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# **Teaching a Multiagent Systems Class with Game Days: Designs and Lessons Learned**

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## **Abstract**

In the Fall semester of 2002, I introduced and taught a class in Multiagent Systems. The class was aimed for seniors (with special permission) and graduate students in Computer Science, covering some breadth and depth of issues in multiagent systems. One of the requirements was participation in four Game Days. On each Game Day, student teams competed against each other in games related to issues such as auction, task allocation, coalition formation, and negotiation. This article documents my designs of and lessons learned from these Game Days. The Game Days were very successful. Through role-playing, the students were motivated and learned about multiagent systems. I believe that the Game Days are a good, educational tool for teaching a multiagent systems class. It is my hope that other instructors teaching a similar class may find my experience and insights useful and helpful.

## **1. Introduction**

In the Fall semester of 2002, I introduced and taught a class in Multiagent Systems. The class was aimed for seniors (with special permission) and graduate students in Computer Science, covering some breadth and depth of issues in multiagent systems. The requirements of the class were: 3 homework assignments (15%), 7 topic summaries (15%), game days (group) (10%), one mid-term examination (20%), one seminar presentation (group) (10%), and one final project (group) (30%). In this article, I focus on the Game Days that I created for the class. Briefly, on each Game Day, each student team was an agent trying to win games related to multiagent systems. On different Game Days, the students played in different games focusing on different areas; for example, auction, task allocation, coalition formation, and negotiation. This article documents my designs of and the lessons learned from these Game Days. It is my hope that other instructors teaching a similar class may find something useful and helpful from my experience.

## **2. Designs and Specifications**

There were four Game Days: (1) Auction Day, (2) Allocation Day, (3) Coalition Day, and (4) Negotiation Day. Each Game Day was allotted 75 minutes. I video-taped each Game Day<sup>1</sup>. The videos were more than a capture of the activities. They were also helpful for me when reviewing each Game Day and computing some of the parameters that I tracked (such as the number of bids a particular team offered on Auction Day). Each student group had two students and had a team name.

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<sup>1</sup> The students were not bothered by the fact that they were being taped.

Each team received a Game Day Package. The exact format of the Game Day Package was given to the students on-line before each Game Day. However, the actual values (utility values, amount of money, etc.) were given out as part of the Game Day Package only on each Game Day. So, the students could work on pre-game strategies using the on-line version beforehand.

I designed a Monitor Package for myself for each Game Day. In this Monitor Package, I had the actual values of every team. Also, I had tables with parameters (that I wanted to track) listed as columns. This Monitor Package allowed me to observe and record the activities conveniently during the games.

I graded each team based on two items: (1) Game Day Worksheets (50%) and (2) End-Of-Day Ranking. I gave customized worksheets to each team as part of the Game Day Package. On the worksheets were itemized rounds, tables, and blanks for the student to record their during-game actions. The students were also encouraged to submit their pre-game discussions and strategies at the end of the Game Day together with their worksheets. At the end of each Game Day, I evaluated each team on their Game-Day Performances and ranked them. Usually, the team that won would have all 50%, the second team would have 45%, and so on.

In the following, I briefly described the four Game Days. Readers are referred to my class website<sup>2</sup> for the detailed Game Day assignments.

I used (Weiss 1999) as my textbook for the class.

### **2.1. Game Day 1: Auction Day**

The objectives of Auction Day were to learn and familiarize with various auction protocols, to learn how to manage resources to obtain services/goods of high utility, and to learn how to observe the environment (e.g., the behavior of other agents) to support own decision making process. Each student team's goal was to obtain goods through bidding. Each team's key to winning the game was to obtain goods that were important to itself with the limited amount of resources that each team had.

Here are some key features of Auction Day:

- I was an honest Auctioneer and conducted the auctions based on five different protocols (Table 1).
- The student teams offered bids and bidder collusions were *not* allowed.
- Each team was given the same amount of paper money and a list of items with associated utility values. Every group thus knew the amount of paper money initially owned by each group.
- In the beginning of Auction Day, each group received a list. On the list, every item to be auctioned off was associated with a utility value particular to that group. Every team had a different set of utilities. The sum of utility values of all items for each team was, however, the same. This list was kept secret to each group.

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<sup>2</sup> [http://www.cse.unl.edu/~lksoh/Classes/CSCE496\\_896\\_Fall02/gamedays.html](http://www.cse.unl.edu/~lksoh/Classes/CSCE496_896_Fall02/gamedays.html)

- Some items had the same utility values for two or more groups; thus each group should expect *competition* from other groups for the same item.
- The auctions were *private value auctions*; that is, the value of an item depends only on a group's own preferences (the utilities). There is no re-sale value here.
- All auctions are all-pay auctions. There is a fee for each bid. If you sit out, then you will not be charged with a fee.
- There were 10 items to be auctioned off.
- To ensure active participation, each group must win at least one item. There would be a 15% deduction on the Game-Day Performance score for failing to comply with this requirement.
- If the best offer the Auctioneer received from the bidders was below the market price of the item being auctioned, then the Auctioneer would keep the item.
- In the two "sealed bids" protocols, if multiple teams had the same bid, then there would be another round of bidding between those teams only, using the same protocol.

Protocol	Description
English Auction (first-price, open-cry)	Each bidder is free to raise its bid. When no bidder is willing to raise anymore, the auction ends, and the highest bidder wins the item at the price of his/her bid
English Auction (first-price, open-cry) 2	Same as above but with open-exit. For our Game Day, I modified the protocol: after each new cry, each team would be asked to declare an exit. If a team did not declare, and the team ended up not submitting a bid after the bidding was over, then it would be penalized for violating the protocol.
Dutch (descending) Auction	The auctioneer continuously lowers the price until one of the bidders takes the item at the current price. For our Game Day, I modified the protocol: before the bidding started, each team was asked to declare whether to participate. If yes, a fee would be collected from the team. If no, then the team could not participate.
First-Price Sealed-Bid Auction	Each bidder submits one bid without knowing the others' bids. The highest bidder wins the item and pays the amount of this bid. Other groups know the winning transaction.
Vickrey (Second-Price Sealed-Bid) Auction	Each bidder submits one bid without knowing the others' bids. The highest bidder wins, but at the price of the second highest bid. Other groups know the winning transaction.

**Table 1.** Auction Protocols for Game Day 1: Auction Day.

## 2.2. Game Day 2: Allocation Day

The objectives of Allocation Day were to learn and familiarize with the various allocation mechanisms, to learn how to consider or decide which task to perform, and to learn how to re-allocate tasks/resources better from observing the environment. At the implementation level, this Allocation Day also exposed students to how multi-threaded programming was needed for efficient and effective processing for an agent in this environment. Each team's key to winning the game the objective was to solve as many problems as possible with as low costs (costs of tasks and re-allocations) as possible, while helping with as many other teams as possible in solving their problems.

Here are some key features of Allocation Day:

- All agents (teams) were considered rationally helpful and honest. If an agent could perform a requested task that it rationalized to be useful to the entire system, it would.
- Agents would not be paid for their help.

- Agents did not speculate and did not accept non-individual rational contract in anticipation of a later synergic contract.
- Every team was required to solve a list of problems by securing a coalition of student groups to perform the tasks required to solve each problem.
- Initially, each group was given the following: (1) a list of tasks that they were capable of doing, and each task had a number indicating the number of such tasks that could be performed, and the cost of each task, and (2) a list of problems to solve, and each problem was provided with several solutions, and each solution was a set of tasks.
- If a team failed to solve a problem, it would be penalized. For example, if the House-Moving task required a team to get 2 movers and 3 drivers, and at the end of the round, the team only had 2 movers and 2 drivers, then the team had failed to solve the problem.
- To simulate multi-threaded exercises, a transaction of a team's goods/services could only take place at the team's desk. Each team was not allowed to carry their paper tokens (goods/services) around. Each team could walk around to solicit and obtain other teams' tokens, however. Thus a team must split up its two members, one at the station, and one roaming.
- Once a team had obtained other teams' tokens, the team could not simply throw them away or return them. Once the tokens were in a team's hands, the team was liable for them. This feature forced the students to be cautious.

