

Intro to Systems Optimization



John Vande Vate

Our Focus Broadly



- **Application** of mathematical analysis to the design and analysis of **systems** through the intermediary of abstract **models**.
- Focus on robust industrial, off-the-shelf tools.
- Balance between superficial intuition and painful technical detail
- **Objective:** Confidence to identify and exploit opportunities for the application of optimization

Toys vs Tools



- Enough to be dangerous
- Know the distinction between desk-top and industrial tools
- Passing familiarity with industrial tools

Topics



■ Networks

- ▶ Specially structured problems
- ▶ Introduction to mathematical modeling
- ▶ Intuition behind solution methodology

■ Linear Programming

- ▶ General modeling framework
- ▶ Fundamental solution methodology

■ Integer Programming

- ▶ Powerful industrial tool
- ▶ Modeling is an art

Course Organization



■ Non-Linear Programming

- ▶ Less robust tools
- ▶ Local optimum vs global optimum
- ▶ More customized solution strategies

■ Heuristics

- ▶ Some off-the-shelf tools, e.g., Genetic Algorithms
- ▶ General trends and strategies
- ▶ Illustrative examples

Value of Optimization



- A way of thinking
- A personal tool, eg, Excel
- An industrial tool
 - ▶ Raises the level of the debate
 - ▶ Automate tedious or complex tasks
 - ▶ Facilitate integration
 - ▶ Better answers

Optimization Caveats



- Toys vs Tools
- Only as good as your data
- Robustness
- Careful with uncertainty
- What is/are the objective(s)
- Users may game the system

A Closing Example

- Stable Marriages
- National Resident Matching Program

- ▶ www.nrmp.org

- ▶ Al Roth's home page on market design

<http://www.economics.harvard.edu/~aroth/alroth.html#design>

- Optimization to find a solution that people can live with

A brief history



- Resident programs introduced around 1900
- 1940's offers being made two years before graduation
- 1945 Agreement on dates
- Late 40's: Exploding offers, renegeing, ...
- 1951 Centralized Matching Process

Other markets



- British physician markets less centralized
- Several mechanisms employed
- Failures indicate what's necessary:

Stability

No resident prefers another program that also prefers her

Many Objectives



Application of optimization to find a solution that addresses everyone's preferences or objectives

How to find one answer



Deferred Acceptance Algorithm of Gale & Shapley

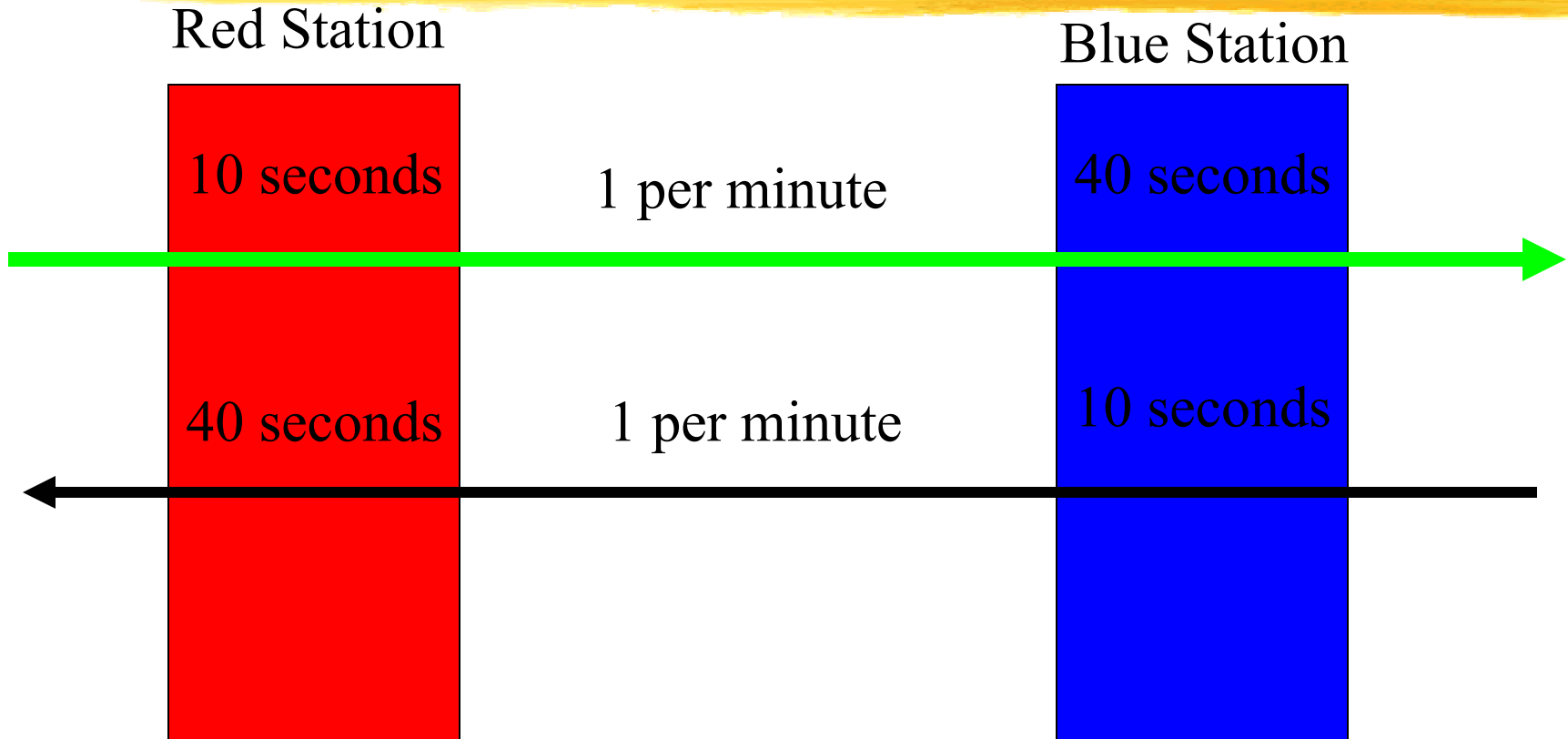
- Each man proposes to his favorite woman
- Each woman rejects all but her favorite proposal
- Repeat this process with men proposing to their favorite among those who have not yet rejected them

Actually Two Answers



- If the men propose, all men will agree this is the best stable answer. The women will agree it is the worst.
- If the women propose, they will all agree the matching is the best stable answer. The men will agree it is worst.

Re-entrant



Priority to the shorter processes