UNIVERSITY OF ALBERTA

CMPUT 675: Optimization and Decision Making under Uncertainty

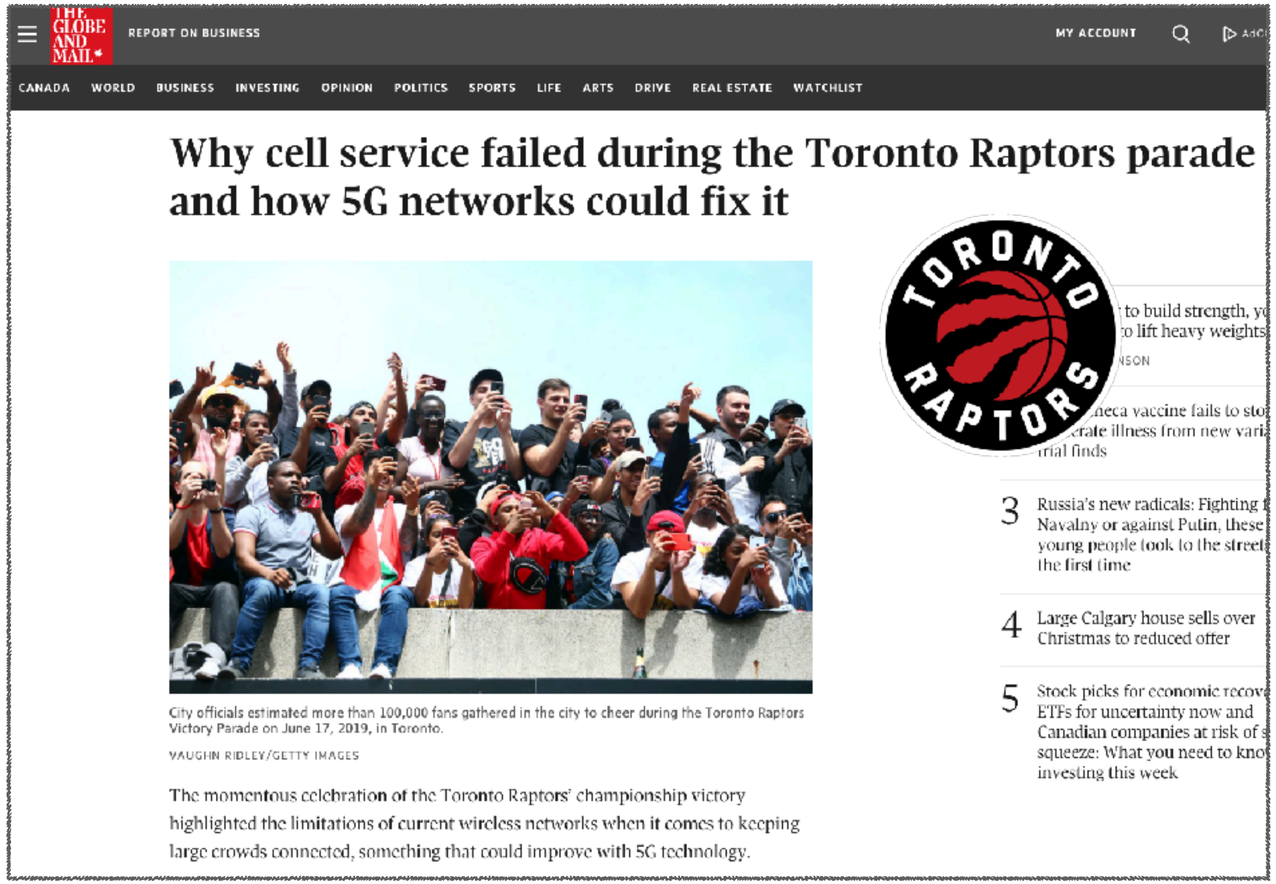
Fall 2021, CS@UAlberta

Xiaoqi Tan

Lecture 1: Introduction

- Overview
- Course Topics
- Logistics

2019 Toronto Cell Service Failure



THE GLOBE AND MAIL · REPORT ON BUSINESS · MY ACCOUNT

CANADA WORLD BUSINESS INVESTING OPINION POLITICS SPORTS LIFE ARTS DRIVE REAL ESTATE WATCHLIST

Why cell service failed during the Toronto Raptors parade and how 5G networks could fix it

City officials estimated more than 100,000 fans gathered in the city to cheer during the Toronto Raptors Victory Parade on June 17, 2019, in Toronto.

VAUGHN RIDLEY/GETTY IMAGES

The momentous celebration of the Toronto Raptors' championship victory highlighted the limitations of current wireless networks when it comes to keeping large crowds connected, something that could improve with 5G technology.

