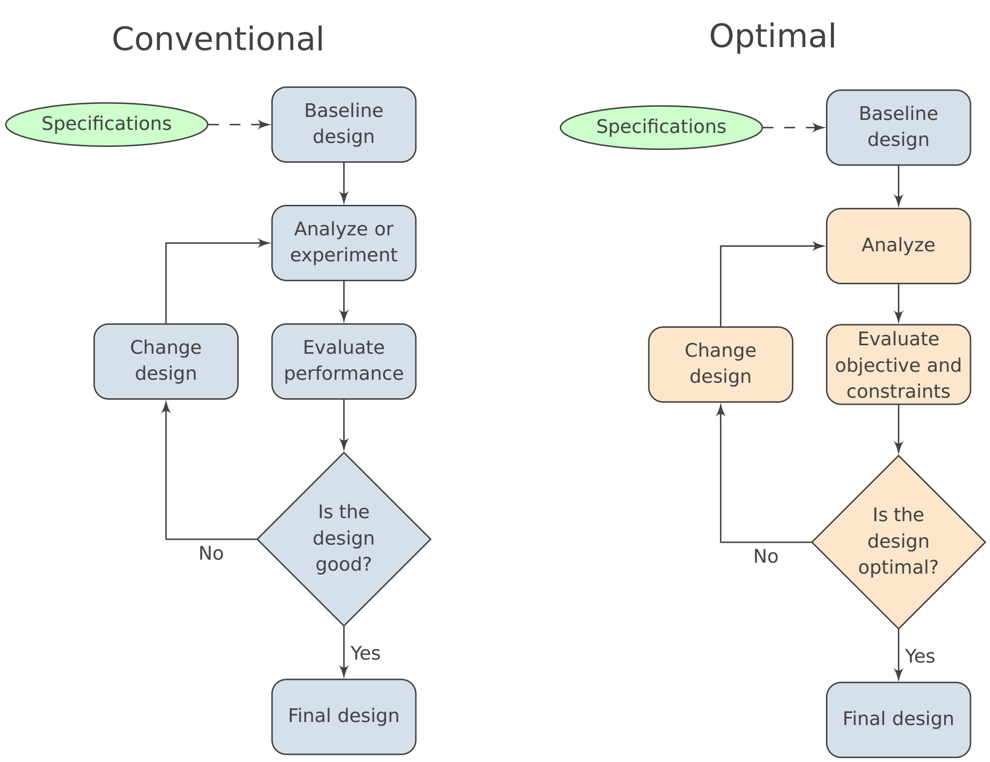
Optimization Basics

Examples (from past students)

Syllabus: Some Important Points

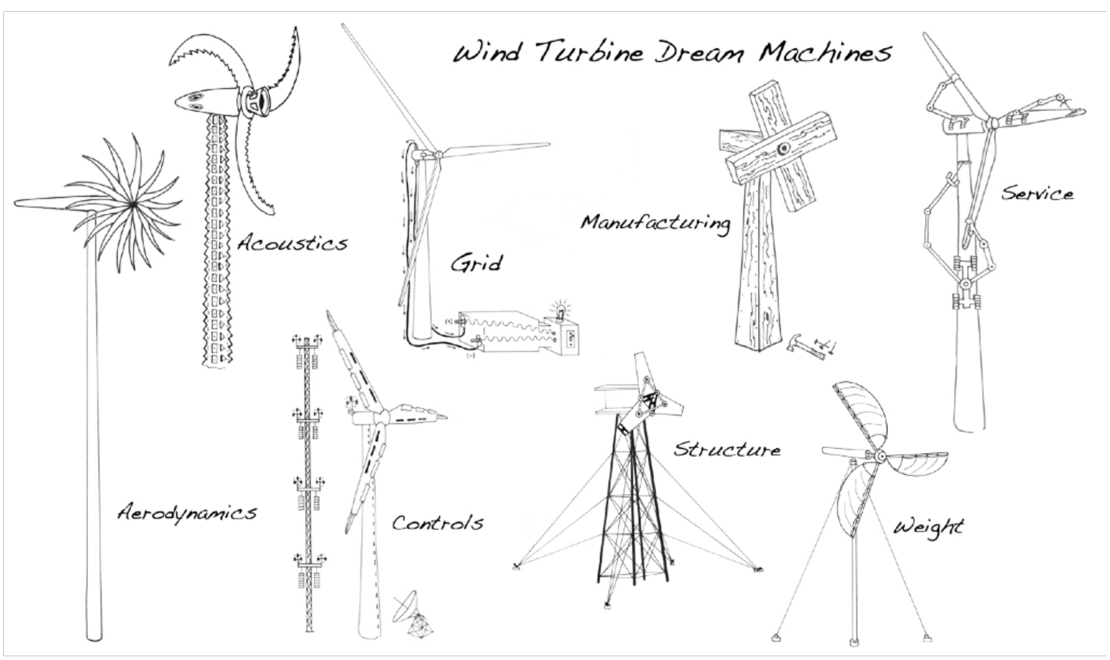
- Make sure your email is current on Learning Suite
- Prerequisites
- Matlab or Python
- Must not refer to homeworks from prior students
- Project
- Weekly Quizzes
- Piazza
- Discussion Session?
- Ask Questions!