### 2.3 Game Day 3: Coalition Day

The objectives of Coalition Day were to learn and familiarize with the various coalition formation mechanisms (coordination and communication), to learn how to manage resources to obtain services/goods of high utility, and to learn how to observe the environment (e.g., the behavior of other agents) to support own decision making process. At the implementation level, this Coalition Day also exposed the students to how multi-threaded programming was needed for efficient and effective processing for an agent in this environment. This Game Day focused particularly on three mechanisms: blackboard, voting, and matchmaking (or facilitating). In blackboard, every team's offers were viewable by all other teams. The round involving voting was only a demonstration of the "pass-around-the-buck" mechanism. The goal here was to allow teams to analyze the advantages and disadvantages of this mechanism. For matchmaking, the consumers looked for services with low prices; while the providers looked for providing their services with high prices; and the matchmaker kept both sides happy. Here, only the matchmaker knew each team's offers. Each team's key to winning the games was to solve as many problems as possible while keeping as much money as possible.

Here are some key features of Allocation Day:

- All agents were honest. No lying and speculation were allowed.
- Once agreed, a resource, service, or task was committed. No decommitment was allowed.
- **Blackboard:**
  - Every team had a list of problems to solve. Each problem needed a certain set of resources/services. Every team had a limited supply of unique resources.
  - Each team could post advertisements (for resources), with the cost of one of its resources. Each posting cost a constant value.

- This game would start with a blank blackboard, and each round started with every team posting simultaneously. Then, each team may grab the postings that he/she wanted from the blackboard. Thus, this mechanism was asynchronous (simulated)<sup>3</sup>.
- Each team must keep track of their posting as they did not want to overdraw their resources. The teams would be penalized for overdraws.
- **Pass-Around-The-Buck:**
  - For each coalition, each team could only perform one task.
  - Each team had a list of tasks that they could perform with certain costs.
  - Every time a team received the “buck”, it needed to pick the best task (lowest cost), and passed the buck to the next team.
  - It was possible that when a team received the “buck”, it was not able to perform any of the remaining tasks. Thus, this team became an impasse to the coalition formation process. This “impasse-maker” informed all other teams and assumed the leader role for the next round of coalition formation. That is, this “impasse-maker” would now make the first choice and then passed the buck to other teams.
- **Matchmaking:**
  - I was the matchmaker (or facilitator).
  - Half of the class was service consumers; the other half was service providers.
  - The consumers’ goal was to obtain the needed services with low prices.
  - The providers’ goal was to supply the needed services with high prices.
  - A consumer told the matchmaker the maximum price that they were willing to pay for a particular service, and a provider told the matchmaker the minimum price that they were willing to receive for a particular service.
  - The matchmaker would find a match and inform the both sides, and a transaction was executed.
  - An offer or a request was binding once made unless retracted before a deal was reached.

## 2.4 Game Day 4: Negotiation Day

The objectives of Negotiation Day were to learn and familiarize with the various negotiation protocols, and to learn how to observe the environment (e.g., the behavior of other agents) to support own decision making process. On Negotiation Day, students were required to participate in two types of negotiations. The first was an open, free market where each team was a monopoly on a unique product. Each team also needed to obtain goods from all other teams to solve their problems. The second type was a hostage rescue simulation where the kidnappers and police negotiated using some argument types. I scored the teams playing in the hostage rescue scenarios based on the number of argument types that they used.

Here are some key features of Negotiation Day:

- There were two types of games: (1) market place, and (2) hostage rescue.
- **Market Place:**
  - Each team was a provider of one unique product.
  - Each team started with the same amount of money.

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<sup>3</sup> I forewarned the students that this game might lead to fights as they simultaneously went for possibly the same resources.

- Suppose the number of student teams was  $N$ . Each team was required to have in possession one item of  $N$  unique products in the market.
- Each group started with  $2N$  items of its own product, and 0 items of other products.
- I was the Market Monitor and would announce the starting price of each product.
- There were two phases in this type of game.
- Phase I: Indirect
  - The offers and responses were written and private.
  - An offer should contain the name of the product, the number of items, and the price that you want to pay for it.
  - A response should contain “agreed”, or “higher”, and “swap <#your product> <#my product>”.
  - The prices would not be announced as they were private knowledge between the two sides of a successful transaction/deal.
  - Once a deal was struck, I would instruct the provider to turn over the product to the buyer.
  - Reneging on a deal would result in an immediate expulsion from the market place/
  - At the start of each round, each team submitted their offers and counter-offers to me. I would then relay the offers to the corresponding counterparts and obtain in return their responses. And then I would act on the transactions. Intentionally, I was the bottleneck in this market place.
- Phase II: Direct
  - Each team was allowed to communicate directly with all other teams.
  - Each team was allowed to split up their team so it may conduct multiple concurrent negotiations together.
  - To prevent chaos, I would call a time out after every 5 minutes of negotiations. The time out would last for 1 minute where everybody could regroup before continuing.
- Each team’s goal was to obtain all  $N$  unique products and obtain as much money as possible, and as quickly as possible.
- Once a team obtained all  $N$  unique products, it must yell out “BINGO!” Then the team might continue with other negotiations to obtain more money.
- Each team might draw their negotiation tactics, issues, strategies from (Faratin *et al.* 1998).
- **Hostage Rescue:**
  - Student teams were paired up.
  - For each pair, one team was the kidnappers; the other was the police.
  - Both teams should use the Automated Negotiation Agent (ANA)’s six argument types in the negotiation (Kraus *et al.* 1998) (See Table 2).
  - I monitored the negotiation to see whether the teams deviated from the six argument types, and whether the teams used all six types.
  - A coin toss decided the roles (the kidnappers or the police) of the teams at game time.
  - Table 3 lists the scenarios given to them beforehand.

Argument Types
Appeal to Prevailing Practice
Counter-Example
Appeal to Past Promise
Appeal to Self Interest

Promise of Future Reward
Threat

**Table 2.** The Automated Negotiation Agent (ANA)’s six argument types for Game Day 4: Negotiation Day.

Description
<b>Situation 1</b> The kidnappers are well-known bad dudes. They have carried out other kidnappings as well. This time, they have held 100 school children in a school as hostages. Their demands include cash, an airplane to transport them safely to a remote island, the publication of their memorandum, the release of some known bad dudes currently in jail, and so on. If their demands are not met, they will harm the school children. The police try to convince them to release the children.
<b>Situation 2</b> The kidnappers are well-known anti-environmentalists. They have buried many fire charges in a very ancient and endangered forest and threatened to set fire to the forest if their demands are not met. Their demands include passing new laws for tree harvesting, the publication of their memorandum to environmental groups, protecting human rights over animal rights, 1 hour of air time for them to address the nation, and so on. The police try to convince them to surrender peacefully.
<b>Situation 3</b> The kidnappers are well-known Earth protectionists. They have hijacked an oil tanker fully loaded with crude oil. Their demands include strict environmental laws for all countries in the world, sanctions on countries that have poor pollution records, an International fund managed by them, complete elimination of fuel-powered automobiles in 5 years, and so on. If their demands are not met, they will drive the oil tanker to the South Pole and crash it there. The police try to release the workers on the oil tanker and to surrender peacefully.