TORONTO RAPTORS

to build strength, y
o lift heavy weights
NSON

neca vaccine fails to sto
erate illness from new vari
rial finds

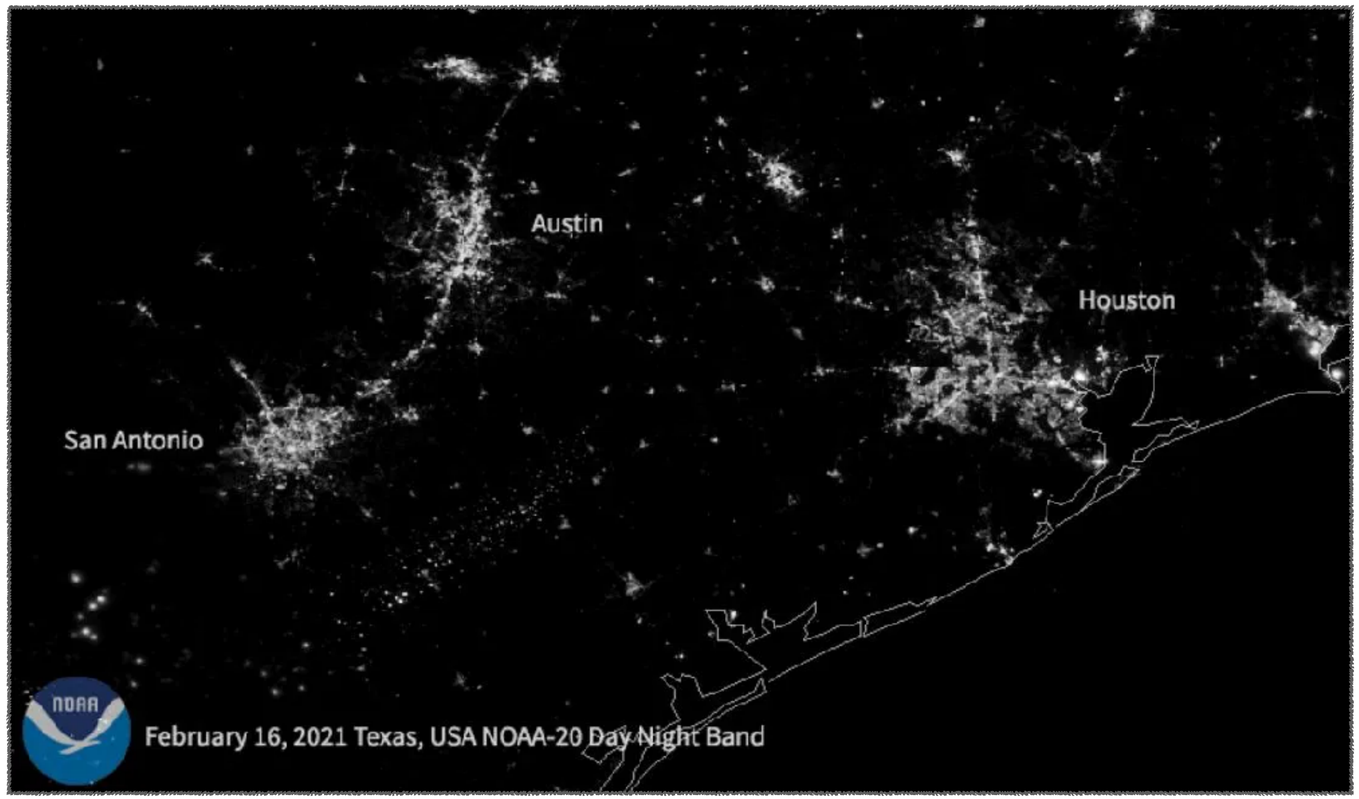
3 Russia's new radicals: Fighting f
Navalny or against Putin, these
young people took to the street
the first time

4 Large Calgary house sells over
Christmas to reduced offer

5 Stock picks for economic recov
ETFs for uncertainty now and
Canadian companies at risk of s
squeeze: What you need to kno
investing this week

