

Game Theory and Its Applications



Syllabus
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Audience Q&A

① The Slido app must be installed on every computer you're presenting from

What is Game Theory?

- the study of mathematical models of strategic interaction between rational decision-makers.
- Which are in the field of game theory?

chess playing? **bidding?**
trade war? **buying a lottery?**
solving a puzzle? **bargaining?**
playing Sudoku? **forming an alliance?**



Which are in the field of game theory?

What's the difference?

- Whether your choice is good or not depends on other people's choice(s).
 - and vice versa



Interdependence

So What?

- ‘I can select a best choice considering all other people’s possible choices.’--- a belief
- Sometimes you have **no knowledge** of other people’s choices.
- Sometimes there are just **too many** possible choices to consider
- Sometimes everyone’s best choice (despite thoughtful) is **not the best** as a whole

You certainly know ...

- The best outcome for one may not be the best for the other



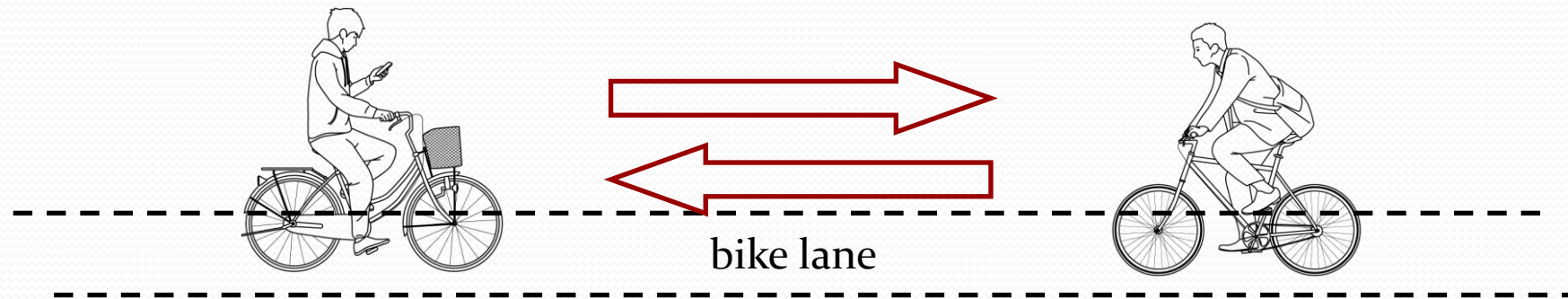
WIN



LOSE

And sometimes

- we can reach a 'win-win' outcome



- But can we reach an outcome that dissatisfies **everyone**?

**Let's take a look at a classic
example**

Prisoner's Dilemma

- Two gangsters (A and B) are arrested and imprisoned
- They are interrogated separately with no means of communicating with the other

A \ B	B stays silent	B betrays
A stays silent	-1 / -1	0 / -3
A betrays	0 / -3	-2 / -2

https://en.wikipedia.org/wiki/Prisoner%27s_dilemma

If you were Prisoner A ...

- What would be your choice? Remember you don't know B's choice (but you may know B's payoffs because the matrix is likely symmetric)



		B	
		B stays silent	B betrays
A	A stays silent	-1, -1	0, -3
	A betrays	0, -3	-2, -2

Even if you don't know your partner's payoff...

- What would be your choice?



		B	
		B stays silent	B betrays
A	A stays silent	-1 / ?	-3 / ?
	A betrays	0 / ?	-2 / ?

If you consider Prisoner B ...

- What would be B's best choice?
- What will be your best response?
- Will B change her choice knowing your best response?
- Is there any better result?

		B	
		B stays silent	B betrays
A	A stays silent	-1 / -1	-3 / 0
	A betrays	0 / -3	-2 / -2

Why should I learn this?