**Table 3.** Hostage Rescue situations for Game Day 4: Negotiation Day.

## 2.5. Game Day Packages

The design of the Game Day Packages had the following common features:

- A very brief, informal Introduction. For example:

Welcome to Soh’s Auction House. Today, we have a collection of rare items, in mint conditions, to offer to you—our much appreciated and esteemed collectors who are intelligent and skilled in many auction protocols. Hope you succeed in your ventures today. Good luck.

- A procedure or setup description. For example:

There are five rounds of auctions. For each round, two items will be on the auction block. For each round, you will have 2 minutes of preparation time. And you will also have 3 minutes of post-auction time to summarize your activities for the round, and also to discuss strategies based on your observations of other groups. (Use your Worksheet to document your activities, attached.) For every item that you bid, regardless of the auction outcome, you have to pay a fee: \$1. I will collect this at the end of each round. If you sit out, then you will not have to pay a fee.

- A team-specific description of utilities. For example:



### Tod & Copper

Round	Item	Market Value	Your Utility
1. English	1	\$150	\$450
2. English	2	\$50	\$100
3. English 2	3	\$150	\$200
4. English 2	4	\$50	\$200
5. Dutch	5	\$100	\$100
6. Dutch	6	\$100	\$200
7. 1st Price Sealed	7	\$15	\$70
8. 1st Price Sealed	8	\$100	\$300
9. Vickrey	9	\$15	\$70
10. Vickrey	10	\$100	\$300
	<b>TOTAL</b>	<b>\$830</b>	<b>\$1,990</b>

Ideally, if there is only one bidder, and if you obtain all items auctioned at their respective market values, you will have a total sum of  $\$1990 + (\$1030 - \$830 - \$10) = \$2180$ . So, the maximum sum you can get is \$2180. That is the best you can do. If you do not participate in any bidding, you will have \$1030, the original amount of money. So, it is good to bid successfully and wisely. Sometimes, it is even acceptable to pay for more than an item's utility value, just to prevent somebody else to obtain the item that they want.

- A description of how the game was scored. For example:

So, each group will receive in the Game Package a list of items with the group's utility, in terms of dollar amounts. And your "utility" list is only known to you and not other groups.

Your goal is to achieve as high as possible a sum of (1) your remaining monopoly money and (2) the total utility of the items you obtain. So, for example, if you do not participate in any of the auction rounds, you will have a sum of \$1030 in the end. But, for example, if you participate in one round and obtain exotic item #3 with a utility of \$150 to you, and it only costs you \$50, then your final sum will be  $\$1030 - \$1 \text{ (fee)} - \$50 + \$150 = \$1129$ . So, you will gain \$99.

Your goal is *not* to win each round, but to win the Game Day. The group with the highest sum is the winner.

You can bring your textbook and notes to make sure that you follow the auction protocols correctly. Failure to follow the protocols will cost you \$2 per violation. You are not allowed to ask me (the auctioneer) any questions about the protocols during the game.

- Customized and tabulated worksheets. These worksheets were itemized and sectionized to make things as convenient as possible for the students. The worksheets had tables and blanks. For example:

**Round 1: Blackboard, Under-constrained**

The Computer Manufacturing task requires each team to obtain a coalition of 150 units of components. There are 6 types of components: hard disks, monitors, drives, software, operating system, and multimedia. Each team must have at least 25 units of each component. Plenty of time. Use the cost functions given to you. Teams must exchange goods at the costs given.

Trans.	Function/Resource/Task	From	#@\$?
1			
2			
3			
4			
.			
.			
.			
23			

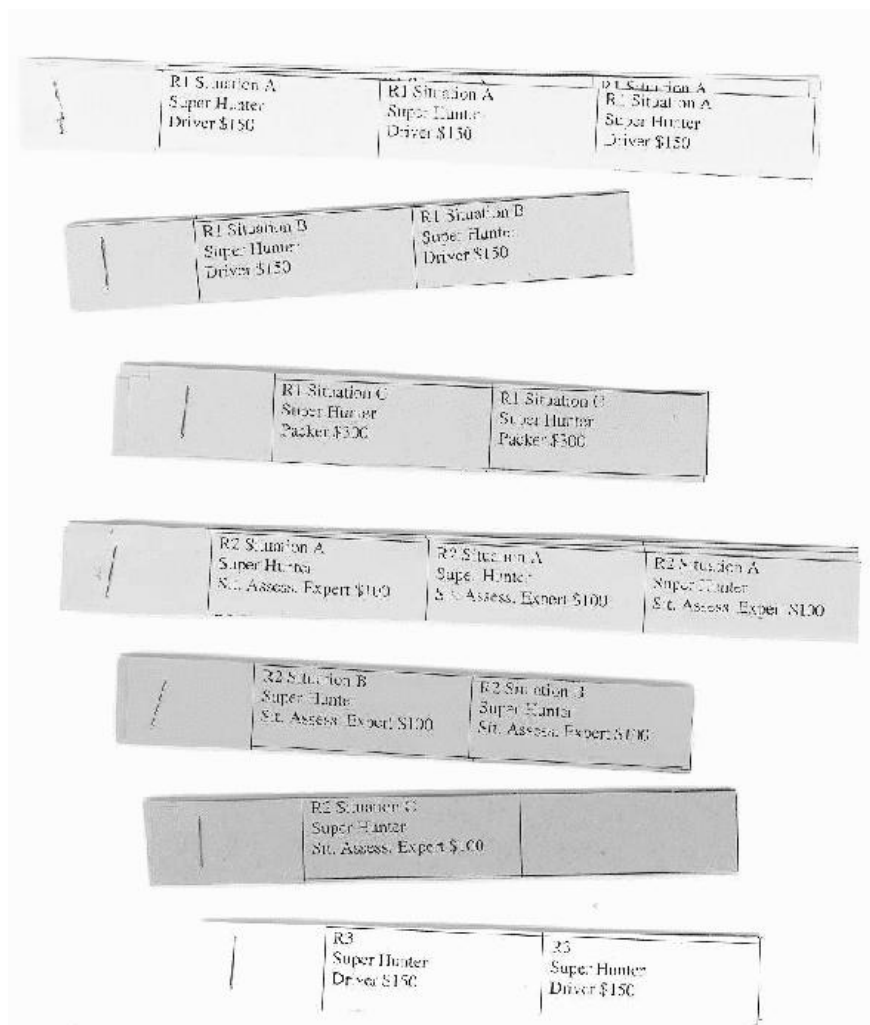
Number of messages posted: \_\_\_\_\_

Computer Manufacturing	#units	Value
Hard disks		
Monitors		
Drives		
Software		
Operating System		
Multimedia		

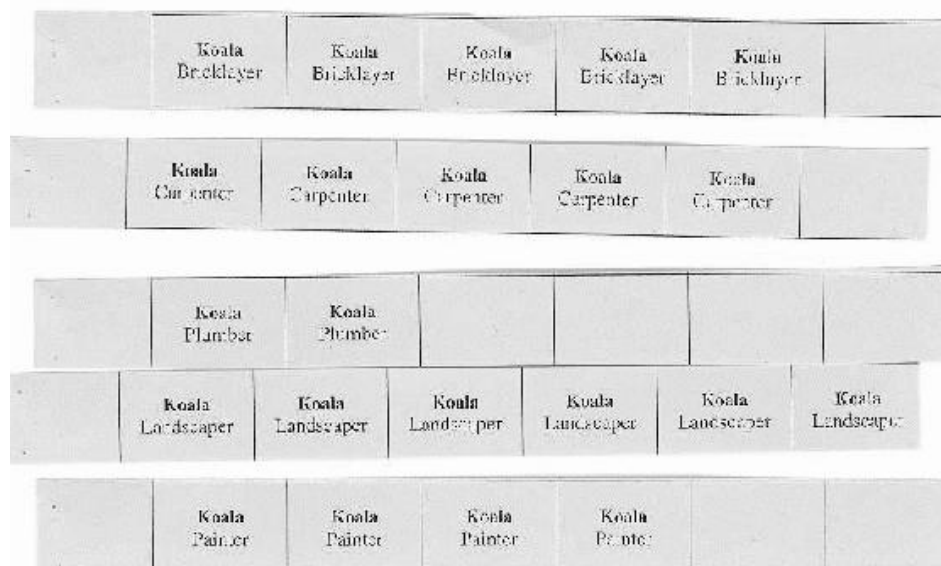
Notes:

- An accounting of the items in the Game Package: Monopoly paper money (amount and distribution of bills), paper tokens (Figures 1-3), placards (to be set up at the “station” of each team), name tags (to be put on each team member), and Post-It notes (for messages),

Figures 1-3 show the various paper tokens made for Allocation Day, Coalition Day, and Negotiation Day, respectively. The paper tokens were designed so that each unit could be accounted for and torn off easily.



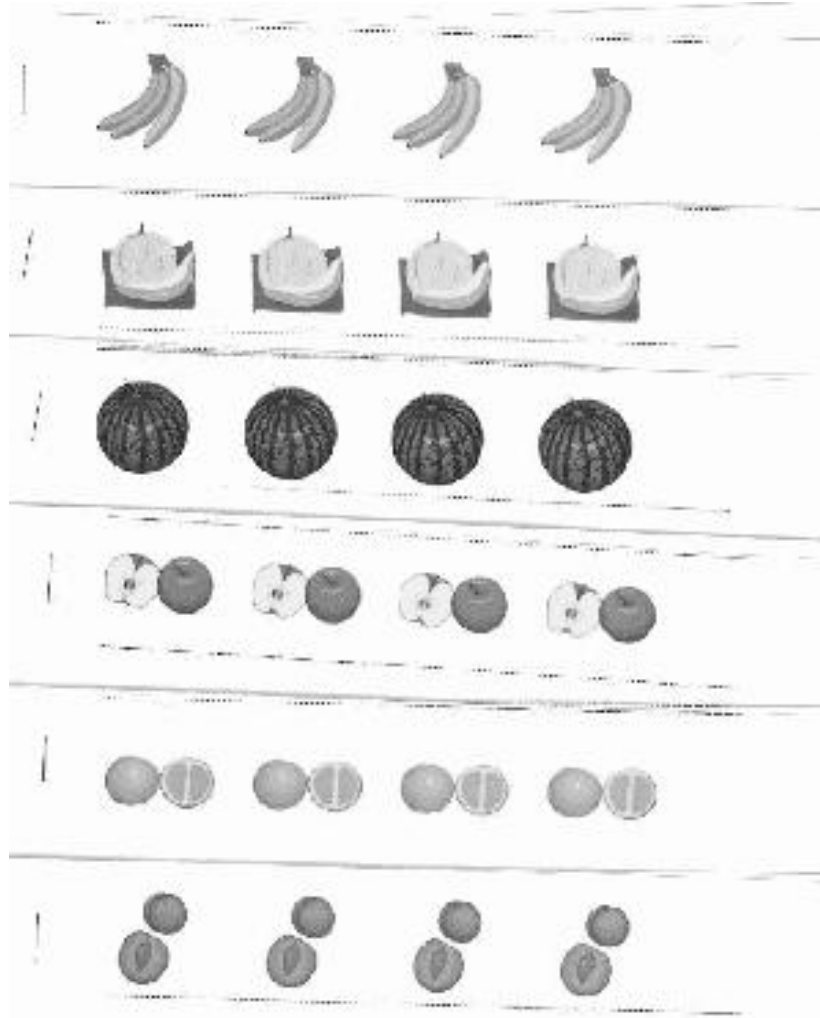
**Figure 1.** Paper tokens (resources available for a team called “SuperHunter”) for Game Day 2: Allocation day.



**Figure 2.** Paper tokens (services available for a team called “Koala”) for Game Day 3: Coalition day.

## 2.6. Monitor Packages

For each Game Day, I designed a Monitor Package. The objective of these packages was for me to track key parameters (bid values, transactions, etc.) easily during the games. They also provided me with team-specific utility values so I could resolve any questions or arguments quickly using them as references. Figures 4-5 show the Monitor Packages for some Game Days. As indicated in the two Figures, there were six student teams in my class: The Duke, Tod & Copper, Koala, Runner, Trackers, and Super Hunter<sup>4</sup>.



**Figure 3.** Paper tokens (goods available for different teams) for Game Day 4: Negotiation day.

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<sup>4</sup> These team names corresponded to the same teams for the Final Project of the class: a Fox-and-Hound game where the teams built systems of hounds (agents) to trap a fox (another agent built by me) in a simulated forest (built by me).

Round	Item	Market Value	Winner	Selling Price	Closest Competitor	Losing Price
1, English	1	\$150				
1, English	2	\$50				
2, English 2	3	\$150				
2, English 2	4	\$50				
3, Dutch	5	\$100				
3, Dutch	6	\$100				
4, 1 <sup>st</sup> Price Sealed	7	\$15				
4, 1 <sup>st</sup> Price Sealed	8	\$100				
5, Vickrey	9	\$15				
5, Vickrey	10	\$100				

Round	Item	# Bidders	# Bids	Time	Notes
1, English	1				
1, English	2				
2, English 2	3				
2, English 2	4				
3, Dutch	5				
3, Dutch	6				
4, 1 <sup>st</sup> Price Sealed	7				
4, 1 <sup>st</sup> Price Sealed	8				
5, Vickrey	9				
5, Vickrey	10				

Round	Item	The Duke	Tod & Copper	Koala	Runner	Trackers	Super Hunter
1, English	1	\$450	\$450	\$450	\$200	\$200	\$200
1, English	2	\$100	\$100	\$100	\$200	\$200	\$200
2, English 2	3	\$200	\$200	\$200	\$450	\$450	\$450
2, English 2	4	\$200	\$200	\$200	\$100	\$100	\$100
3, Dutch	5	\$200	\$100	\$200	\$100	\$200	\$100
3, Dutch	6	\$100	\$200	\$100	\$200	\$100	\$200
4, 1 <sup>st</sup> Price Sealed	7	\$70	\$70	\$70	\$70	\$70	\$70
4, 1 <sup>st</sup> Price Sealed	8	\$300	\$300	\$300	\$300	\$300	\$300
5, Vickrey	9	\$70	\$70	\$70	\$70	\$70	\$70
5, Vickrey	10	\$300	\$300	\$300	\$300	\$300	\$300

Table of Utility Values

Figure 4. Monitor Package for Game Day 1: Auction day.

**Round 1: Market Place**

**Phase I:**

Groups	Products	Initial Price
The Duke	Oranges	\$5.00
Tod & Copper	Apples	\$5.00
Koala	Bananas	\$5.00
Runner	Watermelons	\$5.00
Trackers	Peaches	\$5.00
Super Hunter	Cantaloupes	\$5.00

Groups	# Unique Products	# Own Product	\$	Bingo?
The Duke				
Tod & Copper				
Koala				
Runner				
Trackers				
Super Hunter				

Phase II: not shown here since it is the same as Phase I in terms of parameters to be tracked.

**Round 2: Hostage Rescue**

Groups	Appeal Prevailing Practice	Counter-Example	Appeal Past Promise	Appeal Self Interest	Promise Future Reward	Threat
The Duke						
Tod & Copper						
Koala						
Runner						
Trackers						
Super Hunter						

Figure 5. Monitor Package for Game Day 4: Negotiation day.