What is Optimization?



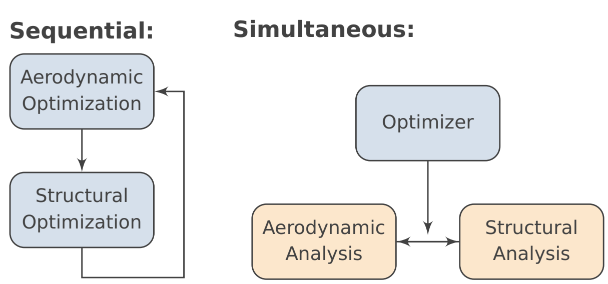
Objective Function

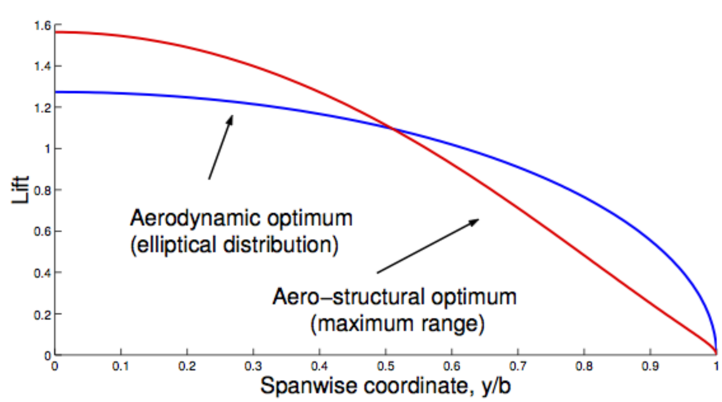
- An objective defines what we mean by "best". It enables us to compare two designs quantitatively.
- If we select the wrong goal, it doesn't matter how good the analysis is, or how efficient the optimization method is. Therefore, it's important to select a good objective function.
- This is not an easy problem, even for experienced designers.



- An objective function may be linear or nonlinear.
- We will represent the objective function by the scalar f or J.
- Our convention will be to minimize the objective.
- Question: What if you want to maximize?
- Question: What if you have multiple objectives?
- Question: What if you have multiple disciplines?

Multidisciplinary Optimization





- Sequential optimization does not lead to the true optimum.
- Need a truly multidisciplinary objective

$$\text{Range} = \frac{V}{c}\frac{L}{D}\ln\left(\frac{W_i}{W_f}\right)$$

- Achieving the proper trade-off requires simultaneous optimization.

Design Variables

- Design variables, also known as decision variables, are the variables in the problem that we allow to change in the optimization process.
- Optimization is the process of choosing the design variables that yield an optimum design.

- Represented by the vector x.
- Design variables should be independent of each other.
- Design variables can be continuous or discrete. Discrete variables are sometimes called integer variables.

Constraints

- Few practical engineering optimizations problems are unconstrained.
- They may be equality or inequality constraints.
- At a given design point, constraints may be active or inactive. This distinction is particularly important at the optimum.