- Traditionally, computer scientists play the role of a god, controlling and manipulating everything
- “Objects” (devices, resources, processes) do not have their **own interests**



The Game from a Computer Scientist's View

- You play the role of a god (omniscience)
- You **figure out** that 'stays silent' is the best choice for both prisoners
- You **instruct** each prisoner to take that strategy
- That's it
- If prisoners have free will and are self-interested, they may **not follow** your instruction

		B	
		B stays silent	B betrays
A	A stays silent	-1 / -1	0 / -3
	A betrays	0 / -3	-2 / -2

Game-Theoretic Approach

- design rules for game players (software agents)
- Players act in their own self-interest, as an indirect way to achieve society's economic goals (i.e., your system goal)
- For scenarios like
 - Task allocations among a fleet of robots, UAVs, or autonomous cars
 - Resource sharing among users, operators, or tenants
 - Clustering, grouping, or federation of a bunch of resource/task producers or consumers
 - Matching resource buyers with sellers or vice versa

Course Goals

- Game theory as an **analytic model**
 - to **model** your problem (but you solve it by another means)
- Game theory for **mechanism design**
 - to **solve** your problem in a decentralized and autonomous way
 - yields an outcome that is accepted by everyone
- Learning some well-known **mechanism designs**
- Solving games

So this course is **not** to ...

- study how to design a fancy computer game
 - You should take courses like “3D Game Programming” (by Prof. Sai-Keung Wong)
- (in most of the time) study how to design a computer program to win a game (e.g., Go and Chess)
 - You should take “Theory of Computer Games” (by Prof. I-Chen Wu)

Compared with other Game Theory courses

- This course offers **broader coverage**
 - It covers non-cooperative game, coalition game, matching, auction, and related examples in CS/commun./networks
 - Many other courses cover only the first two topics
- This course **does not** cover applications of Game theory to economics, politics, and biology
- This course minimizes the use of math. formulas
 - focusing on concepts rather than math.

Criticisms of Game Theory

- They say: people are **not** always rational or self-interested
 - people may show mercy or tend to cooperate
 - Particularly in making economic or political decisions
- **Not a problem** at all in our case: we consider software agents, not human beings

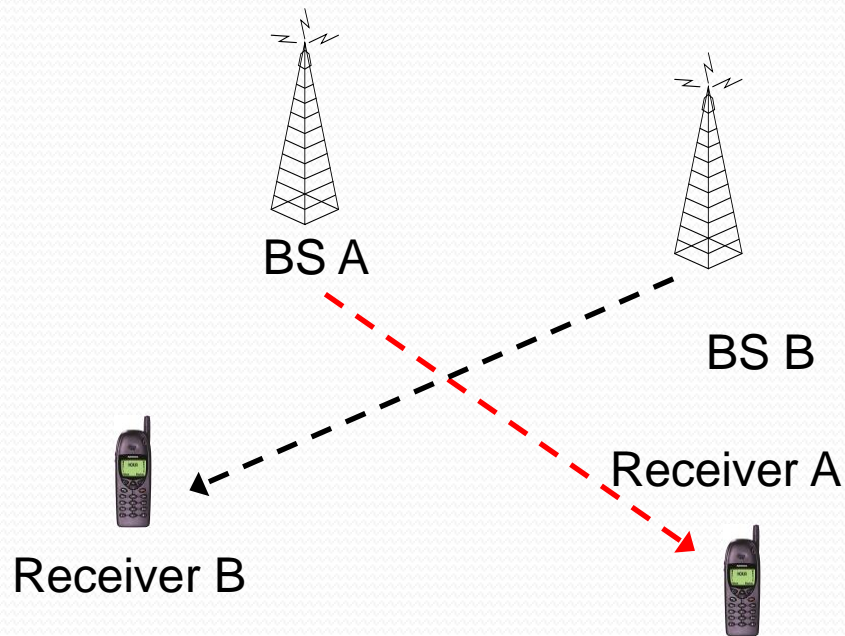
Course Goal One: Help Us Analyze

- Game theory as an **analytic model**
 - To predict what will happen next
 - To see if the interactions among players can lead to a stable outcome (accepted by every player)
 - To see whether we can make an improvement (if any)
 - primary concerns of Economists

