1

T2: Game-theory/Mechanism Design/Auctions in Multi-agent Systems

Makoto Yokoo
Kyushu University, Japan
yokoo@is.kyushu-u.ac.jp
http://lang.is.kyushu-u.ac.jp/~yokoo/

2

Outline

- Why game-theory/economics?
- Game-theory
- Auctions

3

Why Game-theory/Economics?

- Game-theory/Economics provide analytical tools for the design/analysis of multi-agent systems (MAS).
  - Game-theory/economics are specially useful when the MAS
    - are not centrally designed.
    - do not have a notion of global utility.
    - will not necessarily act "benevolently".

4

Why Game-theory/Economics (contd.)?

- Underlying assumptions:
  - Each player (agent) has consistent preference/utility.
  - Each player is rational, i.e., tries to maximize his/her utility.
  - Each player chooses a strategy to play.

These assumptions only approximate human behavior, but are fully applicable to MAS.

5

Why Game-theory/Economics (contd.)?

- Increasing intersectional topics:
  - Internet auctions, electronic commerce
  - resource allocation for automated agents

From the theory for describing human behavior to the theory for designing systems!

6

Why Game-theory/Economics (contd.)?

- MAS research community is divided into several different groups (like clubs).
  - e.g., logic, search/constraint satisfaction, game-theory
- Each club has its own tradition.
- The members of each club speak their own language.
- You need to join a club to publish your paper.
- To join a club, you need to speak their language and understand their tradition.
- Game-theory/mechanism design is one of mainstream clubs in MAS.

7

Outline

- Why game-theory/economics?
- Game-theory
  – Introduction
  – Games with Complete Information
  – Games with Incomplete Information
- Auctions

8

Selfish Agents

- Preference
  – A certain (social) state is preferred than another, e.g., having $100 is better than having $50.
  – Preference may vary among agents, e.g., some prefer having apples while others prefer oranges.
- Utility
  – A value of a (social) state given by each agent.
  – Preferred state derives higher utility.
- “Selfish” agents: Each agent behaves to maximize its own utility.

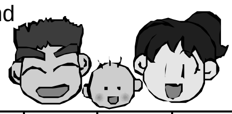
9

Pareto Efficiency (1)

Definition:

A state is said Pareto efficient, iff there exists no state that is

– better for one agent, and
– no worse for all the rest



×	Movie	2	2	2
	Shopping	2	2	5
	Zoo	2	3	1
×	Home	1	1	1

10

Pareto Efficiency (2)

- Pareto efficiency can be considered a minimal requirement for social optimality.
  – If a state is not Pareto efficient, there exists another state that all members think it is better (or the same).
- However, a Pareto efficient state is *not always unique*.

  Example: Dividing $100 between two people. Both “$50 to each” and “$100 to one, $0 to the other” are Pareto efficient.

11

Outline

- Why game-theory/economics?
- Game-theory
  – Introduction
  – Games with Complete Information
  – Games with Incomplete Information
- Auctions

12

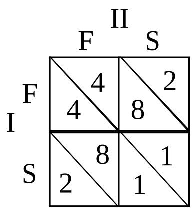
Outline: Games with Complete Information

- Definition
- Dominant Strategy Equilibrium
- Iterated Dominance Equilibrium
- Min-Max Strategy
- Mixed Strategy
- Nash Equilibrium

13

Game with Complete Information

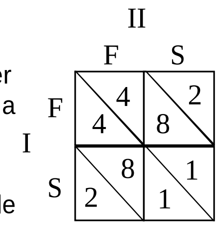
- Each agent knows the possible actions/utilities of both of itself and opponents with certainty.
- Can be described as a matrix.



14

Competing Newspaper

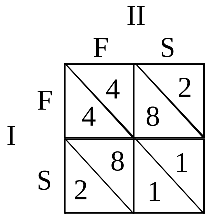
- There are two competing newspapers.
- Each has a choice whether to cover Finance news as a top news or cover Sports.
- 80% of people prefer Finance, while 20% people prefer Sports.



