



# Virtual Markets

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# Topics

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- Trading Agent Competition



# Topics

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- Trading Agent Competition
  - experimental platform for students
  - implementation of a trading agent
  - reflection on results



# Topics

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- Trading Agent Competition
- Game Theory



# Topics

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- Trading Agent Competition
- Game Theory
  - equilibria
  - dominant strategies



# Topics

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- Trading Agent Competition
- Game Theory
- Auctions



# Topics

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- Trading Agent Competition
- Game Theory
- Auctions
  - types, characteristics
  - equivalence between auctions



# Topics

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- Trading Agent Competition
- Game Theory
- Auctions



# Topics

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- Trading Agent Competition
- Game Theory
- Auctions
- Negotiation



# Topics

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- Trading Agent Competition
- Game Theory
- Auctions
- Negotiation
  - Basic principles of negotiation
  - Supporting negotiation on the Internet



# Topics

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- Trading Agent Competition
- Game Theory
- Auctions
- Negotiation
- Infrastructure



# Topics

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- Trading Agent Competition
- Game Theory
- Auctions
- Negotiation
- Infrastructure
  - technology
  - security



# Topics

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- Trading Agent Competition 3X
- Game Theory 6X
- Auctions 4X
- Negotiation 2X
- Infrastructure 1X



# Goals

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- Insight in the use of game theory in virtual markets
- Insight in the limitations of game theory
- Insight in mechanism design for virtual markets



