

# CSC304

# Algorithmic Game Theory & Mechanism Design

Nisarg Shah

# Introduction

- Instructor: Nisarg Shah (/~nisarg, nisarg@cs)
- Guest lectures: Prof. Allan Borodin
- TA: Tyrone Strangway (/~tyrone, tyrone@cs)
- Lectures: Mon-Wed, 3p-4p, BA 1230
- Office Hours: Fri, 3p-4p, SF 2301C
  - “Tutorial Slot”
  - Midterm/lecture → I’ll provide other office hours.

# Course Information

- Course Page:

[www.cs.toronto.edu/~nisarg/teaching/csc304-f17/](http://www.cs.toronto.edu/~nisarg/teaching/csc304-f17/)

- Discussion Board:

[piazza.com/utoronto.ca/fall2017/csc304](https://piazza.com/utoronto.ca/fall2017/csc304)

- Grading – MarkUs system

- Link will be distributed after about two weeks
- LaTeX preferred, scans are OK!
- An arbitrary subset of questions may be graded...

# Course Organization

- Three (roughly equal) parts:
  - Game theory
  - Mechanism design with money
  - Mechanism design without money
- A homework and a midterm for each part
- Final exam = third midterm + a section on entire syllabus

# Textbook

- Not really.
  - Slides will be your main reference.
- But...but...I want a textbook?
  - OK...
  - Book by Prof. David Parkes at Harvard
    - In preparation...
    - Closely follows the syllabus structure
    - Available from my webpage (username/password in handout)
  - A number of other good books mentioned in the handout

# Grading Policy

- 3 homeworks \* 15% = 45%
- 3 midterms \* 15% = 45%
- Final exam (entire syllabus) = 10%
  - Final exam: third midterm + entire syllabus = 15+10 = 25%

# Other Policies

- Collaboration

- Individual homeworks.
- Free to discuss with classmates or read online material.
- Must write solutions in your own words (easier if you do not take any pictures/notes from the discussions)

- Citation

- For each question, must cite the peer (write the name) or the online sources (provide links) referred, if any.
- Failing to do this is plagiarism!

# Other Policies

- “No Garbage” Policy
  - Borrowed from: Prof. Allan Borodin (citation!)
  - 1. Partial marks for viable approaches
  - 2. Zero marks if the answer makes no sense
  - 3. 20% marks if you admit to not knowing how to solve
- 20% > 0% !!

# Other Policies

- Late Days
  - 3 late days total across 3 homeworks
  - At most 2 late days for a single homework
  - Covers legitimate reasons such as illness, University activities, etc.

Enough with the  
boring stuff.

What will we study?

Why will we study it?

# What is this course about?

- Game Theory and Mechanism Design
  - Topics from microeconomics
- + Computer Science:
  - Algorithmic Game Theory (AGT)
  - Algorithmic Mechanism Design (AMD)

# Game Theory

- How do rational, self-interested agents act?
- Each agent has a set of possible actions
- Rules of the game:
  - Rewards for the agents as a function of the actions taken by different agents
- We focus on noncooperative games
  - No external force or agencies forming coalitions

# Example: Prisoner's Dilemma

Sam's Actions \ John's Actions	Stay Silent	Betray
	Stay Silent	Betray
Stay Silent	$(-1, -1)$	$(-3, 0)$
Betray	$(0, -3)$	$(-2, -2)$

- What Sam thinks:

- If John is going to stay silent...
  - Better for me to betray (my reward: 0)
  - Than for me to stay silent (my reward: -1)
- If John is going to betray...
  - Better for me to betray (my reward: -2)
  - Than for me to stay silent (my reward: -3)

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Only makes sense to betray

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John thinks the same

That's cute.

But is this really useful  
in the real world?

# Security Games

Deploying “patrol units” to protect infrastructure targets, prevent smuggling, save wildlife...