15

Rational Agent/Player

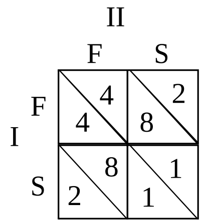
- Each Agent/Player is rational:
  - Tries to maximize its own utility.
  - Does not care about other people's utility.
  - There is no felling such as pity or unfair.
  - Sometimes called selfish, but:
    - if the agent has feelings like sympathy, moral, or whatever, we assume they are already represented in the matrix.



16

Assumption

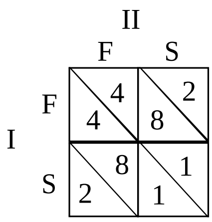
- Each agent knows the possible actions/utilities of both of itself and opponents (i.e., the payoff matrix) with certainty
- Of course, the agent does not know which action his opponent will choose.



17

Assumption (cont'd)

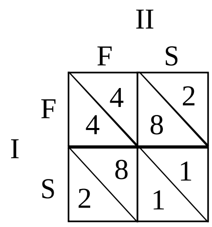
- Each agent chooses its action simultaneously, without negotiation.
  - They cannot negotiate, say, I'll chose F, so could you please chose S, then I'll pay you $1000, etc.
  - An agent cannot choose its action after observing the opponent's action.



18

Competing Newspaper

- Which action should you choose if you are player I?
- Your best scenario is you choose F, and the opponent choose S, but you cannot control the opponent's action.
- Your opponent is not a fool (actually, very wise) and tries to maximize its own utility.



Dominant Strategy

Strategy: the way for choosing an action

Dominant Strategy: the strategy that gives you higher (or equal) utility than any other strategy, no matter the action the opponent chooses.

- Clearly, a rational player will choose a dominant strategy if exists.
- We don't need to care whether your opponent is rational (even for a very weird player, or you have no idea of your opponent's utility, it is just fine).

I \ II	F	S
F	4, 4	8, 2
S	2, 8	1, 1

Dominant Strategy Equilibrium

If each player has a dominant strategy, the combination is called a dominant strategy equilibrium.

- If players are rational, and there exists a dominant strategy equilibrium, we can assume that the result will be that dominant strategy equilibrium.

I \ II	F	S
F	4, 4	8, 2
S	2, 8	1, 1

Dominant Strategy

Dominant Strategy does not necessarily exists.

- Paper-Rock-Scissors: no dominant strategy
- If only paper and rock are allowed, paper is the dominant strategy

- Most games (which a human enjoys to play) does not have a dominant strategy.
- In mechanism design (e.g., auctions), the goal is to design the rule so that a dominant strategy equilibrium exists.

Battle of the Bismarck Sea

- in the South Pacific, 1943.
- Rear Admiral Kimura needs to transport Japanese troops across the Bismarck Sea to New Guinea.
- He can choose either a short north route or a long south route.
- Admiral Kenny must decide where to send his bomber planes.
- If he chose wrong route, the time for bombing is reduced.

Ke \ Ki	N	S
N	2, -2	2, -2
S	1, -1	3, -3

Battle of the Bismarck Sea

- This is a zero-sum game.
- No dominant strategy for Kenny.
- Which route should Kenny choose?

K \ I	N	S
N	2, -2	2, -2
S	1, -1	3, -3

Iterated Dominance Equilibrium

- For Kimura, choosing North is a (weakly) dominant strategy.
- Assuming Kimura is rational, he would choose North.
- Then, Kenny should choose North.
- By iteratively removing dominated strategy, we can obtain an iterated dominance equilibrium.
- Your opponent needs to be rational.

Ke \ Ki	N	S
N	2, -2	2, -2
S	1, -1	3, -3

25

Boxed Pigs

- Example used in a psychological test for animals.
- A big pig and a small pig are in a (large) box.
- If a pig push a button, then some foods appear in a slightly faraway place.
- If a small pig pushes the button, the big pig gets most of the foods.
- If a big pig pushes the button, then a small pig can get about a half.
- What kind of actions these pigs learn?

26

Boxed Pigs

- The payoff matrix is as follows.
- The bigger one does not always win.
- Burn one's bridge can be good!