- **1M ~ 2M** crowds
- **1000%+** increase in uploading
- Service **down**

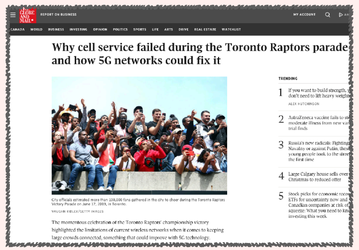
2021 Texas Power Crisis



- **Extreme** weather
- Demand **surge**
- Supply **cut-off**

Core Challenge

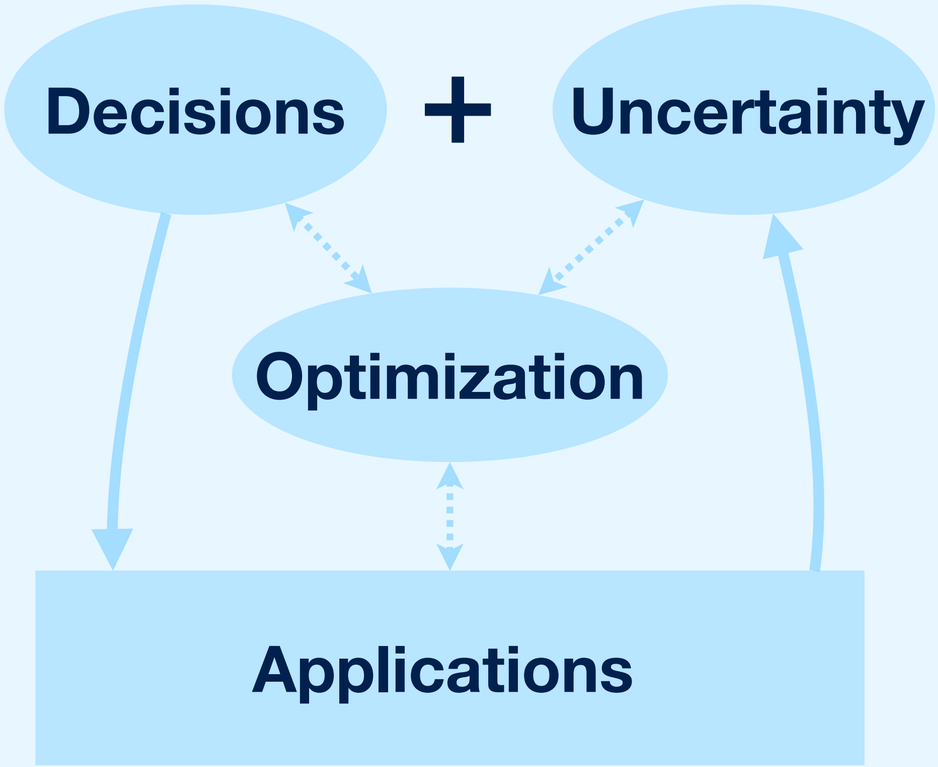
Adapt to **changing** environments



2019 Toronto Cell Service Failure

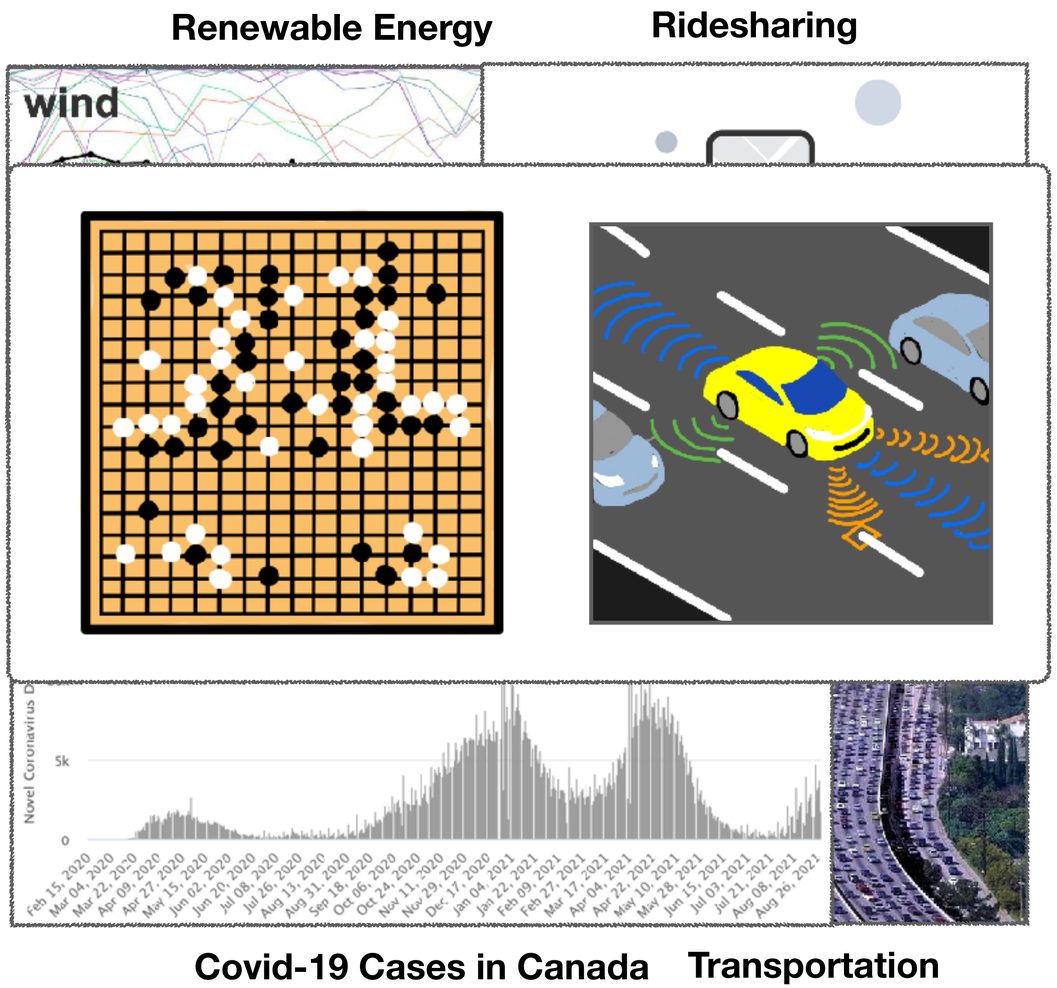
2021 Texas Power Crisis

This Course



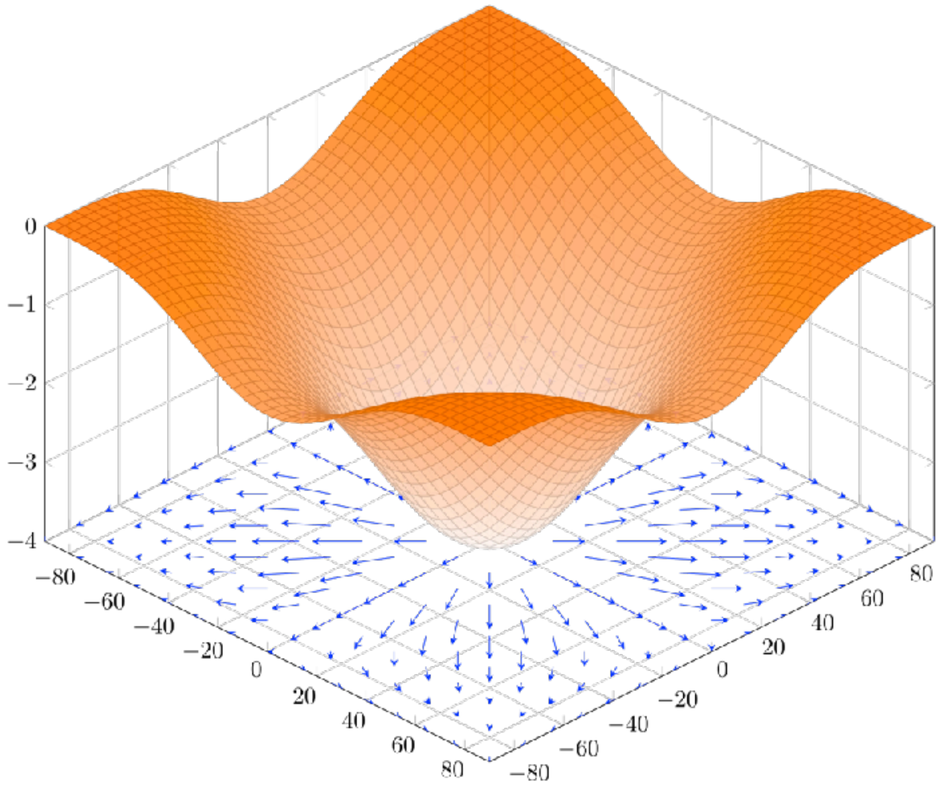
Why Take This Course?

- **Decisions + Uncertainty**
- **Applications**: energy, logistics, transportation, healthcare, data analytics, and AI/ML, etc.
- **Optimization** is key to intelligent decision-making