- Constraints on the design variables are called bounds and are easy to enforce.

$$lb \leq x \leq ub$$

- Like the objective function, constraints can be linear:

$$Ax \leq 0$$

or nonlinear:

$$c(x) \leq 0$$

Optimization Problem Statement

Objective function, design variables, and constraints form the optimization problem statement:

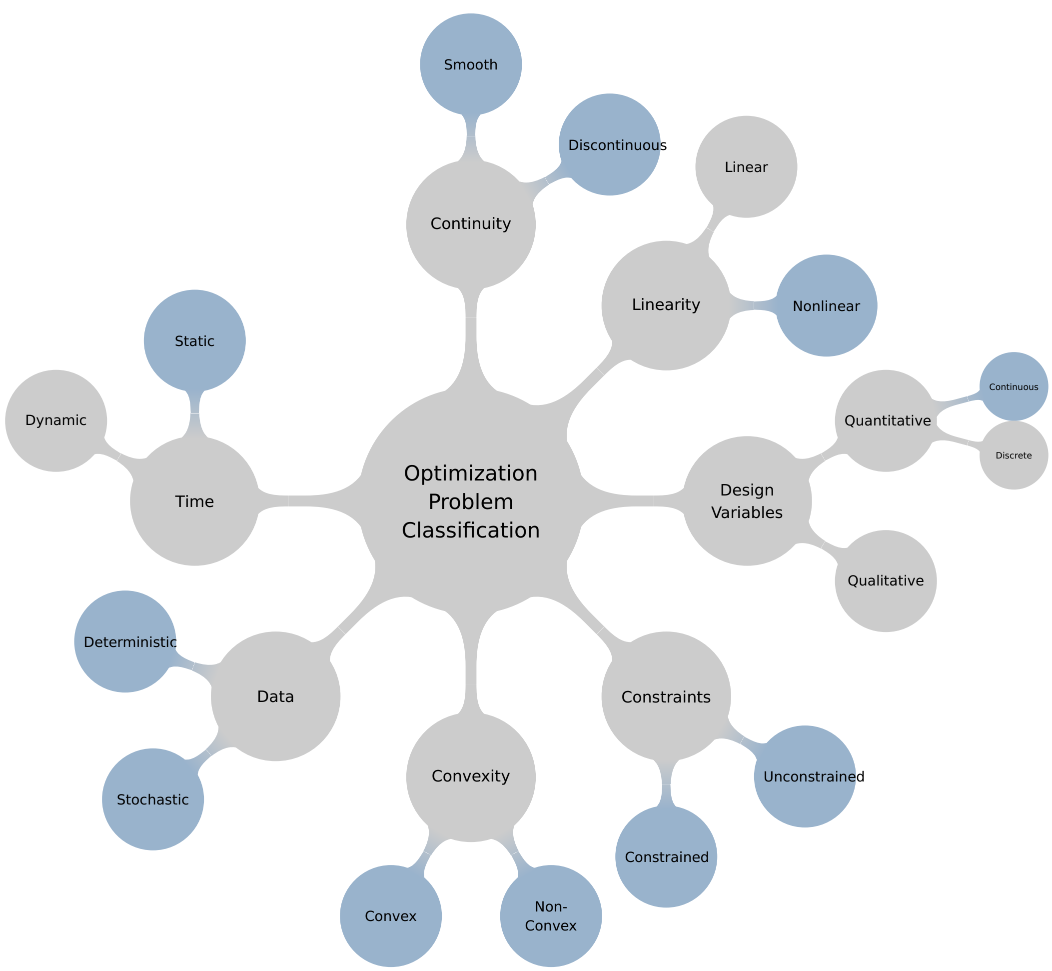
$$\begin{array}{rl} \text{minimize} & f(x) \\ \text{with respect to} & x \in \mathbb{R}^n \\ \text{subject to} & \hat{c}_j(x) = 0, \quad j = 1, 2, \ldots, \hat{m} \\ & c_k(x) \geq 0, \quad k = 1, 2, \ldots, m \end{array}$$

f: objective function, output (e.g., structural weight).

x: vector of design variables, inputs (e.g., aerodynamic shape); bounds can be set on these variables.

$\hat{c}$: vector of equality constraints (e.g., lift); in general these are nonlinear functions of the design variables.

c: vector of inequality constraints (e.g., structural stresses), may also be nonlinear and implicit.