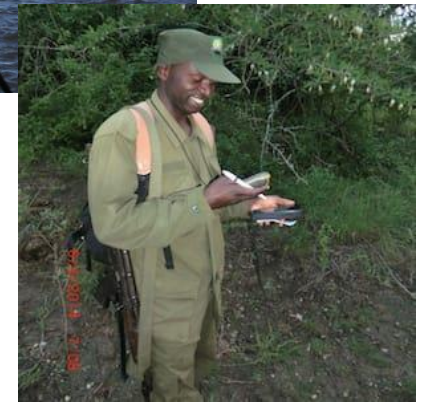
LA Metro



LAX



Staten  
Island  
Ferry



Ugandan Forest

Image Courtesy: Teamcore

# Security Games

- $n$  targets
- Player 1: Attacker
  - Actions: attack a target
- Player 2: Defender
  - Actions: protect  $k$  ( $< n$ ) targets at a time
  - $\binom{n}{k}$  actions – exponential!
- Attacker can observe  $\Rightarrow$  need to randomize
- Large games  $\Rightarrow$  need fast algorithms

# Mechanism Design

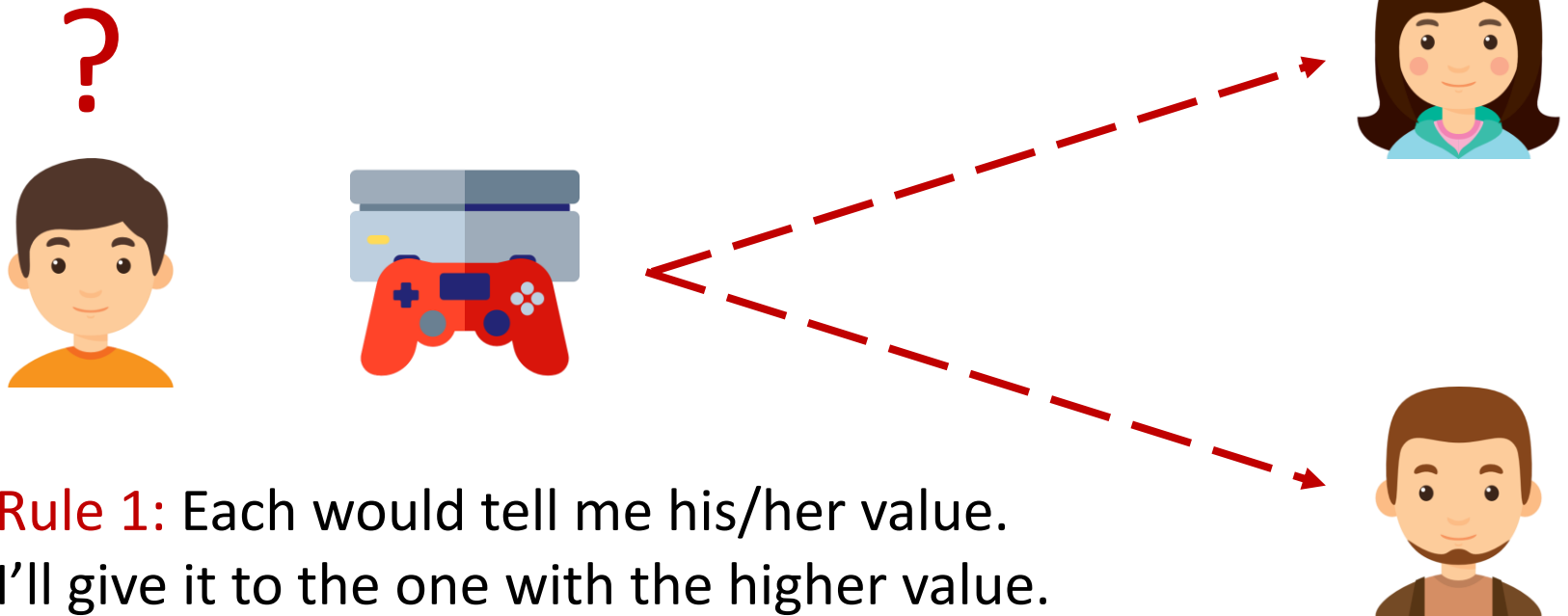
- Design the rules of the game
- A principal in the system
  - Wants the  $n$  rational agents to behave “nicely”
- Decides the rewards (or penalties) as a function of actions to incentivize the desired behavior
  - Often the desired behavior is unclear
  - E.g., want agents to reveal their true preferences

# Mechanism Design

- With money
  - Principal can “charge” the agents (require payments)
  - Helps significantly
  - Example: auctions
- Without money
  - Monetary transfers are not allowed
  - Incentives must be balanced otherwise
  - Often impossible without sacrificing the objective a little
  - Example: elections, kidney exchange