Big Pig \ Small Pig	Push	Wait
Push	5, 1	4, 4
Wait	9, -1	0, 0

27

Outline: Games with Complete Information

- Definition
- Dominant Strategy Equilibrium
- Iterated Dominance Equilibrium
- Min-Max Strategy
- Mixed Strategy
- Nash Equilibrium

28

Min-Max Strategy

- What should we do if there is no dominant strategy/iterated dominance equilibrium?
- One possibility: let's avoid the worst-case!
  - Min-max strategy: for each action, consider the worst-case caused by the opponent action, then choose the best own action for each worst-case.

29

Min-Max Strategy

- The payoff matrix is as follows (zero-sum game, only player I's utilities are shown.
- Which action should player I choose?

II

I				
	7	2	5	1
	2	2	3	4
	5	3	4	4
	5	2	1	6

30

Saddle Point

- What if the player II thinks in the similar way?
- II wants to minimize I's utility.
- The crossing point is minimum in the row, and maximum in the column.

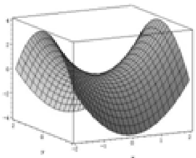
II

I				
	7	2	5	1
	2	2	3	4
	5	3	4	4
	5	2	1	6

31

Saddle Point

- In a zero-sum game, if there exists a saddle point, then the result of the game will be that point.
- Not necessarily exists.



32

Case with no saddle point

- Assume a penalty kick in a soccer game.
- The goal keeper is very good for the right-side.
- If he is expecting the right-side:
  - the kick is actually in the right-side: he can stop 80%.
  - in the left-side: he cannot stop at all.
- expecting the left-side:
  - the kick is actually in the left-side: he can stop 30%.
  - in the right-side: he can stop 10%.

		Kicker R	Kicker L
Keeper	R	8	0
	L	1	3

33

Using Min-Max Strategy

- A timid keeper：I want to avoid the worst-case, let's wait for left-side, then I can stop at least 10%!
- A timid kicker: To be stopped 80% is terrible, let's kick left-side!
- Then, the keeper can stop 30%!

		Kicker R	Kicker L
Keeper	R	8	0
	L	1	3

34

Is this result reasonable?

- This result is too bad for the kicker.
  - Why I need to kick to the left while I'm quite sure that the keeper is expecting the left-side?
  - If I kick to the right-side, then the keeper can stop just 10%.
- On the other hand, if the keeper knows the kick is coming to the right-side, then he can do better.
  - He is good for the right-side!

		Kicker R	Kicker L
Keeper	R	8	0
	L	1	3

35

Mixed Strategy

- The kicker probabilistically mixes left/right.
- The keeper also changes whether to wait left/right.
- Such a strategy is called a mixed strategy.
  - Choosing a single action is called a pure strategy.

		Kicker R	Kicker L
Keeper	R	8	0
	L	1	3

36

Saddle point in a mixed strategy

- If the kick is tend to be right, then the keeper waits for the right-side more often, so that he can stop more.
- If the keeper tends to wait right-side more, then the kicker tries to kick to the left-side more often.
- Where is a stable point?

		Kicker R	Kicker L
Keeper	R	8	0
	L	1	3

37

Saddle point in a mixed strategy

- The probability that the keeper is expecting the right-side: x
- The probability that the kicker kicks to the right-side: y
- stopping probability : 0.1[xy*8 + x(1-y)*0 + (1-x)y*1 + (1-x)(1-y)*3]
  = 0.1[10xy - 3x -2y +3]
- partially differentiate by x: 10y – 3
  - y=0.3, i.e., if the kicker kicks to the right for 30%, then regardless of the keeper's strategy, the stopping probability is 24%.
- partially differentiate by y: 10x – 2
  - if x=0.2, i.e., if the keeper waits for the right for 20%, then regardless of the kicker's strategy, the stopping probability is 24%.

Kicker

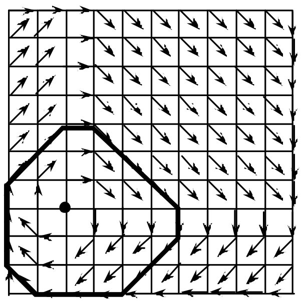
Keeper	R	L
R	8	0
L	1	3

38

Is it really stable?

- Assume each player gradually adapt to the opponent's strategy...