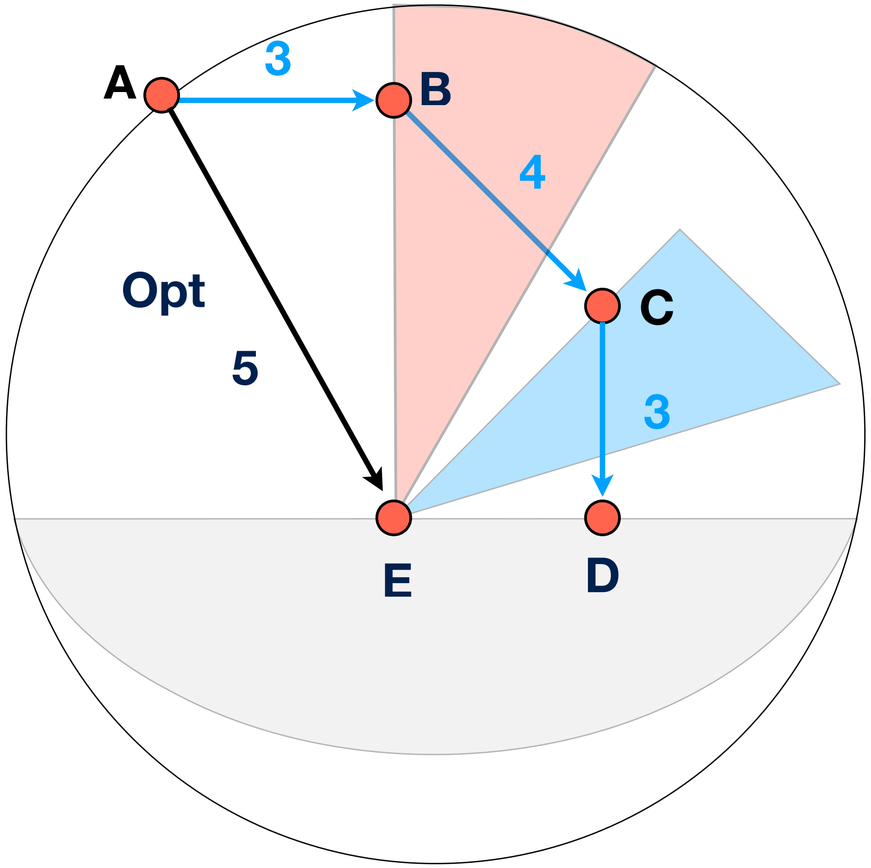


Prerequisites

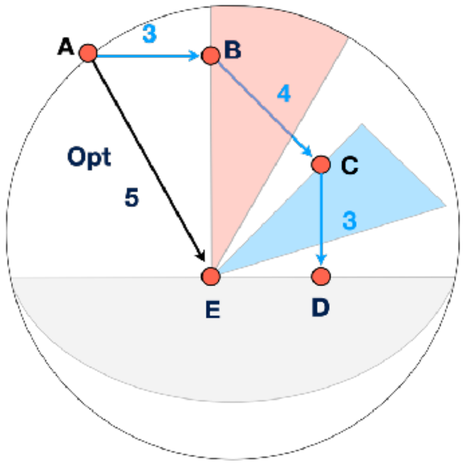
- Calculus
- Linear Algebra
- Probability
- Algorithms
- **Bonus**: Optimization



Warm Up



$$\frac{\text{Cost (Greedy)}}{\text{Cost (Opt)}} = \frac{3 + 4 + 3}{5} = 2$$



Full knowledge

Deterministic Settings

Review

Full Statistical knowledge

Partial Statistical knowledge

Stochastic Settings

Part-2

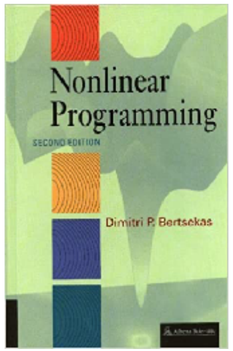
"No" knowledge

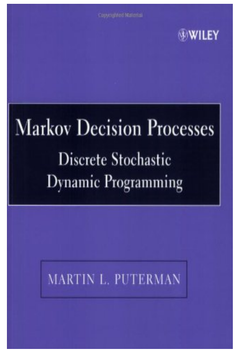
Part-1

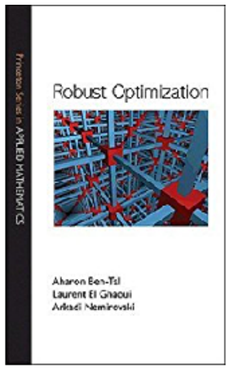
Online Settings

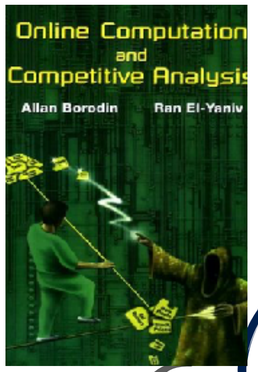
Strategic Settings

Part-3









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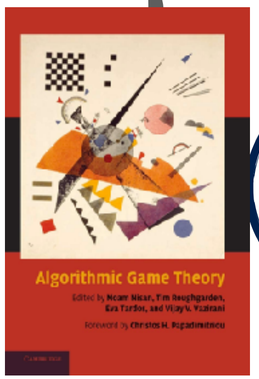
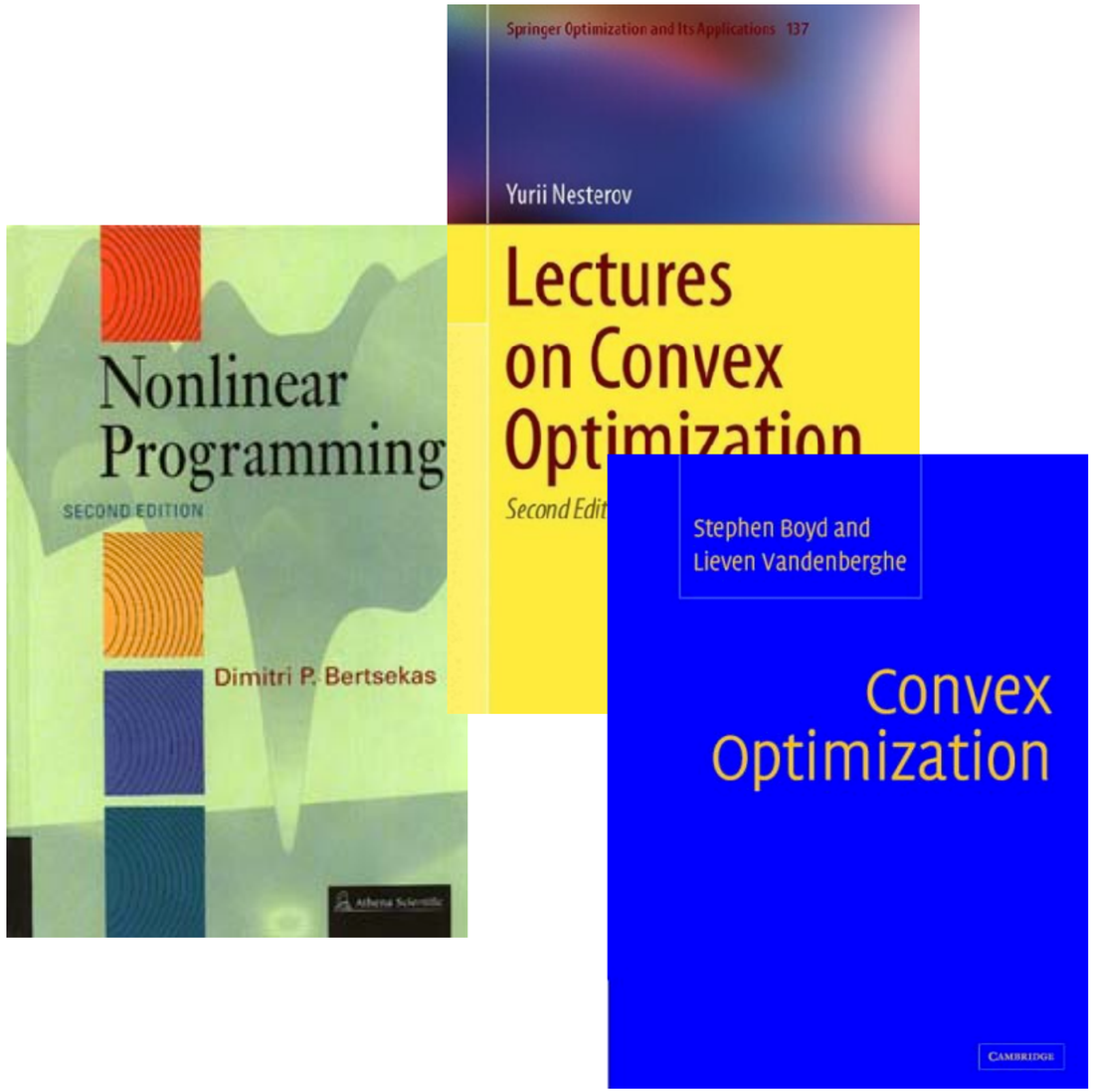