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# Trading Agent Competition

<http://www.sics.se/tac/>

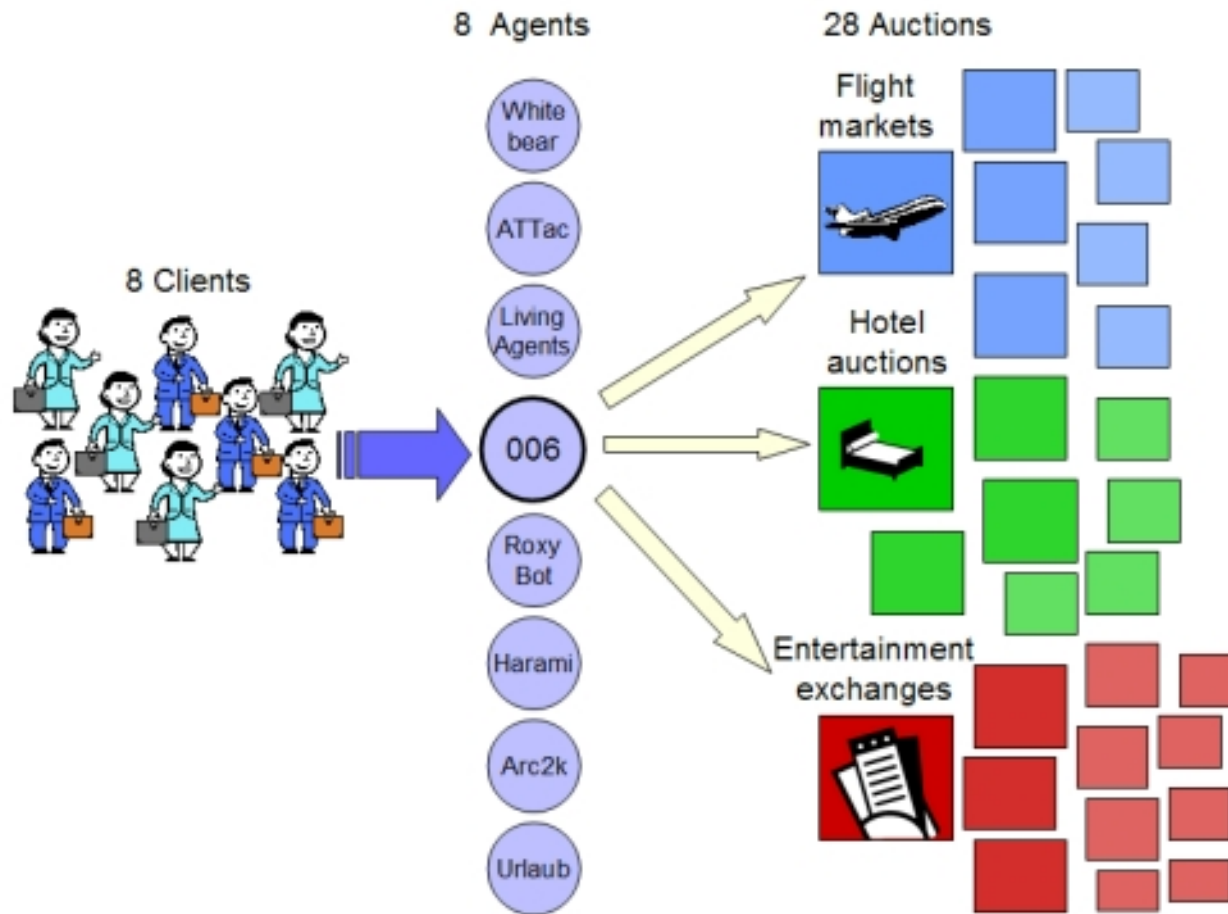


# TAC

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- Travel agents try to assemble packages for 8 customers.
- All customers need to travel in an interval of 5 days
- Each customer wants:
  - A round trip flight between TACtown and Tampa
  - A hotel reservation
  - Tickets to entertainment:
    - Alligator wrestling
    - Amusement park
    - Museum

# TAC





# TAC Flights

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- Unlimited number of seats all sold by TACAIR
- Prices are established by TACAIR and start between \$250 and \$400.
- $P(t+1) = P(t) + d$ 
  - $d$  is a value drawn uniformly from the interval
    - $[-10, x(t)]$  if  $x(t) > 0$
    - $[x(t), 10]$  if  $x(t) < 0$
    - $[-10, 10]$  if  $x(t) = 0$
  - $x(t) = 10 + (t/9:00) * (x - 10)$
  - $x$  is a value drawn uniformly from the interval  $[-10, 30]$
- Prices are always restricted between \$150 and \$800



# TAC Hotels

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- Two hotels: Tampa Towers (TT) and Shoreline Shanties (SS).
- Clients cannot move from one hotel to the other
- Both hotels have 16 rooms per night available
- Rooms are sold to the highest bidder(s) for the price of the lowest bid that still gets a room
- E.g. ((2 4) (6 6)) ((4 8)) ((7 10))  
The price would be 6



# TAC Entertainment

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- 8 tickets for each type of event per day/night
- So, no tickets for day 5!
- Initially each travel agent gets 12 tickets as follows:
  - One bundle of 4 of a particular type on day 1 or 4.
  - One bundle of 4 of a particular type on day 2 or 3.
  - One bundle of two of a particular type (different from above) on day 1 or day 4.
  - One bundle of two of a particular type (different from above) on day 2 or day 3.
- Travel agents can both buy and sell tickets in continuous double auctions



# TAC auctions

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All of the auctions run according to the following high-level protocol:

1. An agent submits a bid to the auction.
2. The auction updates its price quote, indicating the current going prices.

The rules for a particular auction specify when, or under what conditions the auction will match the bids and record the transactions.



# TAC bid format

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- Bids have the following format in all auctions:  $((q_1 p_1) (q_2 p_2) \dots (q_n p_n))$
- If  $q_i > 0$  the agent is willing to buy  $q_i$  units for no more than price  $p_i$
- If  $q_i < 0$  the agent is willing to sell  $q_i$  units for no less than price  $p_i$
- E.g.  $((-2 \$40) (3 \$20) (1 \$10))$ , means:
  - "I am willing to sell 2 units if the price is \$40 or more;
  - I am willing to buy 3 if the price is \$20 or less; and I am willing to buy 1 (in addition to the 3) if the price is \$10 or less."



# TAC flight auctions

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- Flight auctions are continuous one-sided auctions that close at the end of the game.
- E.g. TACAIR places a sell bid of  $((-64\ 300))$ , then:
  - A bid of  $((5\ 370))$  would match five units at \$300 each.
  - A bid of  $((3\ 290))$  would not match, and would remain standing in the auction. A subsequent sell bid at \$290 or lower would match three units at \$290 each from the buy bid.
  - A bid of  $((2\ 370)\ (3\ 290))$  would match two units at \$300 each. Since the entire bid would not match, the remaining portion,  $((3\ 290))$ , would remain standing in the auction.