Kicker



Keeper

39

Outline: Games with Complete Information

- Definition
- Dominant Strategy Equilibrium
- Iterated Dominance Equilibrium
- Min-Max Strategy
- Mixed Strategy
- Nash Equilibrium

40

Equilibrium of a Game

- What should we do if there exists no dominant strategy equilibrium or iterated dominance equilibrium?
- Let's consider a weaker notion of equilibrium.
  - Nash equilibrium

41

Nash Equilibrium

- A set of strategies (s,t) is in Nash equilibrium if they are the best reply to each other.
- A dominant strategy equilibrium is a Nash equilibrium, but not vice versa.
- A saddle point in a zero-sum game is a Nash equilibrium.
- If there exists a unique Nash equilibrium, then the result of a game played by rational players would be that Nash equilibrium.
  - Other results are unstable.

II

I				
	7	2	5	1
	2	2	3	4
	5	3	4	4
	5	2	1	6

Multiple Nash Equilibriums

- "The game of chicken" has two Nash equilibriums
  - (D, C)
  - (C, D)
- Not sure which one will occur.
- If a third-party player (who does not have any power, groundlessly) says "(C, D) will occur", then it might be come true.

II

I	D	C
D	1 / 1	2 / 4
C	4 / 2	3 / 3

Nash equilibrium in mixed strategies

- Theorem：Any game has at least one Nash equilibrium in mixed strategies (Nash 1951) .
- In P-R-S, choosing each for probability 1/3 is a Nash equilibrium.

44

Quiz: Nash Equilibrium?

- Play P-R-S at a stairway.
- win by rock: advance 3 steps.
  win by paper: advance 6 steps.
  win by scissors: advance 6 steps.
- The one who reaches the top first wins.

	0, 0	1, -1	-2, 2
	-1, 1	0, 0	2, -2
	2, -2	-2, 2	0, 0

45

Games with Incomplete Information

- Several sources of uncertainty
  - The utilities of opponents (types) are not known.
  - The result can be probabilistic (the choice of the nature)
  - In a game where plays are interleaved: the play of opponents cannot be observed.

46

Modified Game of Chicken

- There can be different types of players.
  - Bull: losing is as bad as dying
  - Chicken: be scared to death for not hitting brakes

Bull

	D	C
D	2, 1	4, 2
C	2, 4	3, 3

Chicken

	D	C
D	1, 1	3, 2
C	2, 4	3, 3

47

Bayesian Nash Equilibrium

- Assume the probability of each type normal/bull/chicken is 1/3.
- Assume this probability distribution is common knowledge.
- In the following strategy profile, each strategy maximizes the expected utility (given that other player uses this strategy).
  - A normal player chooses D/C for 0.5
  - A bull chooses D.
  - A chicken chooses C.
- Such a strategy profile is called Bayesian Nash equilibrium.

48

Signaling

- It is not clear whether the education at universities really improve the productivity of workers; then why people go to universities and companies hire university graduates with high salary?
- One possible answer: the university education works as a “signal” to distinguish high-quality workers and low-quality workers.

49

Problem Settings

- Worker:
  - There are high-quality worker (High) and low-quality worker (Low); the probability is ½ for each.
  - High can produce 6, while Low can produce 3.
  - The cost for graduating from a university is 0 for High, 3 for Low.
- Company: can choose whether to offer a worker a high salary (4) or low salary (1). It's utility is the difference of the productivity and salary.
- High can obtain 3 by himself if he decided not to work for a company, while Low cannot make money alone.
- A worker can choose whether to go to a university.
- A company can set a salary according to the education level (or just ignore it).

What kinds of Bayesian Nash equilibrium exist?

50

Characteristics

- The type of a worker (High/Low) cannot be observed by a company.
- Getting the university education does not increase the productivity at all (in a sense, it is just a waste of efforts).

51

Separating Equilibrium

- The company offers a high salary (4) to university graduates, and a low salary (1) to others.
- High goes to the university: his utility is 4.
- Low does not go to the university: his utility is 1.
- The utility of a company is 2, i.e., (6-4)*0.5+(3-1)*0.5.
- Low cannot increase his utility if he goes to the university.
- For workers, the university education works as a signal to show his ability.

52

Pooling Equilibrium

- The company offers a high salary (4) to university graduates, and a low salary (1) to others.
- Everybody goes to the university.
- The utility of the company is: (6-4)*0.5 + (1-4)*1/2=0.5
- The company cannot increase the utility if it decides to hire everybody with low salary.
- Low cannot increase his utility if he decides not to go to the university.
- The signaling does not work; the university education is totally a waste in this case.
- Solution: make the university education more difficult for Low.