Strategic Settings

Part-3

Review

- Linear algebra; Probability
- Algorithm design and analysis
- **Linear programming**
- **Convex optimization**
- **Duality**
- **Optimality conditions**



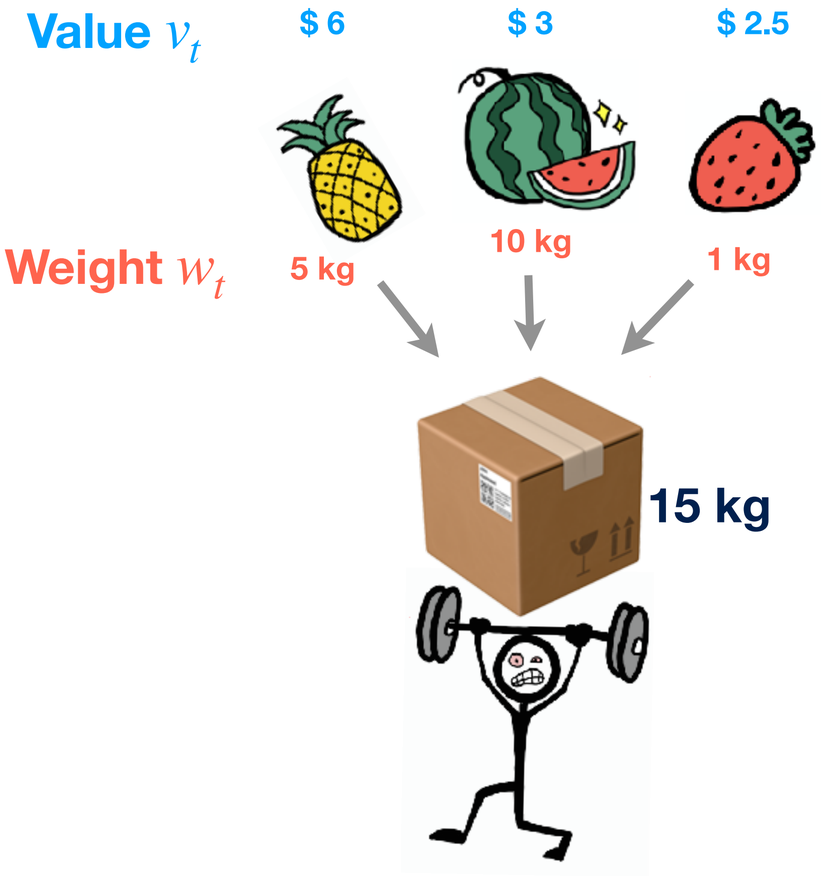
Part 1: Online Settings

- **Online search**
  - Time series search; One-way trading
- **Online packing and covering**
  - Online knapsack problems
- **Online matching; Online scheduling**
- **Online convex optimization**

Example 1

$$\max_{x_t \in \{0,1\}} \sum_t v_t x_t - f\left(\sum_t w_t x_t\right)$$

Value — **Cost**



Example 1

Part-1

Online algorithms and competitive analysis

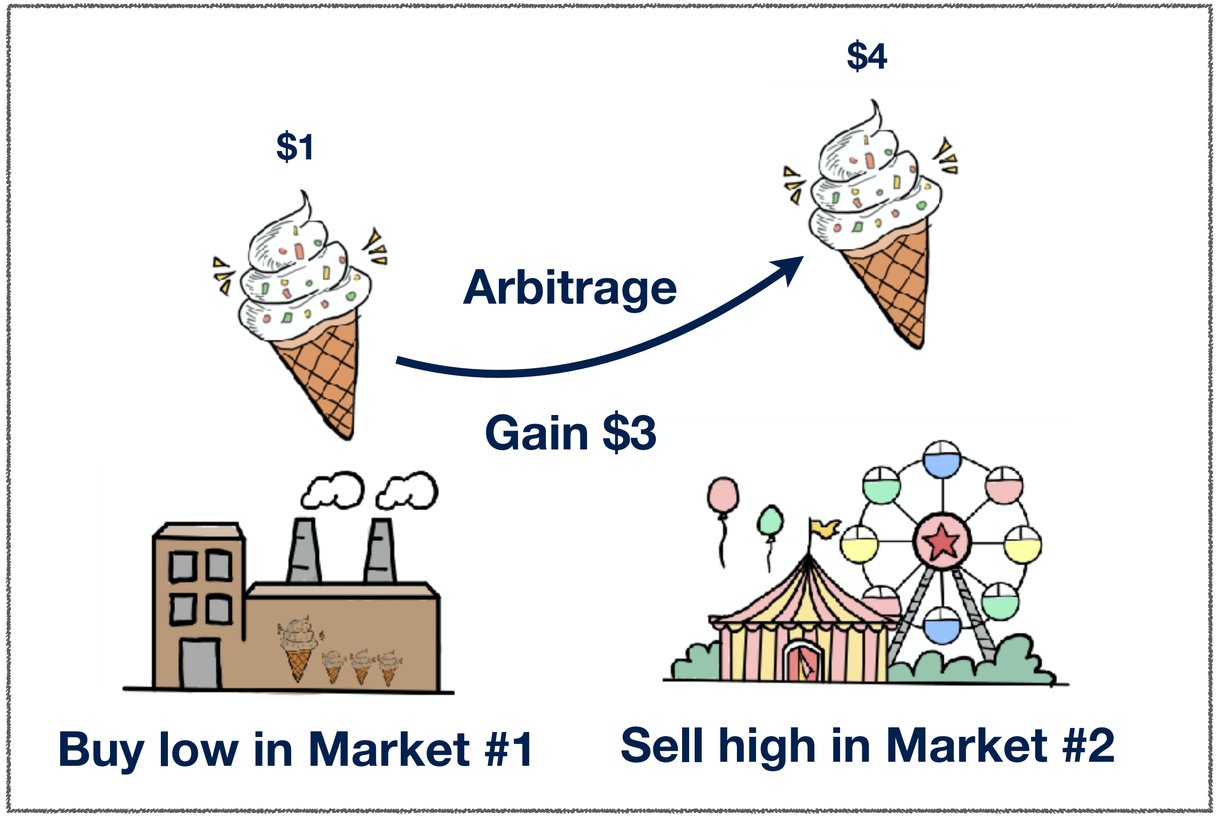
$$\max_{x_t \in \{0,1\}} \left(\sum_t v_t x_t \right) - f\left(\sum_t w_t x_t \right)$$