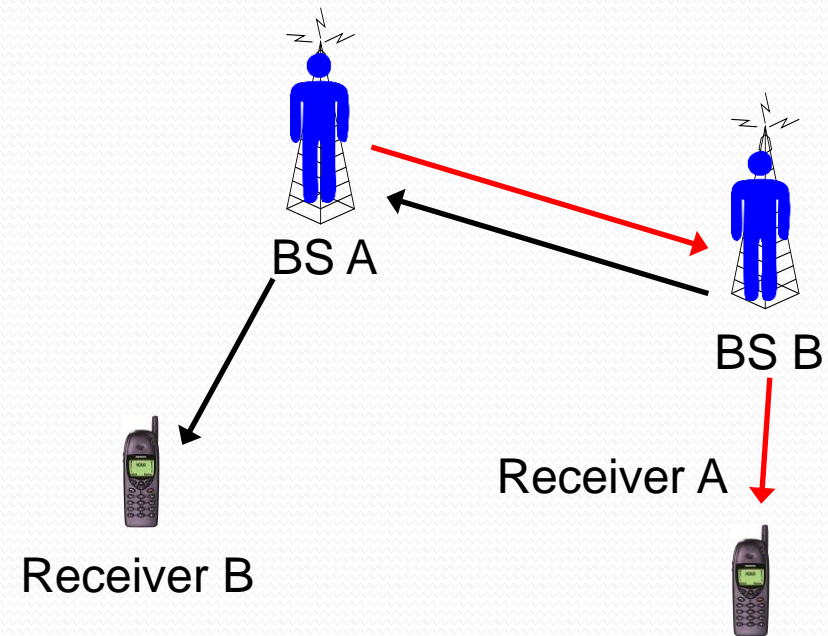


Example: Wireless Relay System

- Will a BS relay signal for the other?
- Can we motivate cooperation?



Direct Transmission



Relay Transmission

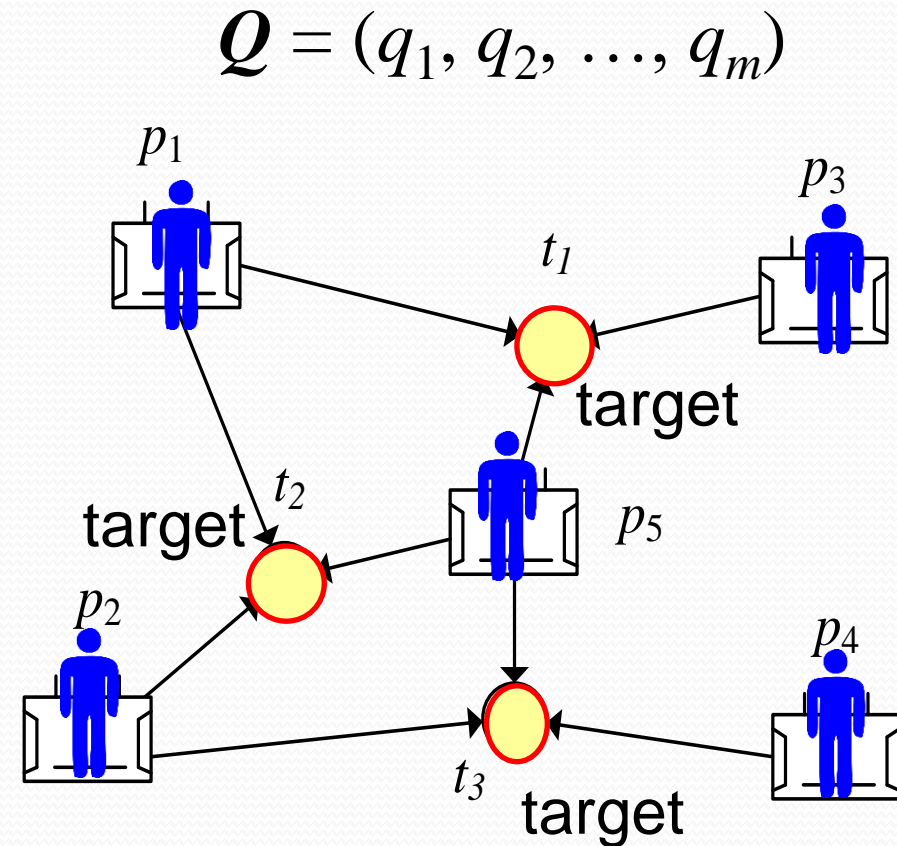
Course Goal Two: Help Us Design

- Game theory for **mechanism design**
 - To achieve a system goal via incentive-compatible rules
 - Design game rules for selfish yet rational players, yet achieve the system goal
 - Decentralized, autonomous, adaptive, self-stabilizing, self-optimizing
 - main focus of computer scientist



