

Lesson 1. Introduction

SA305 – Linear Programming

Spring 2021

What is operations research?

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

What is operations research?

- 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 most well-respected OR departments in the US
- *Naval Research Logistics* is a prominent academic journal featuring research in OR

The traveling salesperson problem

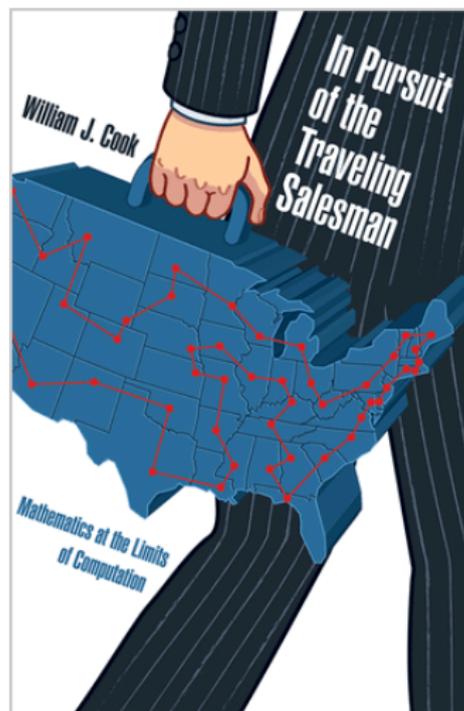
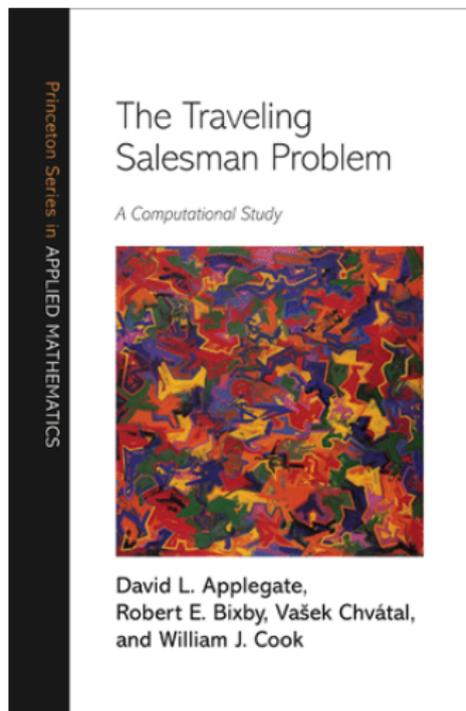
The traveling salesperson problem



- 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?

The traveling salesperson problem

- Entire books have been written on the TSP



The traveling salesperson problem

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

HELP! WE'RE LOST!

HELP "CAR 54" ... AND WIN CASH
54...\$1,000 PRIZES
ONE...\$10,000 GRAND PRIZE

START & FINISH

Help Toddy and Mulbon find the shortest round trip route to visit all 33 locations shown on the map. All you do is draw connecting straight lines from location to location to show the shortest round trip route.

HERE'S THE CORRECT START...
Begin at Chicago, Illinois. From there, lines show correct route as far as Erie, Pennsylvania. Next, do you go to Carlisle, Pennsylvania or Mead, West Virginia? Check the easy instructions on back of this entry blank for details.

© PROCTOR & GAMBLE 1962

OFFICIAL RULES ON REVERSE SIDE

The traveling salesperson problem

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

SCIENCE

Santa Claus and the traveling salesman problem

Old Saint Nick has one night to deliver gifts to children around the world. To save time and wear and tear on his sleigh, Santa plots the shortest journey possible among thousands of cities. It sounds easy enough, and for Santa it probably is, but for scientists, who call it the traveling salesman problem (TSP), it is a challenge that grows increasingly difficult as more and more cities are added to the list.

Traveling salesman problem explained

3 A salesman has to identify each company's best deal and determine the best route to visit all of them. The more cities on the list, the more difficult the problem becomes. In a 1995 study, researchers found that the number of possible routes for a salesman to visit 10 cities is 3,628,800. For 20 cities, the number of possible routes is 243,290,200,000,000.



City	Order	Distance (miles)	Total Distance (miles)
Los Angeles	1	814	814
Denver	2	1,264	2,078
Chicago	3	1,314	3,392
San Francisco	4	1,941	5,333
Los Angeles	5	2,677	8,010

30 Solution for Santa

The best solution ever for the traveling salesman problem was found by a mathematician in 1991. He found a route that visits 48 cities in California and the surrounding area in 30 days. The route is 10,000 miles long.

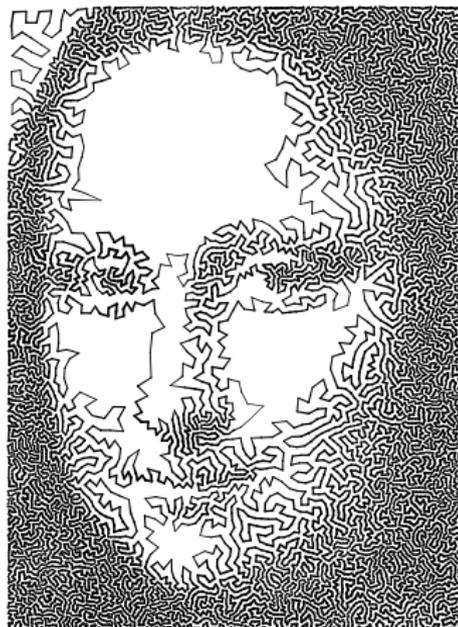
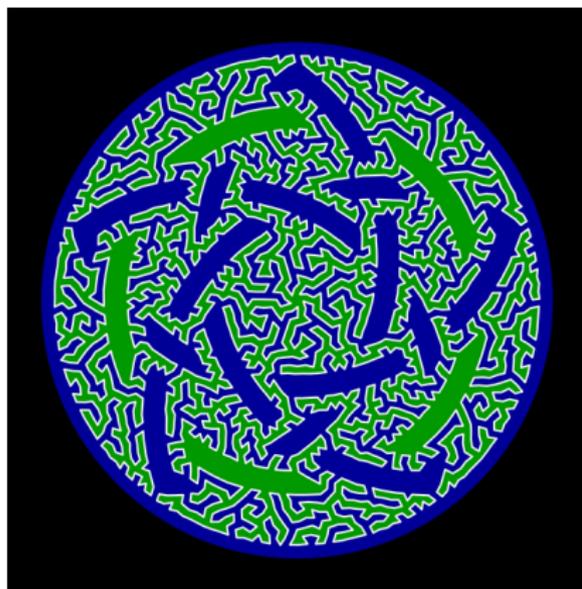
4 Traveling salesman problem (TSP) is a classic problem in computer science. It is the problem of finding the shortest possible route that visits every city exactly once and returns to the origin city.





