Algorithmic Game Theory

LECTURE 8

Main Topics Covered

- Indirect Mechanisms
- Selling Items Separately
- Case Study: Simultaneous Ascending Auctions
- Package Bidding
- Case Study: The 2016 FCC Incentive Auction

Revisiting Combinatorial Auctions

- There are ‘n’ bidders, ‘m’ items
- Each bidder i’s valuation specifies her value $v_i(S)$ for each bundle S of items she might receive
- In principle, ‘VCG Mechanism’ provides a DSIC and Welfare-Maximizing Combinatorial Auction
- Problems:
  - The problem is practical only if bidders’ valuation is sufficiently simple, and not otherwise
  - E.g., the number of parameters that each bidder reports in the VCG or any other direct-revelation mechanism, grows exponentially with the number of items ‘m’

The utter absurdity of direct-revelation combinatorial auctions motivates *indirect mechanisms* !

Indirect Mechanisms

- Learns information about bidders' preferences on a "need-to-know" basis
- Also known as the famous English Auction (often shown in movies)
- Proceeds as follows:
  - Auctioneer keeps track of the current price and tentative winner
  - Auction stops when only one interested bidder remains
  - Dominant strategy of each bidder: Stay in the auction as long as the current price is below his/her valuation
    [And to drop out once it reaches his/her valuation]
  - If all bidders apply these strategies, the outcome of the auction is same as that of a second-price (sealed bid) auction
  - ∴ Second-price auction is the result of applying revelation principle to English Auction

Selling Items Separately (1/3)

- What can be the simplest natural indirect mechanism for a combinatorial auction ?
  - Selling each item separately by using a single-item auction for each
  - Requires only 1 bid per bidder per item !

- **BUT**
  Could selling items separately conceivably lead to allocation with high social welfare ?
  - Turns out, the answer depends on the type of items in the combinatorial auction
  - A combinatorial auction can have items that are *substitutes* of each other
  - Or, the items may be *complements* of each other

Selling Items Separately (2/3)

Items are "*substitutes*"

- Items in a combinatorial auction are substitutes if
  - Having one item makes the other less valuable
  - For two items A and B, substitute condition means

    $$v(AB) <= v(A) + v(B)$$
- E.g.: In a spectrum auction context
  - Two licences for the same area with equal frequencies are substitutes
- Selling items separately can work well, if implemented correctly, in this case
  - Welfare-maximization becomes a computationally tractable problem
  - Undesirable incentive and revenue properties of VCG mechanism evaporate

Selling Items Separately (3/3)

Items are "*complements*"

- Items in a combinatorial auction are complements if
  - Possessing one makes the other more valuable
  - For two items A and B, the complement condition is
    $$v(AB) > v(A) + v(B)$$
- E.g.: In a spectrum auction context
  - Bidders wanting licenses for areas that are adjacent either geographically or in terms of frequency
- Selling items separately does not work in this case
  - Welfare maximization becomes computationally intractable

Case Study: Simultaneous Ascending Auctions
Two Rookie Mistakes (1/3)

- We will look at two different design decisions that matter a lot while designing separate single-item auctions
- There are two common mistakes that a designer could commit:

ROOKIE MISTAKE #1: Holding the single-item auctions sequentially, one at a time

This can be explained through examples:

- Example 1: k-unit auction as back-to-back second price auctions
  - Suppose you are a bidder with a very high valuation
  - You were expected to win if the auction had been normal. You would have to pay an amount equal to 2^{nd} highest bid in that case.
  - But now, in case of back to back auctions, you can reduce the amount you have to pay by not participating in the first auction !
  - Then, the 2^{nd} highest bidder would win the first auction and leave. You have to pay the 3^{rd} highest bid now by winning the second auction !
  - Straightforward truthful bidding is not a strategy anymore !

Two Rookie Mistakes (2/3)

- Example 2:
  - In March 2000, Switzerland auctioned off 3 blocks of spectrum via sequential second-price auctions
  - The first two auctions (for identical item – 28MHz blocks) were sold for 121 million and 134 million Swiss francs respectively
  - The third auction (for 56MHz) was sold for only 55 million francs !
  - There is a significant price variation in these back-to-back auctions
  - The auctions were far from optimal

Both these examples show that selling items sequentially is not a good decision.

It leads to unpredictable outcomes, low social welfare and low revenue !

The auction should be simultaneous instead !

Two Rookie Mistakes (3/3)

- ROOKIE MISTAKE #2: Using sealed-bid single item auctions
- Example:
  - In 1990, New Zealand government auctioned identical licences for TV broadcasting using simultaneous single-item auctions
  - A potential strategy would be to either choose one license at random or to bid less aggressively at multiple licenses
  - The difficulty is trading off the risk winning too many licenses to too few
  - It was seen that the revenue of the New Zealand auction was a mere $36 million whereas the projected amount was $250 million

Therefore, this mistake also leads to loss in revenue and welfare !

A possible solution is the Simultaneous Ascending Auctions !

Merits: Simultaneous Ascending Auctions

- What are SAAs ?
  - Similar to a bunch of single-item English Auctions being run parallelly in the same room with one auctioneer per item
  - Each bidder can place a new bid on any subset of items, that it wants, subject to an *activity rule*
  - It is required that the on which a bidder bids decreases over time
  - The first round with no new bids ends the auctions
- Merits:
  - *Price discovery*: As a bidder acquires knowledge about the likely selling prices, there is room for mid-course corrections
  - Bidders only need to determine their valuations on a need-to-know basis
  - SAAs achieve higher social welfare and revenue

Demerits: Simultaneous Ascending Auctions

- Demand Reduction:
  - Occurs when a bidder asks for fewer items than it really wants
  - This leads to lowering in competition
  - This in turn leads to lowering of the prices paid for the items that the bidder gets
  - This problem is relevant even when the items are substitutes

- Exposure Problem:
  - Relevant when the items can be complements
  - An overly aggressive bidder might acquire unwanted items
  - An overly tentative bidder might fail to acquire an item for which he/she has highest valuation
  - Leads to economically inefficient allocations

Package Bidding

- Package bidding means bidding on sets of items in addition to individual items
- Allows a bidder to bid aggressively without the fear of receiving only a subset of a bundle of items
- Can resolve the exposure problem and demand reduction
- Design Approach 1:
  - An extra round after SAA wherein bidders submit package bids on a subset of items they want subject to an activity rule
  - These package bids compete with each other and the winning bids from SAA rounds
  - The final allocation is determined by a welfare maximizing computation
- Design Approach 2:
  - Predefining a limited set of allowable package bids instead of allowing bidder to propose their own
  - These predefined bids are aligned with what the bidders want

Case Study: 2016 FCC Incentive Auction

- The U.S. Federal Communications Commission (FCC) is the first to use a reverse auction where the government buys back licenses from TV broadcasters to reclaim spectrum
- These reclaimed spectrums are then resold via a forward auction to bidders who can put them to better use
- The format of the forward auctions is similar to past designs
- The reverse auction uses a new approach of the deferred allocation rule (using a reverse greedy algorithm)
  Here N = set of bidders and W = set of winning bidders

Deferred Allocation Rule

initialize $W = N$ // initially feasible
while there is an $i \in W$ with $W \setminus \{i\}$ feasible **do**
  remove one such i from W // i not bought out
halt with winning bidders W

References

- Twenty Lectures on Algorithmic Game Theory by Tim Roughgarden, 2016, Cambridge University Press
- https://www.youtube.com/playlist?list=PLEGCF-WLh2RJBqmxvZ0_ie-mleCFhi2N4

THANK YOU