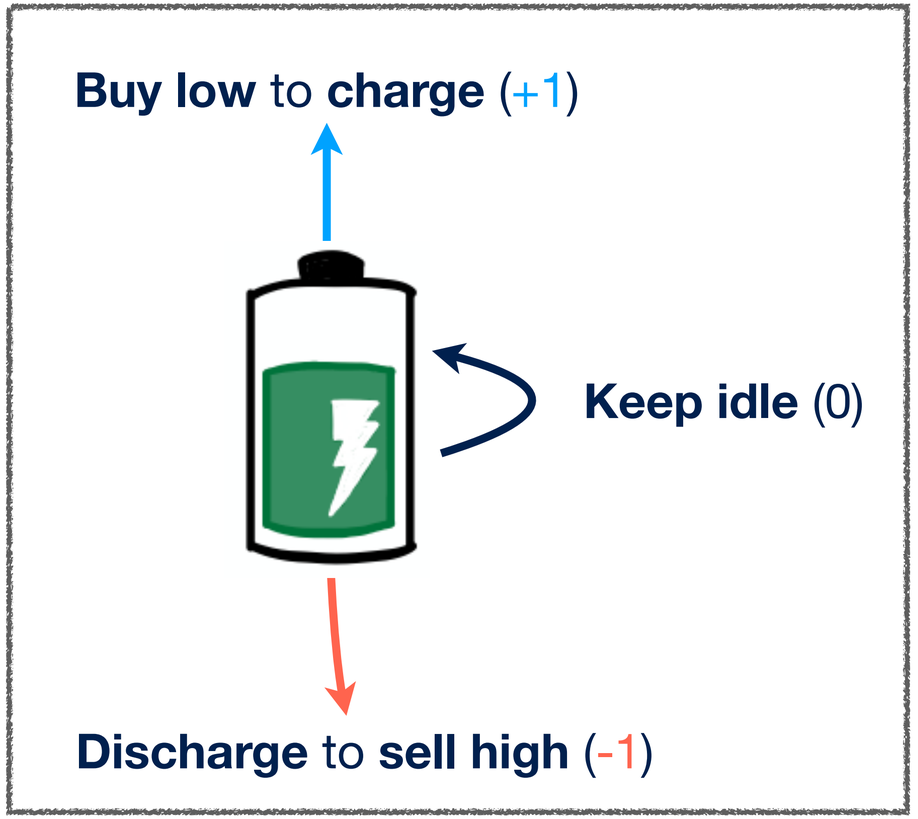
Value **Cost**

Part 2: Stochastic Settings

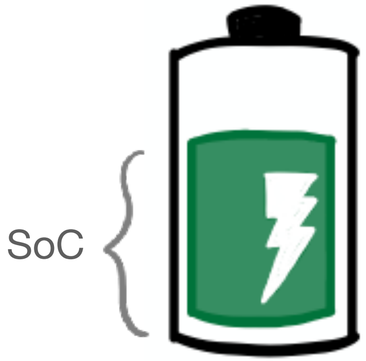
- **Stochastic modeling**
- Markov decision process
- Reinforcement learning; Online learning; Bandits
- **Stochastic approximation**
- **Prophet inequalities**

Example 2


$4
$1
Arbitrage
Gain $3
Buy low in Market #1
Sell high in Market #2

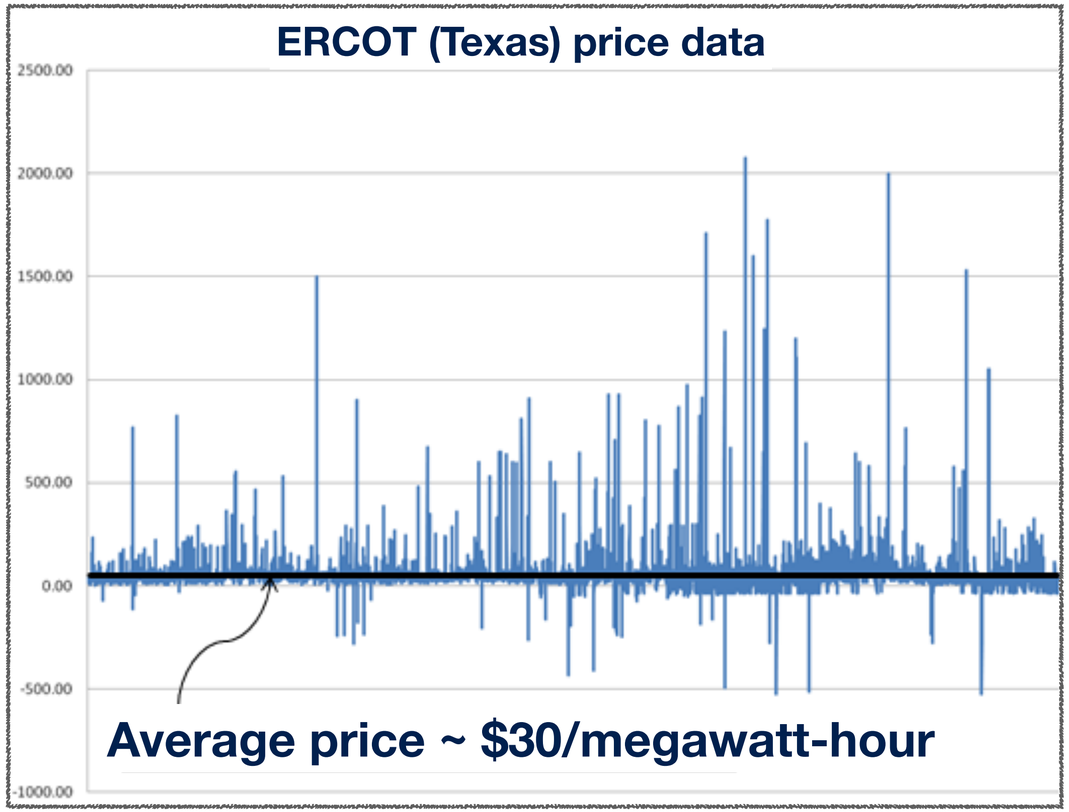

Buy low to charge (+1)
Keep idle (0)
Discharge to sell high (-1)