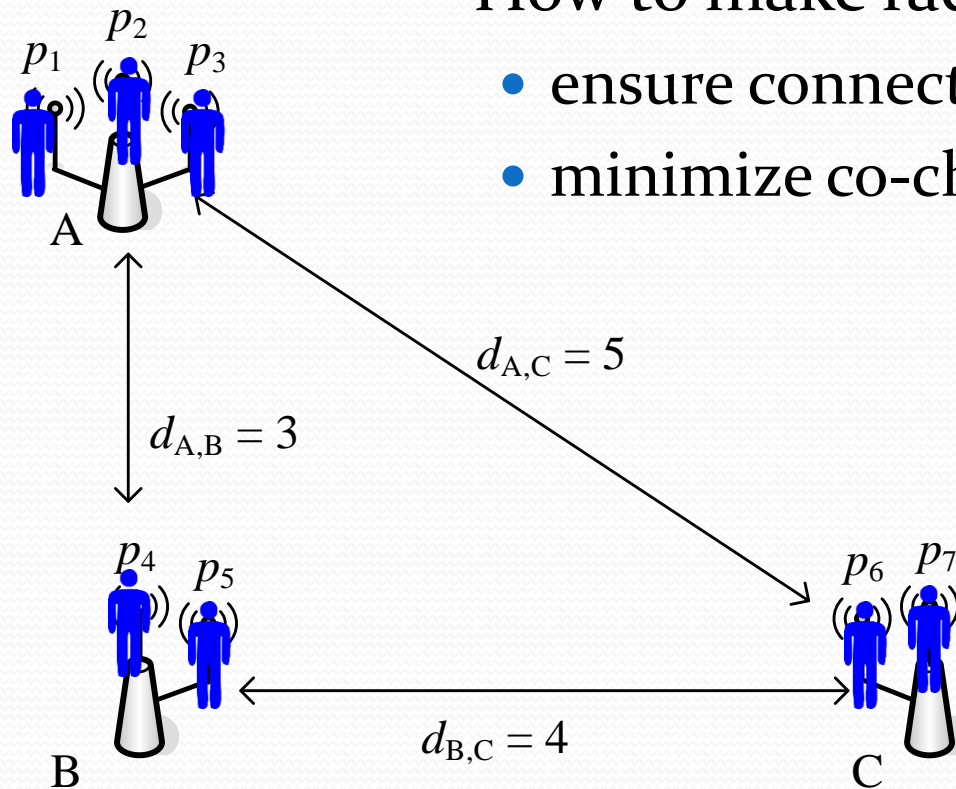
Example: Sensor Coverage

- n sensors are densely deployed to monitor m targets
- Target j must be covered by q_j sensors
- How to motivate sensors (game players) to meet coverage requirement while turning off sensors as many as possible?



Example: Channel Selection

- How to make radios select channels to
 - ensure connectivity
 - minimize co-channel interference



Course Goal Three: Help Us Know

- Learn some well-known **mechanism designs**
 - Auction
 - Matching
- with system goals
 - Pareto optimality
 - stability
 - social optimality



Example: Combinatorial Auctions

- How to select the set of winning bidders to maximize social welfare?
- How to enforce truthful bidding (bid indicates valuation)?

bidder	P1	P2	P3	P4	P5
valuation	\$63	\$54	\$93	\$70	\$28
bundle	{A,C,D}	{A,B,C}	{B,D,E}	{D,E}	{A,C}
bid					