# TAC hotel auctions

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- Hotel auctions are multi-unit English auctions. One for each hotel and each night (8 auctions in total)
- They close at random times, starting after 1 minute. After that one closes every minute.
- The bids are cleared once, when the auction closes
- Price quotes are issued every minute, on the minute. The price quote is the ask price, calculated as the 16th highest price among all buy bid units

# TAC hotel auctions

- Let ASK be the current ask quote (16th highest price). Any new bid  $b$  must satisfy the following conditions to be admitted to the auction:
  1.  $b$  must offer to buy at least one unit at a price of  $ASK+1$  or greater.
  2. If the agent's current bid  $b'$  would have resulted in a purchase of  $q$  units in the current state, then the new bid  $b$  must offer to buy at least  $q$  units at  $ASK+1$  or greater.
- Agents may not withdraw bids from hotel auctions

# TAC hotel auctions



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E.g. let the bids at the end of the auction be:

- Hotel bid:  $((-16 \ 0))$ ,
- Agent 1:  $((8 \ 2))$ ,
- Agent 2:  $((2 \ 4) \ (6 \ 6))$ ,
- Agent 3:  $((4 \ 8))$ ,
- Agent 4:  $((7 \ 10))$ .

In this example, Agent 4 would win 7 rooms, Agent 3 would win 4 rooms, Agent 2 would win 5 rooms, and Agent 1 would not win any rooms. The price of the rooms would be \$6.



# TAC entertainment ticket auctions

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- The entertainment ticket auctions are standard continuous double auctions that close at the end of the game
- The auctions are cleared immediately.
- Bids that do not match completely have a portion remaining on the auction



# TAC entertainment ticket auctions

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- E.g.
- $((-1 \ 100))$
- $((-4 \ 90) \ (-2 \ 50))$
- $((-6 \ 60))$
- $((1 \ 40) \ (3 \ 10))$
- $((1 \ 20))$
- A bid of  $((6 \ 70))$  would match two units at \$50 each and four units at \$60 each. The ask price would become \$60.



# TAC client preferences

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- A single preferred arrival date (*PA*).
- A single preferred departure date (*PD*).
  - The arrival and departure preferences for each client are chosen randomly such that all possible pairs of arrival/departure days are equally likely.
- A premium value for upgrading to the better hotel (*HP*).
  - Hotel premium values are chosen for each client uniformly in the range \$50 to \$150.
- A premium value for each type of entertainment event (*AW, AP, MU*).
  - Entertainment premium values are chosen uniformly in the range \$0 to \$200 for every entertainment type.



# TAC travel package

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- A travel package is specified by:
- An actual arrival date (AA)
- An actual departure date (AD)
- Tampa Towers indicator (TT? In  $\{0,1\}$ )
- A ticket indicator for each event type (AW?, AP?, MU?, each in  $\{0,1\}$ )



# TAC feasible packages

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- A travel package is feasible if
  - $AD > AA$
  - it contains rooms for every night between AA and AD
  - none of the entertainment tickets are for events on the same day
  - all of the entertainment tickets coincide with nights the client is in town



# TAC client utilities

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$$u = 1000 - \text{travel\_penalty} + \text{hotel\_bonus} + \text{fun\_bonus}$$

where

$$\text{travel\_penalty} = 100 * (|AA-PA| + |AD-PD|)$$

$$\text{hotel\_bonus} = TT? * HP$$

$$\text{fun\_bonus} = AW?*AW + AP?*AP + MU?*MU$$

$u = 0$  if the package is infeasible

	Arr	Dep	Hot	AW	AP	MU	
$U_{\min}$	$= 1000 - 300 - 300 +$	$0 +$	$0 +$	$0 +$	$0 +$	$0 =$	$400$

$U_{\max}$	$= 1000 -$	$0 -$	$0 +$	$150 +$	$200 +$	$200 +$	$200 =$	$1750$
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# TAC Final score

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- At the end of the game the travel agent has to optimally allocate the travel packages it obtained amongst its clients
- If it ends the game holding negative balances of any entertainment tickets (because it sold tickets it did not have), it is assessed a penalty of 200 for each ticket owed
- The final score for a travel agent is the sum of the utilities of the clients minus the expenses of the travel agent, minus a penalty for negative entertainment balances (if applicable).



# TAC Assignment

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- Implement an agent that plays the TAC game
- Describe the strategy of the agent in a separate report
- After the game collect all descriptions of the agent strategies
- Describe why your agent performed well/bad against the other agents in the game.



# TAC Assignment planning

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- Week 2: familiarize with TAC
- Week 3: Play with dummy agent
- Week 4-8: Implement an agent that plays the TAC game
- Week 6: Play test games!
- Week 9-10: Describe why your agent performed well/bad against the other agents in the game.