# Example: Auction

**Objective:** The one who really needs it more should have it.

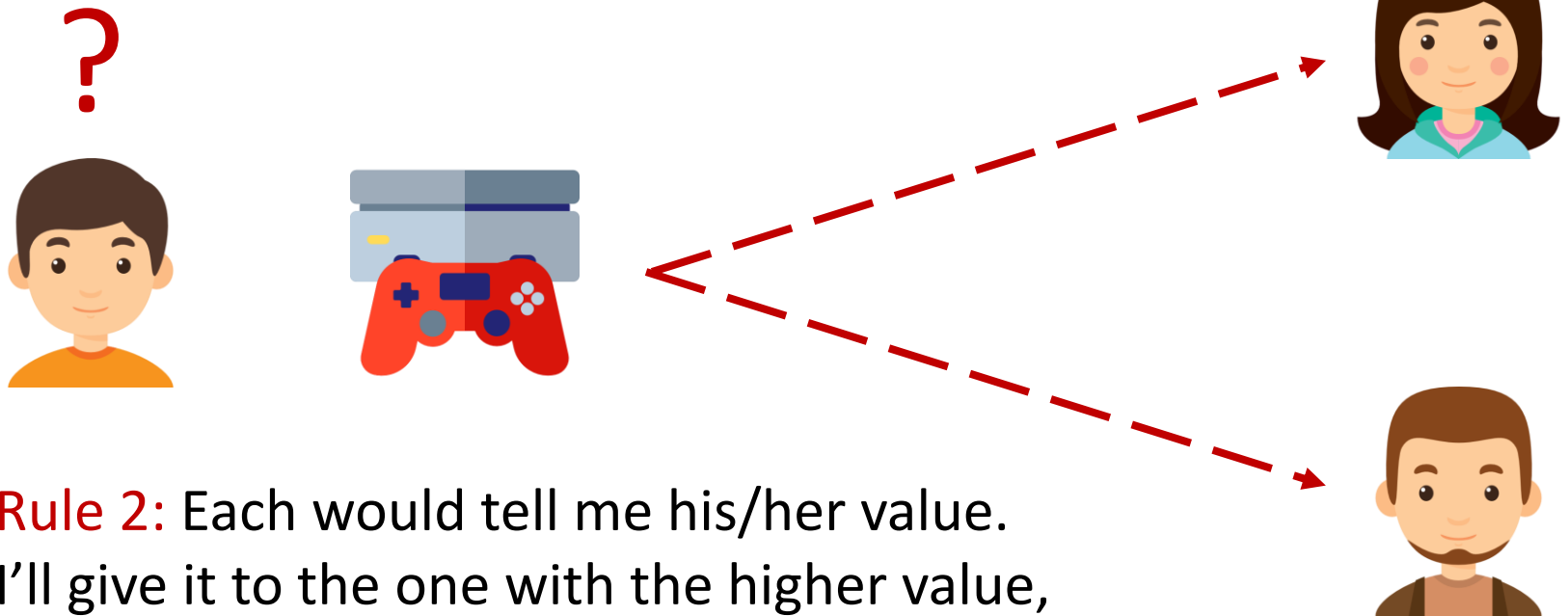


**Rule 1:** Each would tell me his/her value.  
I'll give it to the one with the higher value.

Image Courtesy: Freepik

# Example: Auction

**Objective:** The one who really needs it more should have it.

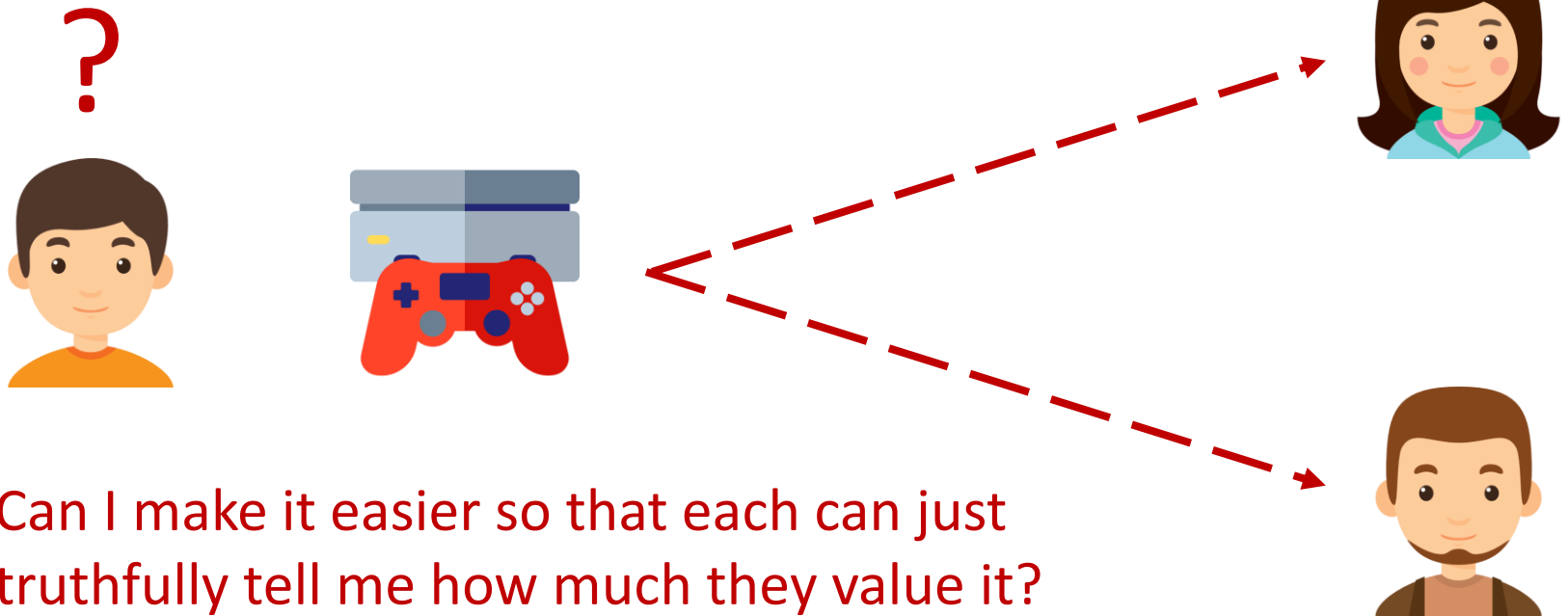