### **3. Post-Game Analysis**

For the Post-Game Analysis of each Game Day, I carried out two tasks.

The first task was the evaluation of the Worksheets (Game Day Packages) that each team turned in. I double-checked all the transactions and the Monopoly paper money amounts of the teams to make sure that all monies and paper tokens were accounted for correctly. I also reviewed the videotape to resolve any conflicts I found in the worksheets. I also examined each team's pre-game strategies, in-game observations, and post-game analyses. I strongly encouraged the teams to come up with a set of pre-game strategies beforehand. I also encouraged each team to pay attention to what other teams were doing during games, as agents are required to observe their environments. At the end of each Game Day, I also required each team to speak for about 1 minute about their views of the Game Day and wrote their views down on the Worksheets. All these I took into account when grading the Worksheets.

The second task was my Post-Game Analysis, which comprised the following items:

- Table of results. I tabulated all parameters that I tracked during games. See Figure 6 for an example.
- Declaration of winners and ranking. Here I ranked each team's Game Day Performance for each round. See Figure 7 for an example.
- Discussion of Operations. I talked about the operational issues of the Game Day in this section, including failures on my part in terms of careless mistakes, of teams failing to follow rules, etc. See Figure 8 for an example.
- General observations. I made some general observations in this section. See Figure 9 for an example.
- Team-specific observations. Here I evaluated each team based on their Game-Day Performances and their worksheets. I targeted specifically my comments for each team. See Figure 10 for an example.

Round	Item	Market Value	Winner	Selling Price	Closest Competitor	Losing Price
1, English	1	\$150	Koala	\$451	SuperHunter	\$450
1, English	2	\$50	SuperHunter	\$100	The Duke	\$90
2, English 2	3	\$150	Trackers	\$200	Koala	\$199
2, English 2	4	\$50	Tod & Copper	\$210	Trackers	\$200
3, Dutch	5	\$100	Runner	\$200	NA	NA
3, Dutch	6	\$100	Tod & Copper	\$175	NA	NA
4, 1 <sup>st</sup> Price Sealed	7	\$15	The Duke	\$76	SuperHunter	\$75
4, 1 <sup>st</sup> Price Sealed	8	\$100	Runner	\$298	Koala	\$280
5, Vickrey	9	\$15	SuperHunter	\$99 (\$120)	Tod & Copper	\$99
5, Vickrey	10	\$100	Tod & Copper	\$303 (\$499)	The Duke	\$303

**Table of Winning Bids**

Round	Item	# Bidders	# Bids
1, English	1	6	10
1, English	2	5	8
2, English 2	3	4	5
2, English 2	4	6	8
3, Dutch	5	5	1
3, Dutch	6	4	1
4, 1 <sup>st</sup> Price Sealed	7	5	5
4, 1 <sup>st</sup> Price Sealed	8	5	5
5, Vickrey	9	5	5
5, Vickrey	10	6	6

**Table of Bidding Activities**

Round	Item	The Duke	Tod & Copper	Koala	Runner	Trackers	Super Hunter
1, English	1	*	*	#	*	*	*
1, English	2	*	*	*	*	*	#
2, English 2	3	*	*	*	*	#	*
2, English 2	4	*	#	*	*	*	*
3, Dutch	5	*	*	*	#	*	*
3, Dutch	6	*	#	*	*	*	*
4, 1 <sup>st</sup> Price Sealed	7	#	*	*	*	*	*
4, 1 <sup>st</sup> Price Sealed	8	*	*	*	#	*	*
5, Vickrey	9	*	*	*	*	*	#
5, Vickrey	10	*	#	*	*	*	*
Money given up		-\$84	-\$695	-\$460	-\$503	-\$209	-\$206
Utility gain		\$70	\$700	\$450	\$500	\$200	\$170
Total sum		\$1016	\$1035	\$1020	\$1027	\$1021	\$994

\* participants # winner

**Table of Participants and Total Sum at the end of Auction Day**

**Figure 6.** Table of results of the Post-Game Analysis of Game Day 1: Auction Day.

Team	R1 A	R1 B	R2 A	R2 B	R3	Total
The Duke	1	0	1	0	1	3
Tod & Copper	1	0	1	0	0	2
Koala	1	0	1	0	1	3
Runner	1	0	1	1	0	3
Trackers	1	0	1	1	1	4
Super Hunter	1	0	1	1	1	4
Total	6	0	6	3	4	19

**Table 6 Number of Problems Solved.** The winners in terms of solving the highest number of problems are Trackers and Super Hunter. The worst is Tod & Copper.

Team	R1 A	R1 B	R2 A	R2 B	R3	Total
The Duke	\$1850	\$1850	\$1850	\$1700	\$1700	\$8950
Tod & Copper	\$1850	\$2000	\$1850	\$2300	\$2350	\$10350
Koala	\$1850	\$2000	\$1850	\$1700	\$2000	\$9400
Runner	\$1850	\$2250	\$1850	\$1850	\$2300	\$10100
Trackers	\$1850	\$2300	\$1850	\$1700	\$1850	\$9550
Super Hunter	\$1850	\$2000	\$1850	\$2000	\$1850	\$9550

**Table 7 Best Allocation Values.** The winner in terms of best allocation values is The Duke. The worst is Tod & Copper.

Team	R1 A	R1 B	R2 A	R2 B	R3	Total
The Duke	\$2100	\$1250	\$2100	\$1100	\$1950	\$8500
Tod & Copper	\$2100	\$1400	\$2100	\$350	\$100	\$6050
Koala	\$2100	\$1400	\$2100	\$1100	\$2000	\$8700
Runner	\$2100	\$1650	\$2100	\$1850	\$500	\$8200
Trackers	\$2100	\$1400	\$2100	\$2000	\$2000	\$9600
Super Hunter	\$2100	\$1400	\$2100	\$1700	\$1850	\$9150

**Table 8 Total Costs (Sum of All Services in Possession).** The winner in terms of total costs is Tod & Copper. The worst is Trackers.

Team	R1 A	R1 B	R2 A	R2 B	R3	Total
The Duke	\$1950	\$1610	\$1950	\$1400	\$1825	\$8735
Tod & Copper	\$1950	\$1760	\$1950	\$1325	\$1225	\$8210
Koala	\$1950	\$1760	\$1950	\$1400	\$2000	\$9060
Runner	\$1950	\$2010	\$1950	\$1850	\$1400	\$9160
Trackers	\$1950	\$1940	\$1950	\$1850	\$1925	\$9615
Super Hunter	\$1950	\$1760	\$1950	\$1850	\$1850	\$9360

**Table 9 Final Scores.** The winner in terms of total costs is Tod & Copper. The worst is Trackers.

Figure 7. Declaration of winners and ranking of teams for each round of Game Day 2: Allocation Day.

First, there were serious rule violations:

1. Some groups brought tokens with them to other groups' desks. This was not allowed, as specified in the Addendums. In real applications, usually you cannot embed a service together in a message—that means you cannot bring your paper tokens with you when you visit other groups' desks.
2. Some groups bargained. This was not allowed. You were supposed to only request for services and let other groups come to your desk to ask for your services. Therefore, multithreaded programming has failed. Moreover, this constrained your offer. When your request is conditional, you may not get agents to cooperate willingly.
3. When you provide a service altruistically, you cannot force the group who asks for the service to take all your services. That is unethical and unfair. By doing that, you become self-interested. As specified in the Announcement for Allocation Day, you were supposed to provide services that had been requested, and nothing more.