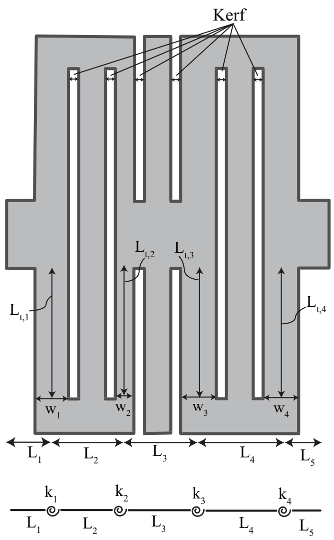


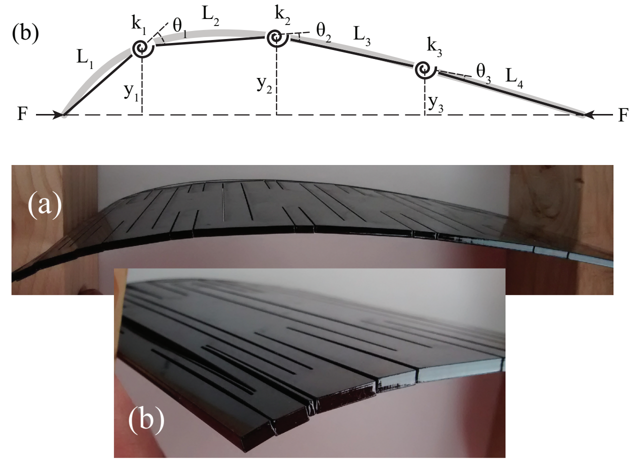
Optimization Methods

- **Convex**: These are ideal. Straightforward to solve, provable global optimum.
- **Integer or Mixed Integer**: Heuristic based. Generally only effective with “convex” problems, or rapid analyses.
- **Gradient-Free**: Robust, useful with discrete variables. Effective only with small to modest number of design variables.

- **Response surfaces**: Useful for noisy functions (that you cannot change), but requires a large number of evaluations to create fit.
- **Gradient-based**: Most efficient, especially for large number of design variables. Objectives and constraints must be smooth functions. Even better if you can supply the gradients.