**Rule 2:** Each would tell me his/her value.  
I'll give it to the one with the higher value,  
but they have to pay me that value.

Image Courtesy: Freepik

# Example: Auction

**Objective:** The one who really needs it more should have it.



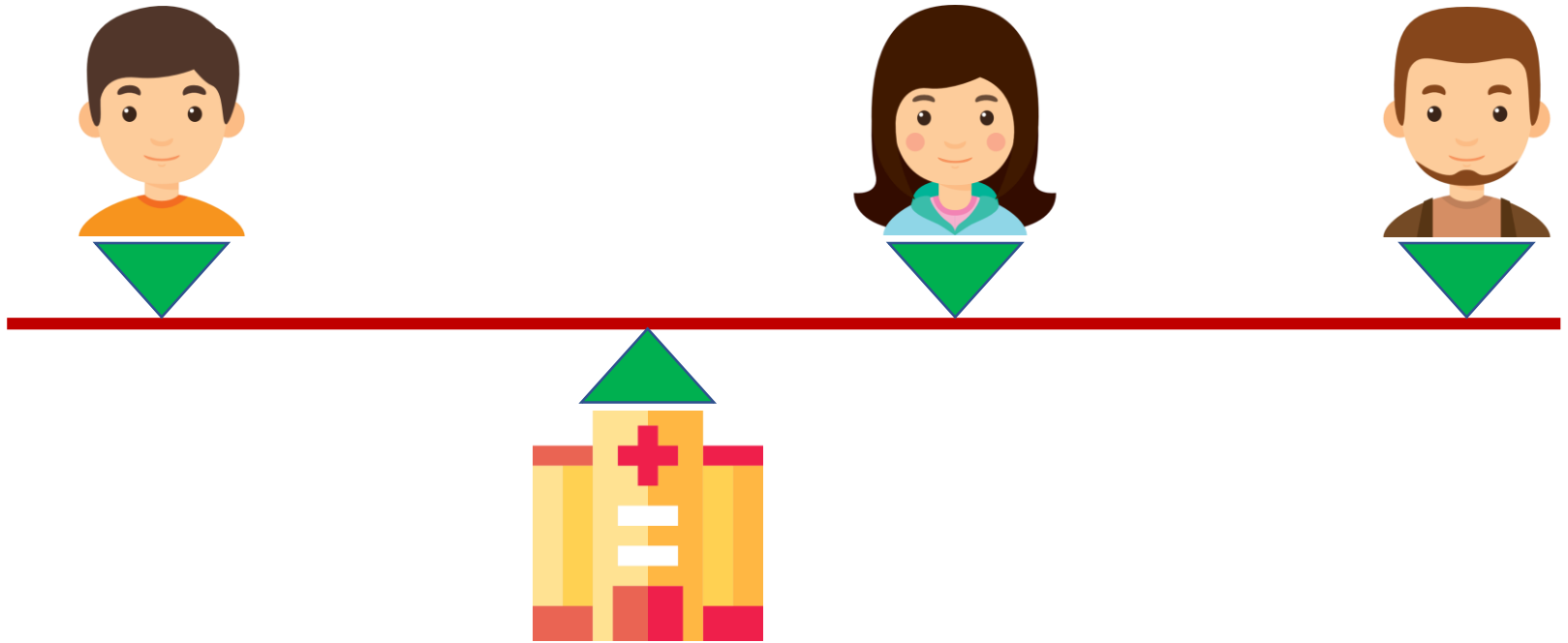
Can I make it easier so that each can just truthfully tell me how much they value it?