Second, there were several failures:

1. Round 1 Situation C was not carried out.
2. Round 2 Situation C was not carried out.
3. The Noisy World step of Round 3 was not carried out.
4. Some groups were not able to compute the Best Allocation values.
5. Rules had to be broken to enable faster communication.
6. The time-constrained, anytime requirement of Round 2 was not fulfilled.
7. The penalty mechanism had to be changed from  $3 * \text{maximum\_cost}$  to simply  $\text{maximum\_cost}$  for each unfulfilled item.
8. The percentages of the Best Alloc (value) and the Total Costs had to be changed from 0.6 and 0.4 to 0.5 and 0.5, respectively.

Figure 8. Discussion of operations for the Post-Game Analysis of Game Day 2: Allocation Day.



#### Round 1: Observations

1. A few teams broke rules. It is very important to follow rules. Without rules, your multiagent system will not work.
2. Most teams were able to give up their most abundant resources/services.
3. Some teams were too aggressive – grabbing whatever they saw on the board. As a result, they were stuck with the resources/services.
4. Nobody posted too many messages on the blackboard.
5. All teams are strongly encouraged to study the Tables above and see why some teams were more successful than the other teams. In general, successful teams (if we ignored the infractions) were teams that obtained services and re-sell services. That means these teams were willing to take some risks.

#### Round 2: Observations

1. We did demonstrate the convenience of this coalition formation strategy, as well as its disadvantages.
2. Some teams failed to make decisions quickly and that defeated the purpose of having this pass-around-the-buck mechanism.
3. Most teams did not observe other teams well. When given the chance, only one team (Tod & Copper) made a choice in naming the next group to pass the buck to.
4. We did not have enough time to play this game enough times to actually learn how to form coalitions better and faster. Ideally, we should have at least 15 rounds.

#### Round 3: Observations

1. Due to time constraints, we were not able to carry out more match-making in this round. This must be taken into considerations for future game days.
2. Since no houses were built, Table 10 was not used.
3. From the producer group, Koala was able to make most attractive and suitable offers. There was one incident where all three producers were matching what a consumer was looking for. But Koala won the transaction because of their low minimum price for their services. So, in a way, staying true or close to your original costs increased the chance of your services getting matched up with the consumers' needs.
4. Some producers offered in bulks. But that might not work out since such offers may not be matched up. To learn whether to offer in bulk or in smaller number of units, the indirect feedback was when no match was announced for your offer. Then you modify your offers accordingly.
5. Some consumers attempted to obtain bulk resources instead of trying to build a house at a time. If you have time, then it might be okay to do so. But if time is pressing, as in our case, then you should try to get the necessary resources for building one house. Once you build that house, you can move on to the second one. Why? This is because you gain so much more from successfully building a house (see Table 10 for house prices).
6. Trackers did very well in the match-making round. They were able to post their needs that suit the supplies. Very adaptive.

**Figure 9.** General observations for the Post-Game Analysis of Game Day 3: Coalition Day.

1. **The Duke:** This team came in without a pre-game strategy. They did learn during the second round that if they could not solve their own problems, then at least they could help other groups solve their problems. They were able to lower their cost very well in Round 1, Situation B.
2. **Tod & Copper:** This team came in without a pre-game strategy. They made some observations of other groups. They finally tried to be completely altruistic indiscriminately. That was not a good practice as an agent, however. They also did something that was illegal. They packaged services together and forced other groups to get either all those services or none. This was not being altruistic. This was against the rules. As specified in the Announcement and on Game Day, you were not allowed to impose on other groups in terms of what services they should get. They came to you for help with their requests. You must not take advantage of that. This group's main goal was to help others first.
3. **Koala:** This team was fixated in selling and buying in the beginning, but was finally able to be helpful in Round 2, Situation B. There was no modeling of other groups. This group's main goal was to solve their own problems first.
4. **Runner:** This team had an excellent pre-game strategy. In Round 2 Situation B, the team was able to obtain an extra unit of component at a cheaper cost and gave away a higher-cost unit. This team made an important observation:  
 "Teams are not altruistic AND task-aware. They are either one or the other. For our system to work, we need just enough altruistic giving teams to supply the task-aware teams. If there is not an equilibrium, then some teams will fall short of their goal. The task-aware teams are likely to win because of the maximum value penalty—even if only multiplied by 1 instead of 3—is greater than the benefit of getting rid of all resources." The observation was generally true. But as we see from Tables 8 and 9, task-aware teams did not win. The benefit (in terms of final scores) of getting rid of all resources was actually greater than the benefit of solving a task.
5. **Trackers:** This team had a pre-game strategy. This team also made very good profiling of other groups. "We had a successful transaction with Super Hunter; in the next round we will go to them first." They also resourcefully solved some problems. They also pointed out that Tod & Copper was not being truly altruistic in their "service packaging". This group's main goal was to solve their own problems first with some helping in mind.
6. **Super Hunter:** This team came in without a pre-game strategy. This team did not do any modeling of other groups. This group's main goal was to solve their own problems first. They did make a good observation:  
 "We learn to be aggressive to approach other agents. If they are cooperative, the problem can be solved. It is better to separate request and service providing."  
 Yes. By combining request and service providing together, you are making things complicated. And that makes an agent less cooperative, and problems more difficult to solve.

**Figure 10.** Team-specific observations for the Post-Game Analysis of Game Day 2: Allocation Day.

- **Lessons learned.** Here I drew conclusions and related the observations made earlier in the post-game analysis back to the design and research issues that I had covered in the class. On average, I had about 4-5 lessons learned for each Game Day. Here are some examples:

**Auction Day:** For our game day, if there were only one agent bidding, then the total gain for the auctioneer would be \$1,990. But by opening it up to a group of six competing agents, the auctioneer gained \$2112 and another additional \$47 in auction fees. So, if the cost of organizing the auctions were larger than the \$169, then the auction would not be too useful. Keep this in mind when you design your multiagent system in the future.

**Coalition Day:** Some teams in the blackboard round blatantly incurred infractions: they grabbed some postings (from other teams) and then returned the postings after they realized that they did not want them anymore. This is absolutely unfair. Think about it. That meant you actually collected the postings (and blocked other teams from accessing the postings), selected the best one to keep, and returned the ones that you did not want. This was really bad agent behavior. We caught one team doing that (Koala) but there was another posting that we could not find the team who did it. Remember this clearly, when you design your multiagent system one day, think about fairness. If you have unintended biases in your design, then your system will not work right. This is a very important lesson. So, Koala and another team think about this carefully. The team that adhered to the rules completely was Trackers. They even charged the re-postings to their total number of messages posted. Teams should learn from them.

**Allocation Day:** For under-constrained problems, agents were not motivated to improve on the quality of their solutions. For over-constrained problems, however, agents were motivated to find a solution, period. So, we see that it is generally more difficult to design a multiagent system in which agents aim to improve on their solutions. The motivation factor has to be delicately implemented to ensure there is enough benefit to force agents to risk, to go to a worse state before ultimately reaching a better state. In other words, in the design of our Game Day, for Round 1 Situation A and Round 2 Situation A, foresight was needed to motivate agents to want to improve on their solutions. *Lesson Learned:* That means whenever we design a multiagent system to solve under-constrained problems where improvement of the quality of the solutions is the goal, we should design a foresight component into the system. Otherwise, it would be generally not suitable. In fact, a system with specialized agents is much more suitable for under-constrained environments than a system with similar agents (such as the student groups on Game Day). So, remember, if the environment is under-constrained, then a more suitable MAS design in general should be one with specialized agents. In general.