Cylindrical surface with tailored stiffness



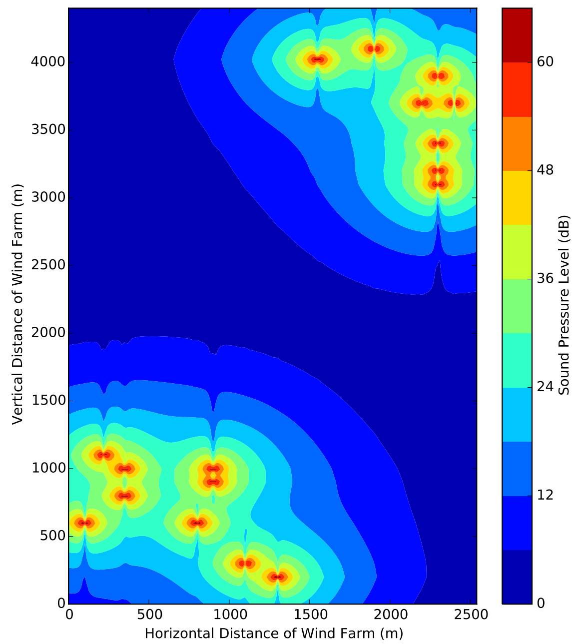


Todd Nelson and Jared Bruton

System evolvability of a cookstove

Jeff Allen and Kendall Thacker

Wind farm power and acoustics

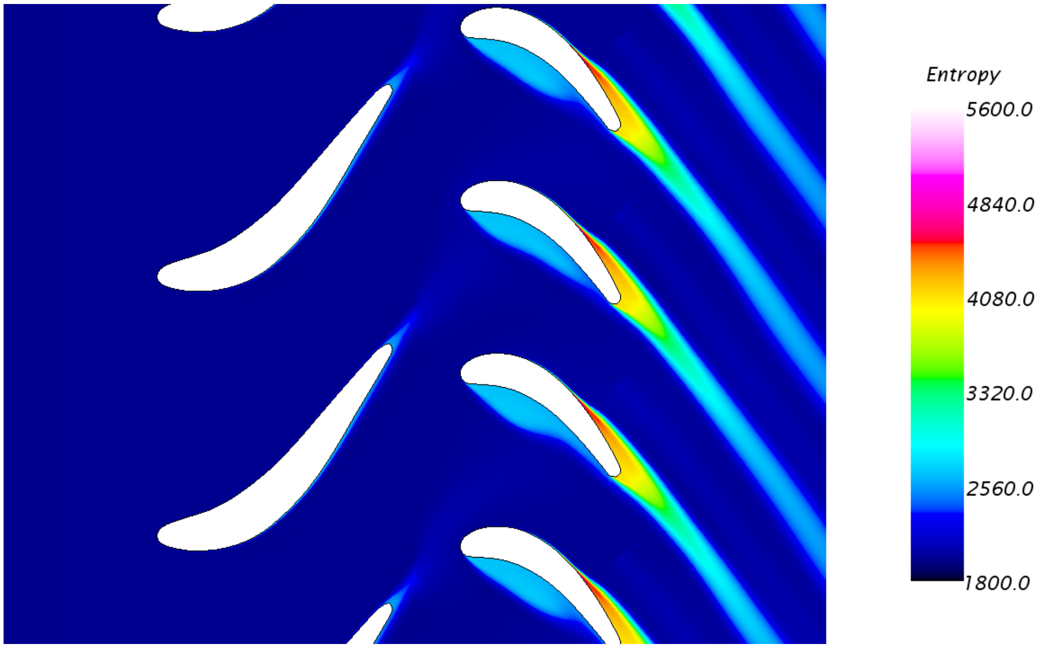


Jared Thomas and Eric Tingey

Optimized schedule simulator for students

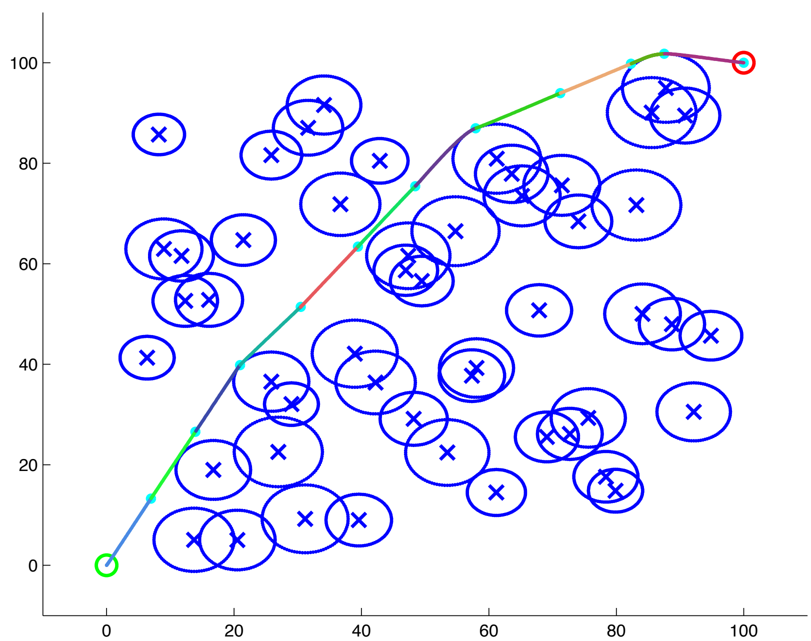
Sam McDonald and Dallin Swiss

Shape optimization of turbine geometry in pulsing flow conditions



Mark Fernelius

UAV Path Planning



Kyle Ingersoll, Patrick DeFranco, and Bryce Ingersoll

Fantasy baseball

NAME	**POSITION**	**SALARY**	**PPG**
MATT WIETERS	C	3	3.3846
JUSTIN MORNEAU	1B	1	3.1407
NOLAN ARENADO	2B	13	3.2522
NEIL WALKER	3B	7	3.1678
ERICK AYBAR	SS	4	2.6346
GEORGE SPRINGER	OF	18	3.5384
JAYSON WERTH	OF	5	3.4082
GIANCARLO STANTON	OF	41	4.1310
JORGE SOLER	OF	4	3.7083
COREY DICKERSON	OF	23	3.3206
BEN ZOBRIST	2B	4	3.0136
CARLOS SANTANA	1B	4	3.2894
AVISAIL GARCIA	OF	1	2.9565
RUSNEY CASTILLO	OF	1	3.7532
KEN GILES	RP	1	3.2694
MASAHIRO TANAKA	SP	[illegible]	[illegible]

Cameron Jones and Scott Jackson