53

Quiz: Signaling

- Point out instances that seem to be "signaling".
  - Something that has no real value itself, but it works to distinguish people, company, product, etc.
  - Something that is relatively easy for a good guy, difficult for a bad guy.

54

Outline

- Why game-theory/economics?
- Game-theory
- Auctions
  - Assumptions/Preliminaries
  - Single-item, single-unit auctions
  - Combinatorial auctions
  - False-name bids

Characteristics of Player

risk neutral/averse

- risk neutral：only cares the expected utility
  - e.g., indifferent between two lotteries:
    1) he/she obtains 0 for the head and $100 for the tail,
    2) he/she obtains $50 for sure.
- risk averse：prefers that is more certain（even with less expected utility）
  - e.g., prefers getting $45 for sure to 1.

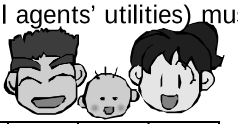
Assumption for Simplicity

Quasi-linear utility: an agent's utility is defined as the difference between its evaluation value of the allocated good and its payment.

- If an agent wins a good whose evaluation value is $100 by paying $90, its utility is $100-$90=$10.
- If it does not win, its utility is $0.
- If it does win, paying $100, its utility is 0.

Social Surplus

- Assuming agents' utilities are quasi-linear, if a state is Pareto efficient, the social surplus (sum of all agents' utilities) must be maximized.



×	Movie **6**	2	2	2
	Shopping **9**	2	2 →**3**	5 →**4**
×	Zoo **6**	2	3	1
×	Home **3**	1	1	1

Incomplete Information in Auctions

- Types of players
  - If the evaluation values of opponents are known, an auction becomes trivial
- His/her own evaluation value
  - There exists some uncertainty in the value of the auctioned good.

Private/Common/Correlated Values

Private Value: each agent knows its value with certainty, which is independent from other agents' evaluation values (e.g., antiques which are not resold).

Common value：the evaluation values for all agents are the same, but agents do not know the exact value and have different estimated values (e.g., US Treasury bills, mining right of oil fields).

Correlated Value: Something between above two extremes.

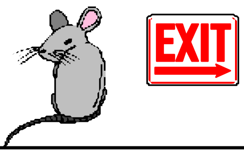
Desirable Properties of Auction Protocols

- For a bidder, there exists a dominant strategy.
- The protocol is robust against various frauds (e.g., spying).
- A Pareto efficient allocation can be achieved.

61

Protocol/Mechanism Design

- Designing a protocol is determining the rules of a game.
- The designer cannot control the actions of each agent.
  - –No way to force an agent to be honest or to refrain from doing frauds.

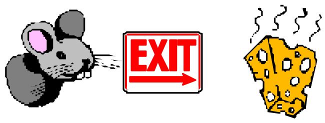


62

Protocol/Mechanism Design

How can a designer achieve a certain desirable property (e.g., Pareto efficiency)?

- Design rules so that:
  - For each agent, there exists a dominant strategy.
  - In the dominant strategy equilibrium, the desirable property is achieved.



63

Incentive Compatibility

Direct revelation mechanism: directly ask types/evaluation values for each agents

Incentive compatibility: A direct revelation mechanism is (dominant-strategy) incentive compatible if truth-telling is a dominant strategy for each agent.

Revelation Principle: If a certain property (e.g., Pareto efficiency) can be achieved in a dominant strategy equilibrium using an indirect mechanism, that property can be achieved using an incentive compatible direct revelation mechanism.

We can restrict our attention only to (incentive compatible) direct revelation mechanism!

64

Outline

- Example
- Why game-theory/economics?
- Game-theory
- Auctions
  - Assumptions/Preliminaries
  - Single-item, single-unit auctions
  - Combinatorial auctions
  - False-name bids

65

English (open cry)

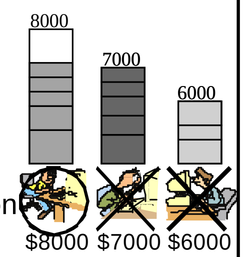
Protocol :Each agent is free to revise its bid upwards. When nobody wishes to revise its bid further, the highest bidder wins the good and pays its own price.