Example 2



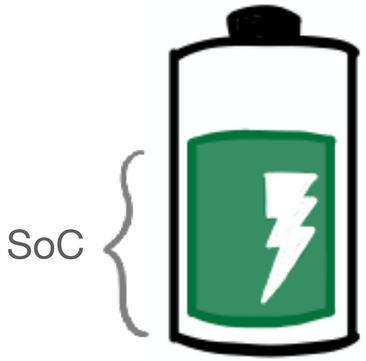
$$\text{SoC}_{t+1} = \text{SoC}_t + x_t$$

Value ~ Sell high - Buy low



Data source: ERCOT official website

Example 2

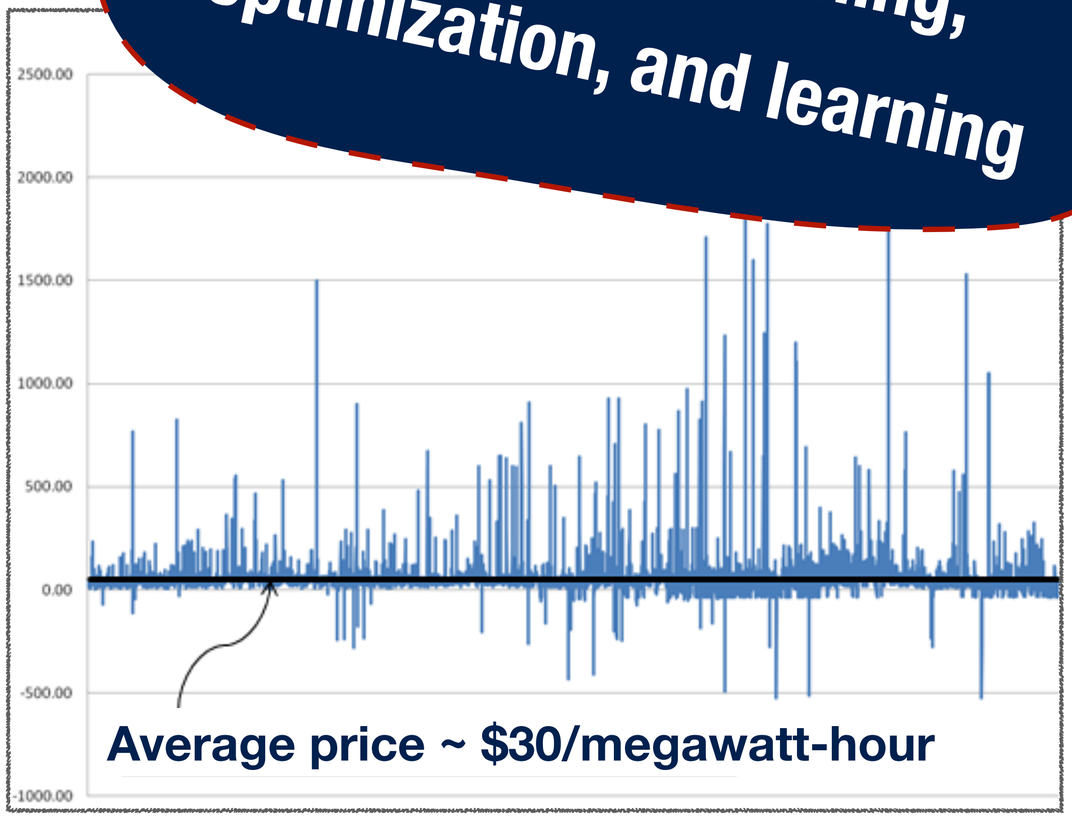


$$\text{SoC}_{t+1} = \text{SoC}_t + x_t$$

Value ~ Sell high - Buy low

Part-2

Stochastic modeling, optimization, and learning



Data source: ERCOT official website

Part 3: Strategic Settings

- Game theory; Nash equilibrium
- **Network congestion games; Price of anarchy**
- **Mechanism design; Auctions**
  - Myerson's auction
  - Second-price auctions
  - VCG auctions
- **Online mechanism design**

Part 3: Strategic Settings

- Game theory; Nash equilibrium
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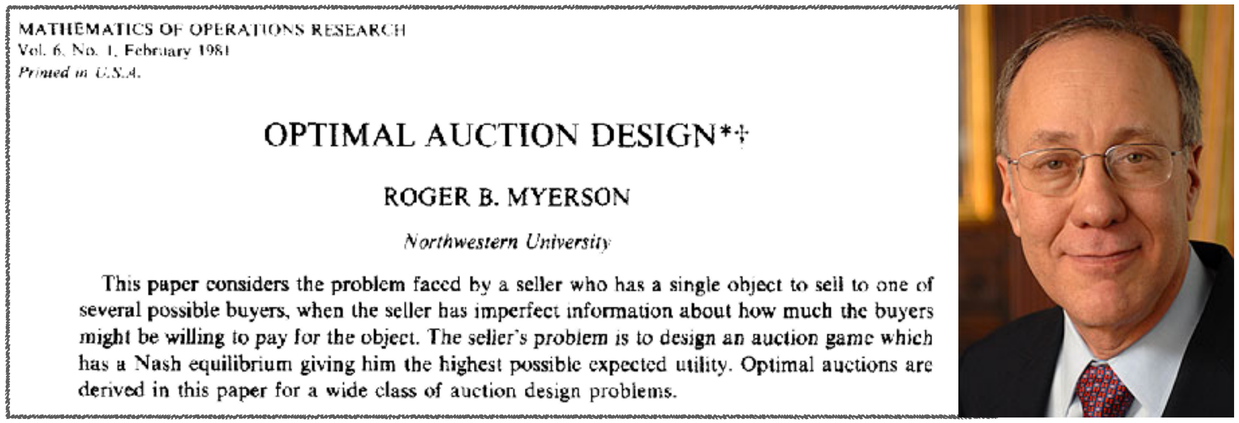


MATHEMATICS OF OPERATIONS RESEARCH
Vol. 6, No. 1, February 1981
Printed in U.S.A.

