Lesson 1. Introduction

What is operations research?

- "The most influential academic discipline field you've never heard of"   [Boston Globe, 2004]

- **Operations Research (OR)** is the discipline of applying advanced mathematical methods to help make better decisions

- "The Science of Better"   [INFORMS slogan]

- "A liberal education in a technological world"   [Thomas Magnanti, former Dean of Engineering at MIT]

- Numerous applications, e.g.

    - logistics
    - manufacturing
    - workforce scheduling
    - finance
    - marketing

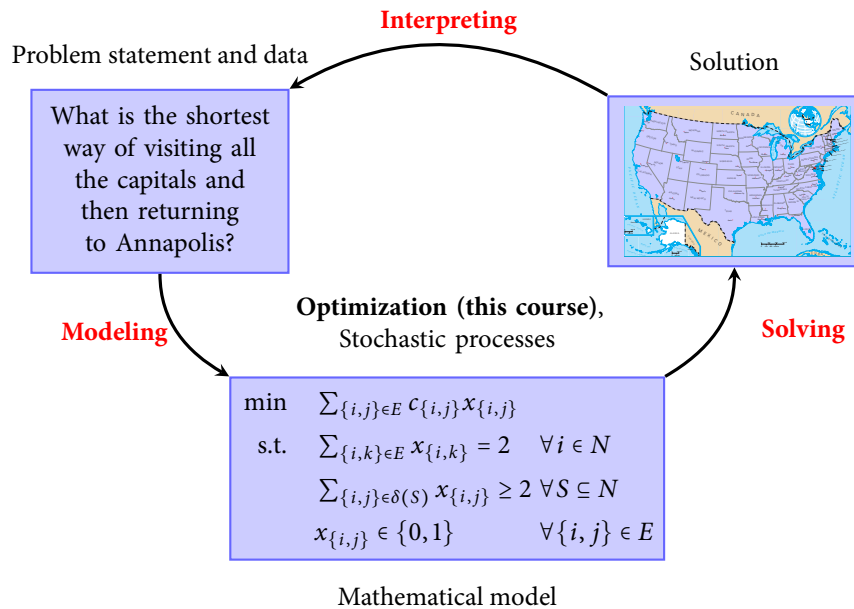**OR and the military**

- The military uses OR to improve decision making in a variety of ways, e.g.

    - force composition
    - weapon selection
    - search and detection
    - flight operations scheduling
    - training and personnel assignment

- Assessment Division (OPNAV N81) at the Pentagon

- The Naval Postgraduate School has one of the oldest and highest ranking OR departments in the US

- *Naval Research Logistics* is a prominent academic journal featuring research in OR

The traveling salesperson problem

- A salesperson located in Annapolis wants to visit clients in each of the 48 state capitals of the continental US and Washington DC

- What is shortest way of visiting all the capitals and then returning to Annapolis?

- Entire books have been written on the TSP

- 1962: contest by Proctor and Gamble - best TSP tour through 33 US cities

- 1998: The Florida Sun-Sentinel's Science page ponders Santa Claus's traveling problem

- One of the most popular problems in operations research

- Numerous applications in expected and unexpected places

  - Circuit board manufacturing
  - Genome sequencing

- Your turn! Try to find the shortest way of visiting all the capitals and then returning to Annapolis

- What about 13,509 cities in the US?

- Sophisticated mathematical techniques are our best bet

The OR approach

Problem statement and data   **Interpreting**   Solution

What is the shortest way of visiting all the capitals and then returning to Annapolis?

Modeling

Optimization (this course), Stochastic processes

Solving

$$\min \quad \sum_{\{i,j\} \in E} c_{\{i,j\}} x_{\{i,j\}}$$
$$\text{s.t.} \quad \sum_{\{i,k\} \in E} x_{\{i,k\}} = 2 \quad \forall i \in N$$
$$\sum_{\{i,j\} \in \delta(S)} x_{\{i,j\}} \geq 2 \ \forall S \subseteq N$$
$$x_{\{i,j\}} \in \{0,1\} \qquad \forall \{i,j\} \in E$$

Mathematical model

Goals for this course

- Modeling

  - Recognize opportunities for mathematical optimization
  - Formulate optimization models – linear programs – that capture the essence of the problem
  - Illustrate applications of real-world problems

- Solving

  - Algorithms to solve these mathematical models

- Detailed topic list and schedule is on the syllabus

Optimization is everywhere

- "Minimize" time it takes to get from class to class

- "Maximize" the company's profits

- (Moneyball) "Best" lineup for the Oakland A's

- We are always trying to make **decisions** in a way that meets some **objective** subject to some **constraints**

- Some success stories of optimization helping solve complex real-world decision-making problems ...

Package delivery

- UPS has an air network consisting of 7 hubs, nearly 100 additional airports in the US, 160 aircraft of nine different types

- Decision:

- Objective:

- Constraints:

- UPS credits optimization-based planning tools with identifying operational changes that have saved over $87 million to date, reduced planning times, peak and non-peak costs, fleet requirements

Sports scheduling

- ACC Basketball earns over $30 million in revenue annually, almost all from TV and radio

- TV networks need a steady stream of "high quality" games, NCAA rules, school preferences and traditions

- Decision:

- Objective:

- Constraints:

  [ ]

- Optimization approaches yields reasonable schedules very quickly

Radiation therapy

- High doses of radiation can kill cancer cells and/or prevent them from growing and dividing

- Can also kill healthy cells!

- Radiation can be delivered at different angles and intensities

- Decision:

  [ ]

- Objective:

  [ ]

- Constraints:

  [ ]

- Many successes reported using different types of optimization models

Next...

- Formulating a small optimization model