**Negotiation Day:** For Round 1, there was a significant difference in the teams' behavior in Phase I and Phase II. Because of a middle person in Phase I, the teams were conservative. They opted to swap goods to begin with. Why? It was inconvenient for a team to execute monopoly power due to the communication delay. It was difficult for a team to check out the supply and demand in the market and thus difficult for a team to raise the price of its products. In Phase II, each team was able to gather more information more quickly and had more control over the negotiations. Thus, this phase is more convenient for a team to execute its monopoly power. So, even though in both phases, each team had the monopoly power, only one team in Phase II exercised it fully (Tod & Copper) and another team in Phase I exercised it partially (Trackers). *Lesson Learned:* Even in a setup like the above, agents can still cooperate fairly because of the reliance on each other for products/services to accomplish own tasks. This gives us designers great flexibility in designing our agents. We can give our agents unique characteristics and be competitive and self-interested, and we can still guarantee to some extent that the agents will cooperate.

I handed my Post-Game Analysis of each Game Day back to the students immediately (the next day) and discussed some of the key points with them in class. I stressed to them that participating and winning a game was one thing; learning about multiagent systems from the game was another. I emphasized that the latter was the ultimate objective of the Game Days.

#### 4. Game Days League

At the end of the semester, I tallied up the Game-Day Performances of the teams for all Game Days and announced the ranking for the Game Days League. Table 4 shows the ranking scores that I announced to the students.

Groups	Auction Day	Allocation Day	Coalition Day	Negotiation Day	Total
The Duke	5	2	3	2	12
Tod & Copper	1	1	6	3	11
Koala	3	3	1	6	13
Runner	2	5	5	1	13
Trackers	4	6	2	5	17
Super Hunter	6	4	4	3	17

**Table 4.** Total ranking scores for all Game Days.

Together with the announcement, I also stressed to the students that the above ranking was simply how they performed on the Game Days, excluding their worksheet scores. So, in terms of playing the games, Tod & Copper won. Also, the above ranking was ordinal. So, the above table was not a completely fair comparison. It was an approximation. This notion of League was a good one as some teams felt very competitive and tried to do well to win the League.

## 5. Evaluation

Before the semester ended, I did a survey about the Game Days. Students were asked to fill out the survey (Figure 11) anonymously. I collected the surveys and tabulated the results. The second question of my survey was based on a pedagogical ordering of five items, from the mastery, to the familiarity, and the exposure of subjects or topics in Multiagent Systems (MAS). 2(a) asked the students about “understanding the concepts of MAS”, 2(b) inquired about “understanding the design issues of MAS”, and so on. In the least, my goal was to expose the usefulness of MAS to the students, and thus 2(d) asked the students about “appreciating what MAS is about”<sup>5</sup>.

Table 5 shows the average scores for Questions 1 and 2. The students thought that Auction Day and Negotiation Day helped them the most, and Allocation Day and Coalition Day not as much. I have an explanation for this. Both Auction Day and Negotiation Day were easier to play. The rules were simpler; computations were simpler; communication among group members of the same team was not needed as much; the environment was much less dynamic. With a less dynamic environment, the students were able to plan pre-game strategies well and I was able to monitor and oversee the game better during the game as well.

Most students thought that the Game Days helped them (a) understand the concepts of MAS (4.58/5.0), (b) understand the design issues of MAS (4.00/5.0), (c) remember the issues or terms of MAS (4.17/5.0), and (d) appreciate what MAS is about (4.08/5.0). Based on this survey, I conclude that the Game Days were very successful.

Table 6 shows the ranking of the helpfulness of the Game Days and other assignments in the class to the students’ learning and understanding of the topics in the class.

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<sup>5</sup> I had 7 non-native English speakers in the class; so I also asked the question 2(e) in my survey.

For the first 2 questions, 1 = strongly disagree, 2 = disagree, 3 = indifferent, 4 = agree, 5 = strongly agree.

1. The following game day was useful.

	SD	D	1	A	SA
(a) Auction Day	1	2	3	4	5
(b) Allocation Day	1	2	3	4	5
(c) Coalition Day	1	2	3	4	5
(d) Negotiation Day	1	2	3	4	5

2. The Game Days were helpful in:

	SD	D	1	A	SA
(a) Helping me understand the concepts of MAS	1	2	3	4	5
(b) Helping me understand the design issues of MAS	1	2	3	4	5
(c) Helping me remember the issues/terms of MAS	1	2	3	4	5
(d) Helping me appreciate what MAS is about	1	2	3	4	5
(e) Helping me communicate better (English)	1	2	3	4	5
(f) Nothing	1	2	3	4	5

3. Comments about the Game Days (good things, bad things, things that need to be improved etc.):

4. Rank the following items from 1 to 7 (with 1 being the least helpful, and 7 being the most helpful) in terms of their helpfulness to your learning and understanding of the topics/subjects of MAS:

Lectures	_____
Game Days	_____
Topic Summaries	_____
Homeworks	_____
Exam	_____
Seminar	_____
Final Project	_____

**Figure 10.** Survey on Game Days at the end of the semester.

Q1	average
a. Auction day	4.50
b. Allocation Day	4.00
c. Coalition Day	4.17
d. Negotiation Day	4.33
Q2	average
a. Understand concepts	4.58
b. Understand design issues	4.00
c. Remember issues/terms	4.17
d. Appreciate MAS	4.08
e. Communicate better in English	3.75
f. Nothing	1.58

**Table 5.** Average scores for Questions 1 and 2 of Survey.

Items	Raw	Normalized
Lectures	5.58	5.00
Game Days	6.33	5.50
Topic Summaries	5.92	5.83
Homeworks	4.33	3.42
Exam	3.83	2.83
Seminar	4.08	3.75
Final Project	5.92	5.42

**Table 6.** Ranking of requirements in the class in terms of helpfulness.

In the raw scoring column, the students scored the Game Days' usefulness at 6.33, way above the closest item (Topic Summaries and Final Project at 5.92).

Some students entered the same scores for different items, such as 7 for Lectures, and 7 again for Game days, and 6 for the other items. I re-scored these. For example, 7s for Lectures and Game Days, but 5 for the other items. Thus, I normalized the scores. As a result, the Topic Summaries<sup>6</sup> overtook the Game Days as the most useful.

Overall, the students thought the Lectures, Game Days, Topic Summaries and the Final Project to be very useful, above 5.0 in a scale of 7.0. They did not think that the Homeworks and Exam were useful. Come to think of it, this makes sense. I used the Homeworks and Exam mainly to evaluate the students, not to teach them.

## 6. Lessons Learned

In this section I discuss the lessons learned from the Game Days.

- (a) First of all, the Game Days that I have designed and conducted are natural role-playing games for students in multiagent systems. Each team is an agent and naturally, the class becomes a multiagent system. So the application of multiagent system-related problems to games is straightforward.
- (b) Second of all, these role-playing games where students get to move around in class, form their own cliques, and discuss and argue loudly and energetically are very motivating. Students feel a sense of accomplishment. I believe that the face-to-face contacts during the games are a key factor to their enjoyment of the games.
- (c) The size of the class has to be small enough. My class had 12 students so it was manageable. Two students comprised a team. Thus, I had only 6 teams to manage. Judging from my experience, I do *not* recommend more than 6 teams in a class. Each team may have 2 to 4 students, however. For Auction and Negotiation Days, 2 students per team are appropriate. For Allocation and Coalition Days, 3-4 students per team would be more suitable.