OPTIMAL AUCTION DESIGN*†

ROGER B. MYERSON

Northwestern University

This paper considers the problem faced by a seller who has a single object to sell to one of several possible buyers, when the seller has imperfect information about how much the buyers might be willing to pay for the object. The seller's problem is to design an auction game which has a Nash equilibrium giving him the highest possible expected utility. Optimal auctions are derived in this paper for a wide class of auction design problems.

Example 3

- **Problem**: Divide a cake for two children.
- **Objective**: To have a **fair** division —> both are **happy**.
- **Solution:** **let the 1st child do the cut, and let the 2nd child do the first pick**.
- **Questions:** How about we let an **adult** do the cut and allocation all the way? What if we have **N>2** children?

Example 3

Part-3

Algorithmic game theory and mechanism design

- **Problem**: Divide a cake for two children.
- **Objective**: To have a **fair** division —> both are **happy**.
- **Solution:** **let the 1st child do the cut, and let the 2nd child do the first pick**.
- **Questions:** How about we let an **adult** do the cut and allocation all the way? What if we have **N>2** children?

Course Organization (Lectures)

Review

Linear programming, convex optimization, duality theory, optimality conditions

1-2 lectures (?)

Part-1

Online algorithms and competitive analysis

6-8 lectures

Part-2

Stochastic modeling, optimization, and learning

4-5 lectures

Part-3

Algorithmic game theory and mechanism design

4-5 lectures

Online search, packing, matching, and scheduling

Online learning
Prophet Inequalities

Online auctions
Posted-price mechanisms

A Systematic Algorithmic Framework

Course Website

https://xiaoqitan.org/optcourse

- Syllabus
- Slides and readings
- Assignments
- Projects

Grade

- Participation (10%)
- **Assignments** (20%)
- **Project - Proposal** (20%)
- **Project - Presentation** (20%)
- **Project - Report** (30%)

} **70%**

Assignments (20%)

- **Three questions**
  - Research-oriented
  - Free to pick any one from the list
  - Treat it as a mini-project
- **Academic integrity**
  - Write your solutions individually
  - Discussion is encouraged

Project - Proposal (20%)

- **Step 1**: Pick two papers **related to this course**
  - Please don’t repeat our reading list
  - Send your selection to me for approval (ASAP)
- **Step 2**: A two-page proposal **which consists of**
  - **One-page review** of the main idea, methodologies, and key results of the papers selected
  - **One-page summary** of i) what could be improved, ii) what could be done differently, and/or iii) new discoveries.

Identify potential topics for your final report

Project - Presentation (20%)

- **Schedule**: TBD
  - Must be based on your proposal
- **Presenter**: be professional
  - Know your slides; Practice
- **Audience**: show your appreciation
  - Questions; Suggestions; Comments

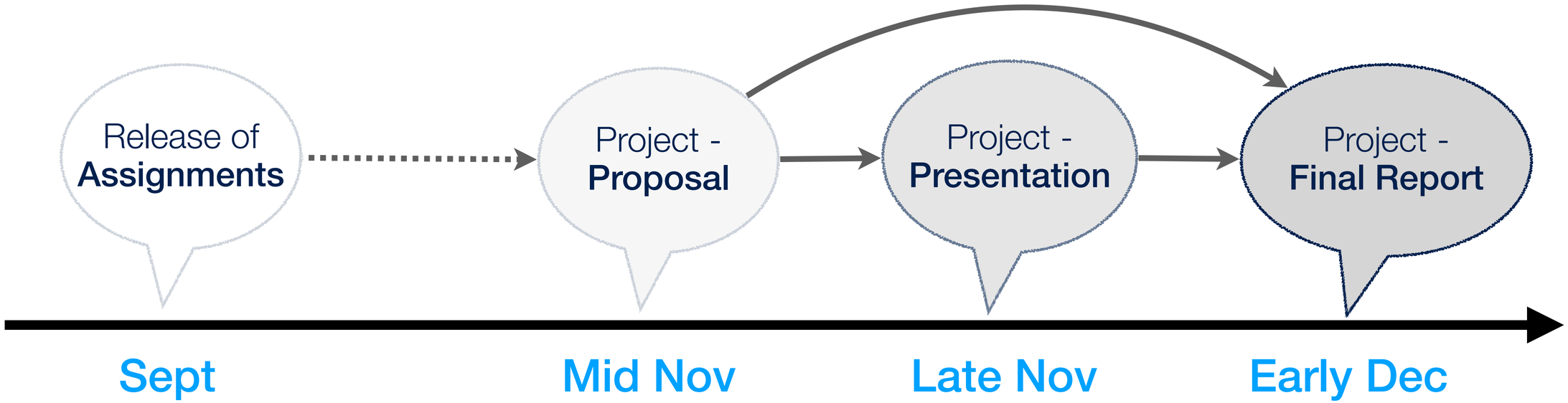
Get feedbacks for your proposal and final report

Project - Report (30%)

- **Relevance: must be related**
  - Proposal & Presentation; This course
- **Novelty: must be something new**
  - A new theorem
  - A new implementation
  - A new application
  - Theory <=> Apps (bravo!)

Get yourself ready for doing serious research in related areas

Timeline (of Your To-Do-List)



Summary

- **Course topics**
  - **Part-1**: Online algorithms and competitive analysis
  - **Part-2**: Stochastic modeling, optimization, and learning
  - **Part-3**: Algorithmic game theory/mechanism design
- **Assignment (20%)**
- **Project-Proposal (20%)**
- **Project-Presentation (20%)**
- **Project-Report (30%)**

Enrollment

- How many are **enrolled**?
- How many are **auditing**?
- How many are **auditing** with the **intention of enrolling**?

- How many have relevant **research experience**?
- How many are **interested in researching** in related areas?

- Class: MW, 2pm-3:20pm
- Venue: VVC 2-277
- Office hours: after class or by appointment
- Course website: xiaoqitan.org/optcourse
- Contact me: xiaoqi.tan@ualberta.ca