Image Courtesy: Freepik

# Real-World Applications

- Auctions form a significant part of mechanism design with money
- Auctions are ubiquitous in the real world!
  - A significant source of revenue for many large organizations (including Facebook and Google)
  - Often run billions of tiny auctions everyday
  - Need the algorithms to be fast

# Example: Facility Location



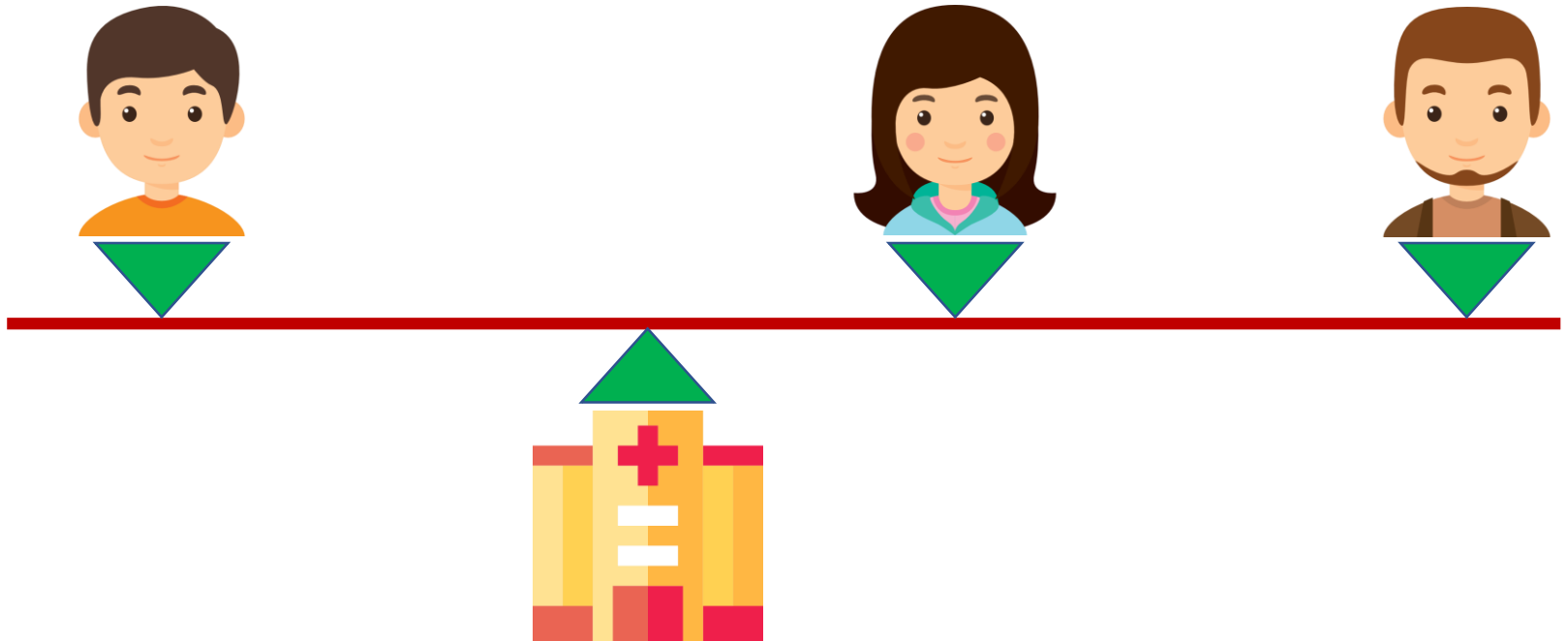
**Cost to each agent:** Distance from the hospital