The traveling salesperson problem

- The TSP has even been used to make art



<http://www.oberlin.edu/math/faculty/bosch/>

<http://www.cgl.uwaterloo.ca/~csk/projects/tsp/>

The traveling salesperson problem

- One of the most popular problems in operations research
- Numerous applications in expected and unexpected places
 - Circuit board manufacturing
 - Genome sequencing

The traveling salesperson problem

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

The traveling salesperson problem

- The solution:



The traveling salesperson problem

- What about 13,509 cities in the US?

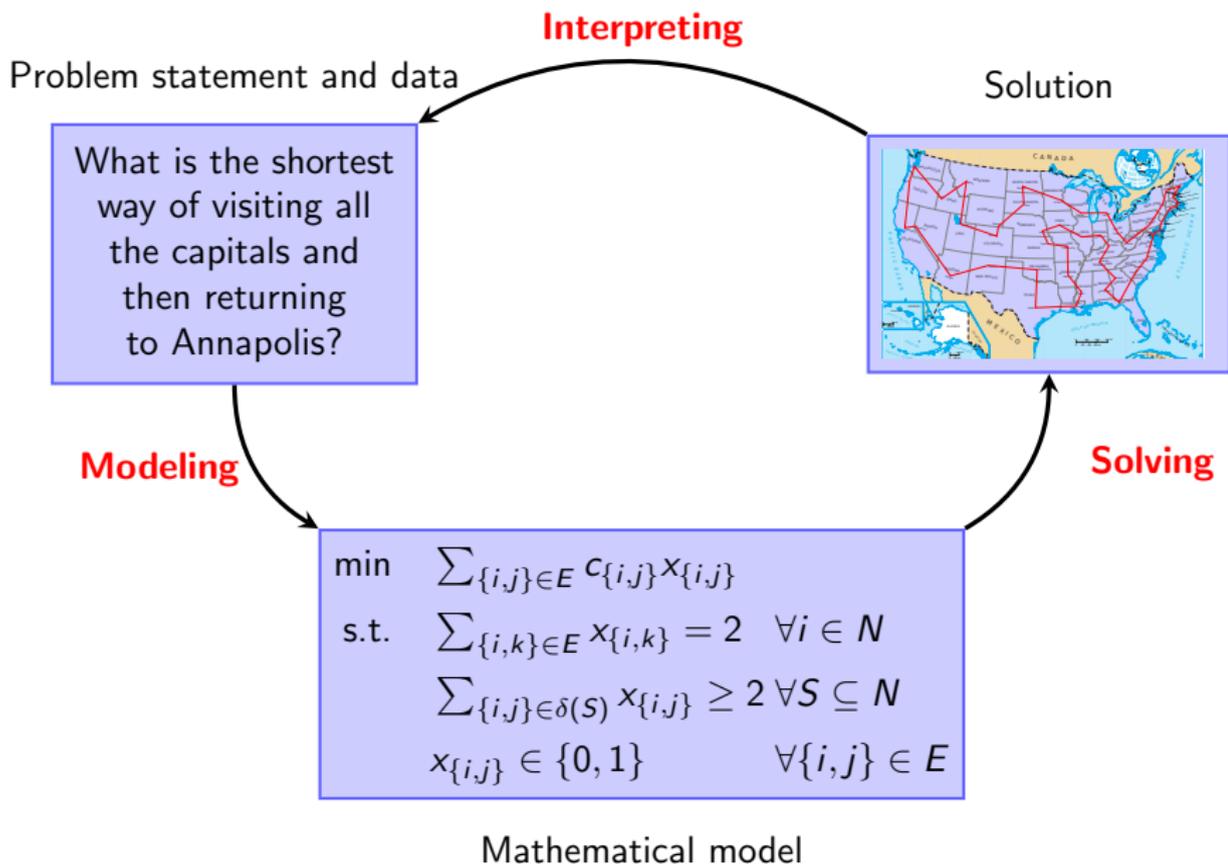
The traveling salesperson problem

- What about 13,509 cities in the US?



- Sophisticated mathematical techniques are our best bet

The OR approach



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: *aircraft routes, package assignments, flight schedules, etc.*
- Objective: *minimize delivery times/costs
maximize delivery throughput*
- Constraints: *aircraft capacity, fuel requirements, traffic considerations, packages delivered correctly*
- 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 millions 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: *who plays who, when, where*
- Objective: *minimize travel times for teams
maximize viewership*
- Constraints: *NCAA rules, travel budgets, school traditions*
- 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: *angles + intensities of radiation*
- Objective: *maximize dose to cancer cells*
- Constraints: *limit on dose to healthy cells*
- Many successes reported using different types of optimization models



Next time...

- Formulating a small optimization model