Dominant strategy (in private value): keep bidding some small amount more than the previous highest bid until the price reaches its evaluation value, then quit.

66

English (open cry)

- In the dominant-strategy equilibrium, the agent with the highest evaluation value wins and pays the second highest evaluation value +e.
- The obtained allocation is Pareto efficient.



67

First-price Sealed-bid

Protocol: Each agent submits its bid without knowing other agents' bids. The agent with the highest bid wins and pays its own price.

Dominant strategy: does not exist in general.

68

Example: First-price

- Assume you attend an auction on behalf of your uncle.
- There are 10 goods to be auctioned.
- Your uncle specifies the maximal price you can bid for each good.
- The generous uncle will give you the difference if you can buy it less than the maximal price.
- If you failed to buy a good, you receive nothing for the good.

69

Example: First-price

- Assume there is only one opponent.
- Your opponent is also a proxy.
- You don't know how much your opponent will bid, but you know his maximal price is uniformly distributed among [0, 200].

70

Strategy for Bidding

- For good 1, assume the maximal price is $100.
- Then, bidding more than $100 is meaningless (you must pay the difference).
- If you bid $90 and win, your profit is $10.
- If you bid $1 and (by any chance) win, your profit is $99.
- How much should you bid?

71

Let's Play with Computer!

- There are 10 goods.
- You see your maximal price, which is chosen from a uniform distribution [0, 200].
- You know the maximal price of your opponent (computer) is also chosen from [0, 200].
- The computer player chooses an optimal strategy (in some sense).

72

Dutch (descending)

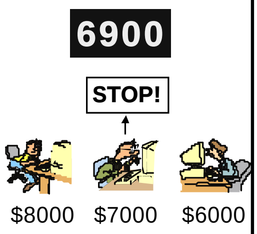
Protocol: The seller announces a very high price, then continuously lowers the price until some agent says "stop", then the agent wins the good and pays the current price.

Dominant strategy: does not exist in general.

73

Dutch (descending)

- Strategically equivalent to the first-price sealed-bid auction
  - there is one-to-one mapping between the strategy sets in two auctions.
- Example:
  - Dutch flower market
  - Ontario tobacco auction
  - bargain sale



74

Vickrey (Second-price Sealed-bid)

Protocol：Each agent submits its bid without knowing other agents' bids. The agent with the highest bid wins and pays the value of the second highest bid.

Dominant strategy (in Private value)：Bidding its true evaluation value is the dominant strategy (honesty is the best policy, incentive compatibility)

- The obtained allocation is Pareto efficient.
- The obtained result is identical to English in the dominant-strategy equilibrium.

75

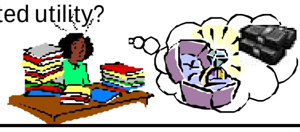
Characteristics of Protocols (in Private Value Auctions)

- Dutch＝First-price Sealed-bid
- English＝Vickrey
- Under several assumptions, the expected revenue of the seller is the same in all 4 auction protocols (revenue equivalence theorem, Vickrey 1961).
  - If there exists a Bayesian Nash equilibrium, the expected revenue would be the same at the equilibrium.

76

Quiz: Expected Utility (for Vickrey auction)

- Assume you are facing one opponent in a Vickrey auction.
- Your evaluation value is 100.
- The evaluation value of the opponent is uniformly distributed from 0 to 200.
- What is your best bid and how much is your expected utility?



77

Difficulties for Using Vickrey Auction

- Hard to understand!
- Do not know/aware of the true evaluation value (even in private value auctions).
- Cannot trust the seller.
- Do not want to reveal the private/sensitive information.