**Objective:** Minimize the sum of costs

**Constraint:** No money

Image Courtesy: Freepik

# Example: Facility Location

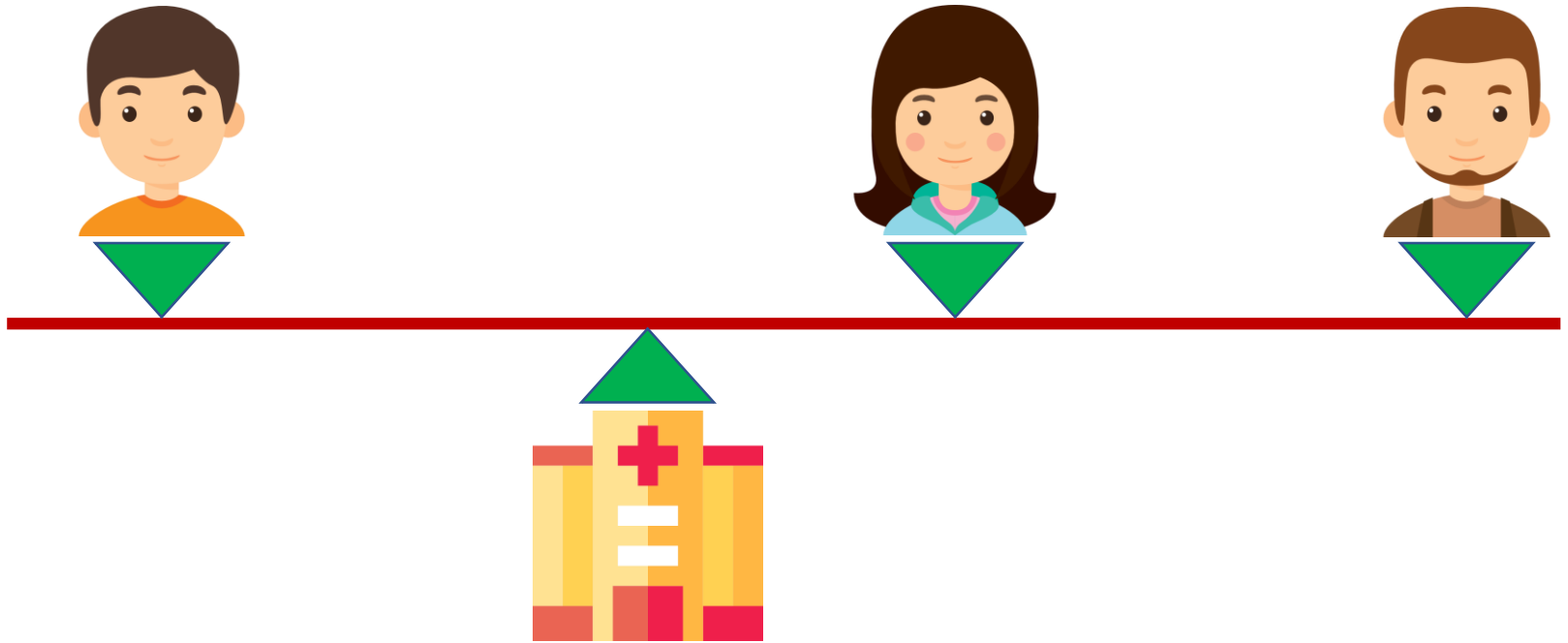


**Q:** What is the optimal hospital location?

**Q:** If we decide to choose the optimal location, will the agents really tell us where they live?

Image Courtesy: Freepik

# Example: Facility Location



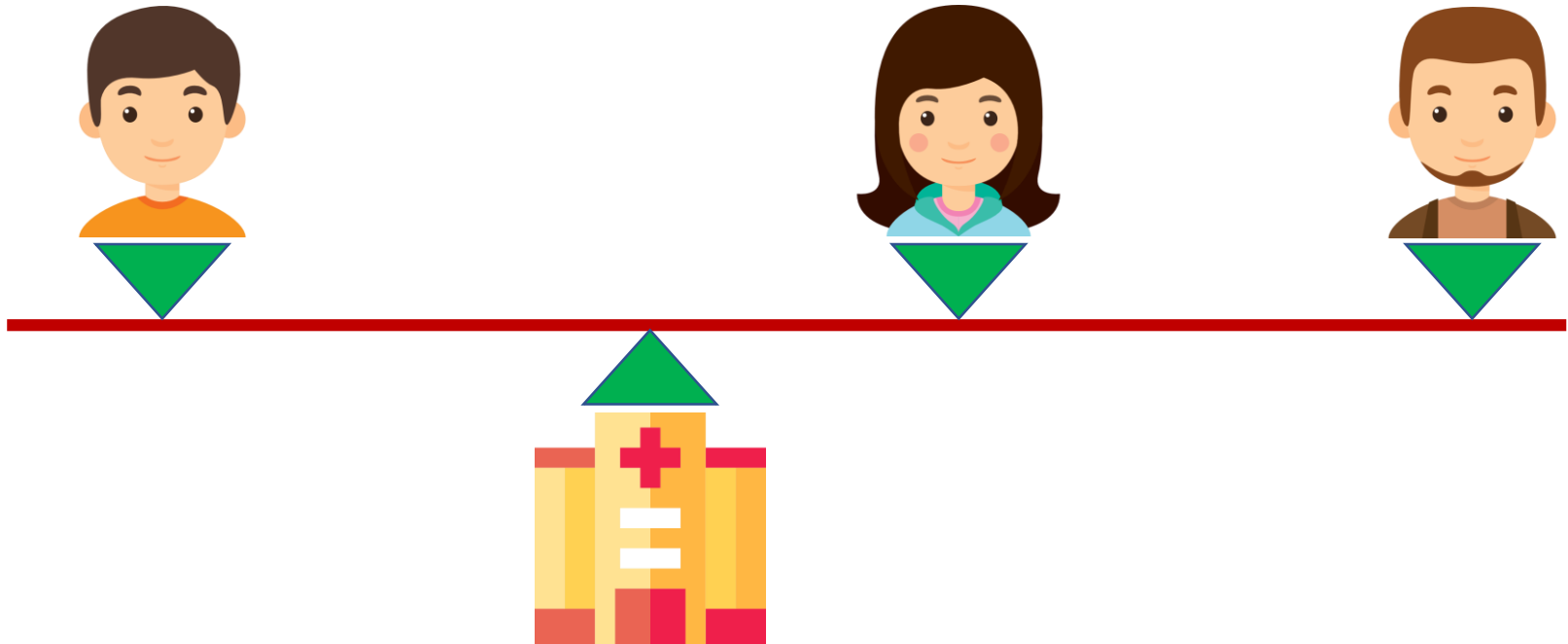
**Cost to each agent:** Distance from the hospital

**Objective:** Minimize the maximum cost

**Constraint:** No money

Image Courtesy: Freepik

# Example: Facility Location



**Q:** What is the optimal hospital location?

**Q:** If we decide to choose the optimal location, will the agents really tell us where they live?

Image Courtesy: Freepik

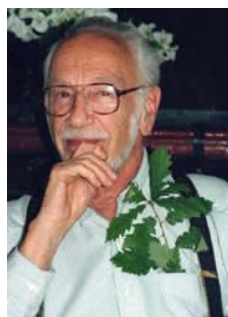
# Mechanism Design w/o Money

- Truth-telling is not the only possible desideratum
  - Fairness
  - Stability
  - Efficiency
  - ...
- Consequently, many subfields of study
  - Fair allocation of resources
  - Stable matching
  - Voting

# Real-World Applications



Roth



Gale



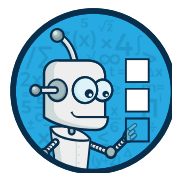
Shapley

National Resident Matching  
Program (NRMP)

School Choice (New York, Boston)

Fair Division

Voting



**ROBOVOTE**