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<sup>6</sup> Each topic summary was a summary of my lectures on a chapter (or a topic) and included at least the following (a) an overview of the topic – motivations and underlying principles, etc., (b) a list of *praises*: a description of what the student thought were the important/useful aspects of the topic, (c) a list of *critiques*: a description of what the student thought were the weaknesses of the topic, (d) a list of *wishes*: areas of the topic that the student thought should be improved, and (e) a list of *questions* on material that the student did not understand from the lectures and textbook

- (d) Keep the games simple and easy to play. Make them as convenient as possible. Make everything as readily available as possible (tables, worksheets, paper tokens, etc.). My Allocation and Coalition Days were more difficult to play as more in-game computations were required. That held up the games and several rounds had to be cancelled. Thus, when you design your own Game Days, keep that in mind. Some teams will be slower than the others<sup>7</sup>.
- (e) Punish rule-breakers and reward rule-abiders fairly. Some teams are bound to break the rules of the games. Hopefully, they are caught during the games so the impact can be minimized. If not, penalize them post-game.
- (f) It is important to make sure that the games are fair to everybody. Students are very particular about this. They want to compete and they want the games to be fair. And it is our responsibility as instructors to ensure that. So, when you assign individual utility values and costs, make sure that they are symmetrical. For games that are not symmetrical (such as consumer groups and provider groups for my Coalition Day), score them differently.
- (g) Give the students their Game Day assignments early. For my Game Days, I gave the students the assignment at least one week before the Game Day. Make sure that a general version of the Game Day Package is available to the students. The students, as I have said, are generally motivated to do well on Game Days, and thus they *do* study the assignments a few days ahead of the Game Day, unlike their other, more conventional assignments. Talk to your students to help them understand the games, and to let them know the importance of the games.
- (h) Give more weight to the Game Days. In my class, the Game Days only accounted for 10% of the final grade. I realized in the end that the students learned much more from the Game Days and spent much time on the preparation for the Game Days that they deserved more than 10%. My recommendation for a semester of four Game Days is 15-20%.
- (i) Encourage the students to come up with pre-game strategies, to perform in-game observations, and to conduct post-game analyses. I stressed these on my Game Days and I scored them accordingly. Encourage them to speak out at the end of the Game Day about the games. Give them enough time to share their views with the class. In my class, some teams enjoyed these requirements; some teams did not. Teams that did were better teams.
- (j) Be flexible on the Game Days. Since you have to fit the Game Day into a class period, that is a really hard time constraint. Eliminate rounds that seem to go nowhere due to poor designs on your part or executions of the teams. Shorten rounds that are going on too long. Some students immediately notice the problems with the design as they play the games. Acknowledge them by fixing the problems (if fixable) immediately. Use these fixes in your Post-Game Analysis. These are very valuable. For my Game Days, I encountered about three of them.
- (k) Be persistent and dedicated to your Post-Game Analyses. Games are just games if the students do not learn from them. So, when you analyze the outcomes of the games, give feedback specifically to each team and draw general observations. Most of all, discuss the lessons learned from the viewpoint of a multiagent system designer. Relate the lessons back to the topics or subjects taught in the class. Make the connections between the games and the lectures for the students explicit through your Post-Game Analyses.

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<sup>7</sup> I used this as an example, to the class, for a multiagent system of agents of different processing speeds. And it was a really good example as all the teams immediately felt the impact of the system slowing down due to slower “agents” during games.

- (l) Invite other faculty to visit your Game Days. Introduce the visitors to your class at the beginning of your Game Days. The students have a sense of pride and tend to do better to show the visitors that they are good and they have fun.
- (m) Every student must be present on Game Days, especially for 2-member teams. I had two occasions where a student failed to show up and another showed up late. In both occasions, the team with only one student had to work doubly hard to cope with the “processing” of information and events in the games. I penalized harshly on those students who failed to show up or show up on time, and gave those students working on their own extra points. If the attendance rate of your class is poor, then these Game Days are not a good idea.
- (n) Be prepared to spend a lot of time pre-game and post-game, at least for the first time you incorporate the Game Days into your class. Based on my experience, I spent probably 25 hours, for each Game Day, on defining the assignment, preparing the Game Day Packages and the Monitor Packages, designing the utility values and costs, and double-checking all numbers were correct. I spent another 5 hours or so on the Post-Game Analysis for each Game Day. Luckily, each Game Day, once designed, is re-usable. That means, in the future, I only have to spend, say, 1 hour on pre-game design and packaging. However, I may only be able to cut one hour or two from the Post-Game Analysis. It is my hope that with this article, instructors interested in introducing the Game Days to their multiagent system classes would spend considerably less amount of time pre-game.
- (o) Make your Post-Game Analyses available to the next class for their Game Days. These provide valuable insights for those future students.
- (p) Here are some recommendations on operational issues:
  - Give every team member a nametag so that other teams and you can track them. I gave two stickers for front and back. This is critical especially when teams get up and move around in the classroom frequently.
  - Use Post-It notes as messages to be passed. Have each team number each note to keep track of the number of messages passed. Specify clearly how a message is done. I gave them specific formats. For example, “sender”, “service available”, “service needed”, and so on.
  - Use Monopoly’s paper money. Make your utility values and costs in round numbers, corresponding to the smallest denomination of the paper money. That makes things easier to process.
  - Use toys as goods. In my Auction Day, I bought some plastic toys and gave them away to the winning bidders. The students enjoyed this part and were proud to showoff their winnings in the end. In my other Game Days, due to the number of units involved, I was not able to get enough toys for the games. Instead, I designed paper tokens. However, I did make an effort to make these tokens colorful and easy to use. The more care you put into making these paper tokens or goods, the more the students appreciate your effort and seriousness about the games.
  - Put each Game Day Package in a sealed envelope. This has two effects. It gives each team a sense of individuality. At the end of the Game Day, each team puts all their materials in the envelope and hands it back to you. So it is also a very easy way of organizing and not forgetting things to be turned in.
  - Compartmentalize as much as possible. For example, for each Game Day, there are several rounds. For each round that involves monies and tokens that are not to be used in other rounds, provide a small envelope to keep those items. Ask each team to “Put all



bills and tokens related to Round 1 into the envelope marked ‘Round 1’” after Round 1, for example. This is a significant time-saver when you do your Post-Game Analysis later.

- Bring a kitchen/oven clock to the Game Days. When you assign  $N$  minutes to a round, simply wind up your clock accordingly. Then you do not have to worry about the time until the alarm sounds. It also allows you to warn the students about the number of minutes left in the game.
- Organize your Game Days in a League. This keeps the interests of the students higher.
- Finally, have fun. Enjoy the Game Days.

## 7. Conclusions

In this article, I have described a new way of teaching a class in multiagent systems: Game Days. I have designed and conducted four Game Days: Auction, Allocation, Coalition, and Negotiation. I have discussed each game day in terms of its design and specifications. I have illustrated the design of the Game Day Packages and Monitor Packages. In addition, I have outlined the key topics in the Post-Game Analyses. Moreover, I have presented a survey that tells me that the students in my class enjoyed the Game Days and agreed that the Game Days were helpful in their learning and understanding of the materials taught in the class. Finally, I listed a set of agendas as lessons learned from my experience for all instructors who are interested in adopting Game Days for their multiagent systems classes.

To conclude, role-playing through games where students get to expend energy in face-to-face interactions is a great way of learning about multiagent systems. In addition, role-playing allows the students build a multiagent system instantly! Each team is an agent that is intelligent and is readily to assume different roles. Each team also communicates with and understands each other. Thus, role-playing is a great way to demonstrate multiagent activities. The students do not have to get bogged down in programming languages or syntax or threads to learn about multiagent systems. Moreover, usually-less-motivated students are more inclined to play games than doing written homework assignments. In my class, there were some students who did not do well in other assignments but yet showed a high level of fervor on the Game Days—they were very involved and much motivated.

Finally, I believe that the Game Days are a good, educational tool for teaching a multiagent systems class. After all, we, young and old, are all agents who enjoy playing games.

## 8. References

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