A



B



C



D



E

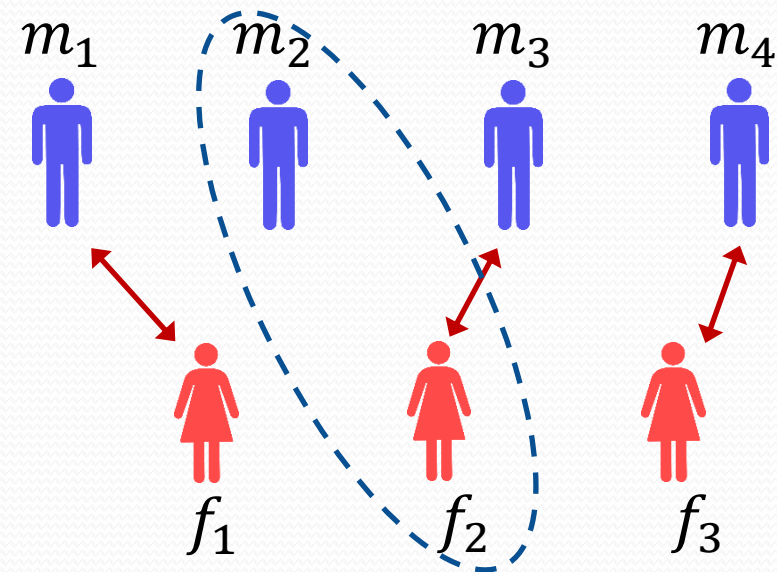


Example: Matching

- How to match females with males so that
 - no pair wants to deviate from the result?
 - no pair can be better off without hurting any others?

Male	Preference
m_1	$f_1 \succ f_2 \succ f_3 \succ m_1$
m_2	$f_1 \succ f_2 \succ f_3 \succ m_2$
m_3	$f_2 \succ f_1 \succ m_3 \succ f_3$
m_4	$f_2 \succ f_3 \succ f_1 \succ m_4$

Female	Preference
f_1	$m_4 \succ m_1 \succ m_2 \succ m_3 \succ f_1$
f_2	$m_2 \succ m_1 \succ m_3 \succ m_4 \succ f_2$
f_3	$m_3 \succ m_1 \succ m_2 \succ m_4 \succ f_3$



Example: Coalition Game

- What coalitions will be formed?
- How to distribute profits to coalition members to make the coalition stable?

	$\{P_1\}$	$\{P_2\}$	$\{P_3\}$	$\{P_1, P_2\}$	$\{P_1, P_3\}$	$\{P_2, P_3\}$	$\{P_1, P_2, P_3\}$
profit	2	6	12	9	15	21	24

- Suppose $(x_1, x_2, x_3) = (5, 6, 13)$ or $(x_1, x_2, x_3) = (3, 7, 14)$
- Can $\{P_1, P_2\}$ block (x_1, x_2, x_3) ? (Can we distribute the profit of $\{P_1, P_2\}$ to P_1 and P_2 such that at least one player is better off and no one is worse off?)
- Can $\{P_2, P_3\}$ block (x_1, x_2, x_3) ?