78

Outline

- Example
- Why game-theory/economics?
- Game-theory
- Auctions
  - Assumptions/Preliminaries
  - Single-item, single-unit auctions
  - Combinatorial auctions
  - False-name bids

Combinatorial Auction

79

- Multiple different goods with correlated values are auctioned simultaneously.
  - Complementary: PC and memory
  - Substitutable: Dell or Gateway
- By allowing bids on any combinations of goods, the obtained social surplus/revenue of the seller can increase.
- e.g., FCC spectrum right auctions

Research Issues in Combinatorial Auctions

80

- Finding the best combination of bids is a complicated combinatorial optimization problem
  - winner determination problem, one instance of a set packing problem
  - NP-complete
  - Various search techniques are introduced
- How to describe the preference of an agent is also a research issue --- 2^m subsets for m goods

Vickrey-Clarke-Groves Mechanism (VCG) aka Generalized Vickrey

81

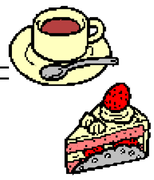
- Each agent declares its evaluation values for subsets of goods.
- The goods are allocated so that the social surplus is maximized.
- The payment of agent 1 is equal to the decrease of the social surplus except agent 1, caused by the participation of agent 1.
- Satisfies incentive compatibility and Pareto efficiency.

An Example of the VCG

82

Setting: three agents (agent 1, 2, 3) are bidding for two goods.

	coffee	cake	both
~~Agent 1~~	~~$6~~	~~$0~~	~~$6~~
Agent 2	$0	$0	$8
Agent 3	$0	$5	$5



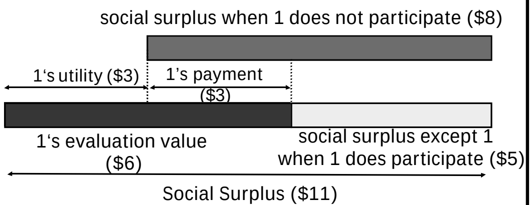
Result:

- Agent 1 gets the coffee, 3 gets the cake.
- Agent 1 pays $8−$5=$3.
- Agent 3 pays $8−$6=$2.

Incentive Compatibility of VCG

83

- Goods are allocated so that social surplus is maximized.
- An agent can maximize its utility when the social surplus is maximized.



Outline

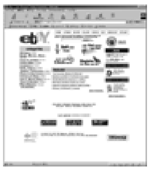
84

- Example
- Why game-theory/economics?
- Game-theory
- Auctions
  - Assumptions/Preliminaries
  - Single-item, single-unit auctions
  - Combinatorial auctions
  - False-name bids

Internet Auction

- Internet auctions have become a particularly popular part of Electronic Commerce.
  - There exist many auction sites.

Merits:

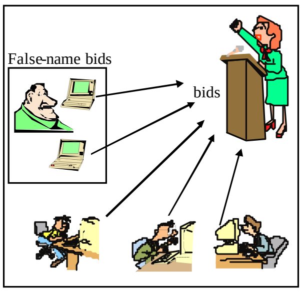


- can execute large-scale auctions with many more sellers and buyers from all over the world
- can utilize software agents

Demerit:

- A new type of cheating using the anonymity available on the Internet is possible (false-name bids).

False-name Bids



- An agent submits several bids under fictitious names.
- Detecting false-name bids is virtually impossible, since identifying each participant on the Internet is very difficult.

A Case where the VCG is Vulnerable

Setting: two agents (Agent 1, 2)

	coffee	cake	both
Agent 1	$6	$5	$11
Agent 2	$0	$0	$8

	coffee	cake	both
Agent 1	$6	$0	$6
Agent 2	$0	$0	$8
Agent 3	$0	$5	$5

When telling the truth:

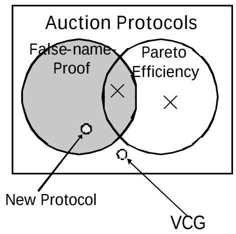
- Agent 1 gets both goods.
- payment: $8 − $0 = $8

When agent 1 uses a false-name 3 and splits its bid:

- Agent 1 gets both goods.
- payment: $3+$2=$5

Main Research Results

[Y, Sakurai, & Matsubara, AIJ-2001, GEB-2004, Y, IJCAI-2003]



- found that the VCG is not false-name-proof
- proved that there exists no auction protocol that is false-name-proof and Pareto efficient at the same time
- proved that revelation principle still holds for false-name-proof protocols
- identified the characteristics that any false-name-proof protocol must satisfy and developed a series of false-name-proof protocols

Non-existence Theorem

- No auction protocol exists that simultaneously satisfies incentive compatibility and Pareto efficiency at the same time for all cases, if agents can submit false-name bids.