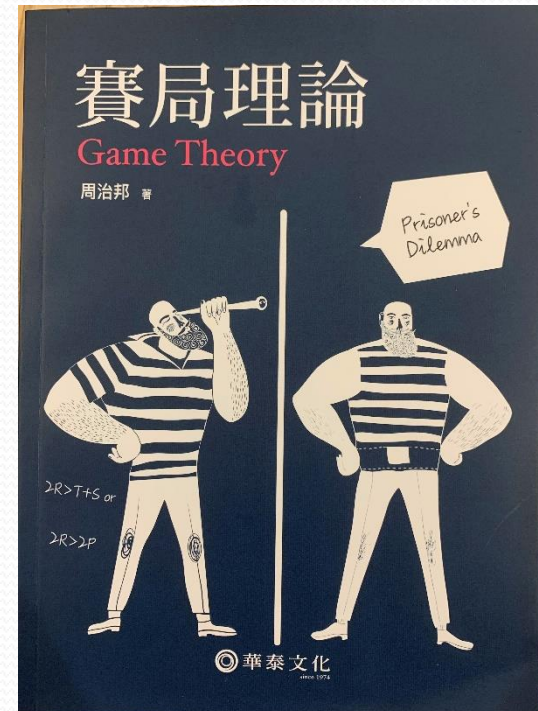
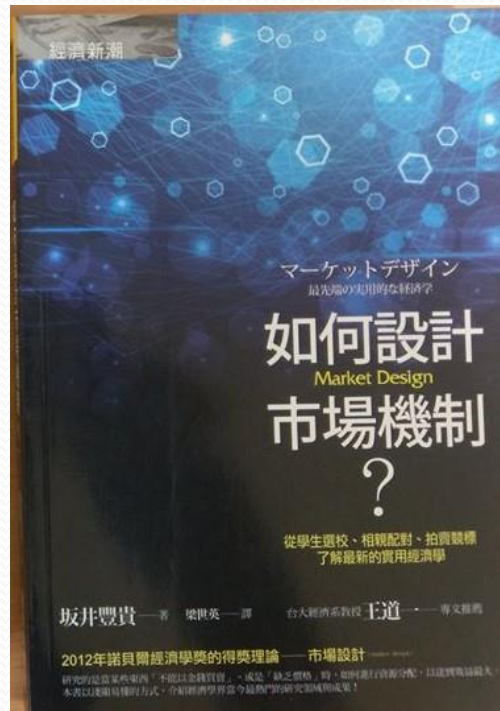
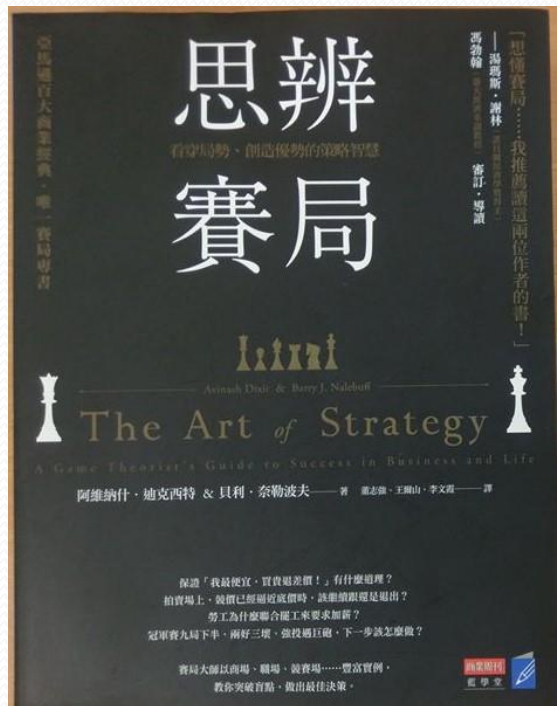
Course Goal Four: Help Us Solve

- **Find strategies for players** to stabilize or improve the game
 - perhaps without full knowledge of the game
 - e.g., Stackelberg game or repeated games
- Learning techniques may help
- Challenge: multiple agents with diverse goals



Text Book: None

- Reference books (in Chinese)



Schedule (tentative)

week	contents	week	contents
1	Introduction and static games	9	Coalition Game (1/2)
2	Static games (cont.)	10	Coalition Game (2/2)
3	Classic and Structured Static Games (1/2)	11	Matching Theory (1/3)
4	Classic and Structured Static Games (2/2)	12	Matching Theory (2/3)
5	Game Designs for Graph Problems	13	Matching Theory (3/3)
6	Game Designs for Network Problems	14	Auctions (1/2)
7	Dynamic Games	15	Auctions (2/2)
8	Repeated Games and Mid-term Exam.	16	Final Exam.

Scoring Policy

- (60+%) Four Programming Assignments (15% each)
 - One for Game design for graph problems (easy)
 - One for finding Nash equilibrium (easy)
 - One for finding strategies in repeated games (easy to hard)
 - One for identifying stable matching (easy)
- (20%) Mid-term exam.
- (20%) Final exam.

Teaching Assistants (TAs)

Name	E-mail	Phone	TA Time/Place
Yan-Wei Chen (Mr.)	ghj0504520.cywjy@gmail.com	ext. 56674	14:00~17:00 Wed. @ES703B
Chun-Yu Lin (Mr.)	leisurelin0717@gmail.com	ext. 56674	14:00-~17:00 Fri. @ES703B

ES: Microelectronics and Information Systems Research Center (電子與資訊研究中心)

Course Materials

- All lectures will be recorded and put online
- Slides are placed in E3 Learning Management System:
<https://e3.nycu.edu.tw/>
- Because all announcements are sent via E3, please confirm your e-mail address settings in E3 is correct
- Instructor's e-mail: lhyen@nycu.edu.tw