Strategy of the Proof

- It is sufficient to show one instance where no auction protocol satisfies the prerequisites.
- By using the prerequisites, we clarify the bound of the payments and derive a contradiction.

91

Proof (Case 1)

two goods A and B, the evaluation value of an agent is represented as: (A only, B only, both)

- agent 1: (a, 0, a)
- agent 2: (0, 0, a+b)
- agent 3: (0, a, a)
- a > b
- By Pareto efficiency, each of agent 1 gets A and agent 3 gets B.
- By incentive compatibility, each pays b +e(no incentive for under-bidding).

92

Proof (Case 2)

two agents

- agent 1: (a, a, 2a)
- agent 2: (0, 0, a+b)
- By Pareto efficiency, agent 1 gets both goods.
- By incentive compatibility, its payment is 2 (b +e).
  - Agent 1 can create the situation identical to case 1 using false-name bids.

93

Proof (Case 3)

- agent 1: (c, c, 2c)
- agent 2: (0, 0, a+b)
- b +e < c, 2c < a + b
- By Pareto efficiency, agent 2 gets both goods.
- If agent 1 lies and submit (a, a, 2a), it can create the situation identical to case 2.
- Agent 1 obtains both goods, its payment is 2 (b +e) < 2c

Cannot satisfy incentive compatibility.

94

Explanation of the Proof

- To avoid free-riders problem, we must set the payment as low as possible in case 1.
- To avoid false-names, we also set the payment as low as possible in case 2.
- However, the payment becomes too low; thus an agent has an incentive for over-bidding (case 3)

95

False-name-proof Mechanism

- What's wrong with VCG?
  - The sum of the price of item a and the price of item B can be smaller than the price of the bundle (a, b).
  - We need to set the prices so that:
    - Buying a larger bundle is always better than buying smaller bundles separately.
    - Adding more bids always increases the prices.

96

Trivial Protocol (Set Protocol)

Protocol: always sell all goods in a bundle, and use the Vickrey auction protocol

- robust against false-name bids
- wasteful if the goods are substitutable for some agents

We need to develop a protocol that can sell goods separately in some cases.

Max minimal-bundle Protocol

- Sort the bids in decreasing order.
- Initially, all bids are active.
- Award the first active bid, make all bids conflicting with it inactive recursively. The price is equal to the next conflicting inactive bid.

Bidder 1: 10 for (a, b) → **Bidder 2: 8 for (c, d)** → **Bidder 3: 7 for (b, d)**

Price: 7 **Price: 7**

→ **Bidder 4: 6 for (a)** → **Bidder 5: 5 for (c)**

Price($B_1 \cup B_2$)
= max(Price(B_1), Price(B_2))
$\leqq$ Price(B_1) + Price(B_2)

Further Readings (books)

- Textbook on Auction:
  - Vijay Krishna, Auction Theory, Academic Press, 2002.
- Textbook on Combinatorial Auctions
  - Combinatorial Auctions, Peter Crampton, Yoav Shoham, Richard Steinberg, eds., MIT Press, 2006.
- Mid-level textbooks on economics in general:
  - Andreu Mas-Colell, Michael D. Whinston and Jerry R. Green, Microeconomic Theory, Oxford University Press, 1995.

Further Readings (papers)

- Combinatorial Auctions
  - S. de Vries and R. V. Vohra, ``Combinatorial Auctions: A Survey'', INFORMS Journal on Computing, Vol. 15, 2003.
- False-name Bids
  - M. Yokoo, Y. Sakurai, and S. Matsubara, ``The Effect of False-name Bids in Combinatorial Auctions: New Fraud in Internet Auctions'', Games and Economic Behavior, Volume 46, Issue 1 , 2004, pp. 174-188, 2004.
  - M. Yokoo, ``The Characterization of Strategy/False-name Proof Combinatorial Auction Protocols: Price-oriented, Rationing-free Protocol'', Proc. of the 18th International Joint Conference on Artificial Intelligence (IJCAI-2003), pp. 733-739, 2003.
  - Makoto Yokoo, Yuko Sakurai, and Shigeo Matsubara, `Robust Combinatorial Auction Protocol against False-name Bids', Artificial Intelligence Journal, 2001.