Agent Based Systems: Extensive Auction Games

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I. Introduction

This assignment involved designing strategies for two different auctions. Each agent in these auctions play with the same initial budget and have the same win condition. Strategy design methodologies started by assuming play against rational agents, then considering actions of other agents indicating irrational play and incorporating strategies that exploit this irrational play. Before starting this coursework, it was assumed that cooperative play is forbidden both in plagiarism of ideas and direct cooperation within the auctions.

II. Ideas shared by both games

Neither of the auction scenarios in this work assign value to the remaining budget of an agent once the auction terminates. Therefore both strategies should aim to fulfill

$$\sum_{i=1}^{k} \text{successful\_bid}_i = \text{budget}, \text{ for the set of successful bids}$$

III. Collection Auction

In this auction the aim is to collect a given bundle of painting types of $\{3,3,1,1\}$ in any permutation. The winner of each round pays their own bid making this a first-price auction. This auction is guaranteed to terminate before 200 rounds for any of the rooms my agent will participate in (maximum 10 agents), therefore determining the actions that move my agent towards terminating the game is very important. The painting auction order is general knowledge among the agents, and is key to formulating a good strategy. The auction requires winning at least 8 paintings with no consideration of budget after the games termination, therefore it is natural to assign successful bids to a permutation of $\{125,125,125,125,125,125,125,126\}$. I assume that all rational players will follow this scheme.

A strategic idea I considered predicted the collisions for a certain painting in the auction collection, and avoided paintings with a large number of predicted collisions. However, I disregarded this idea as the aim of the game is terminate as quickly as possible, and this achieves the opposite. All rational agents will bid on the first painting because every agent improves their position by winning it. A winner for this first bid will be chosen semi-randomly.

I considered a rational agent an agent that checks the currently offered painting and bids 125 if acquiring the painting improves their position, otherwise no bid is given. My agent quantifies 'improving position' by seeing if acquiring the painting reduces the L1 distance to any permutation of the target bundle (handled by the bot_collection_l1value function via the required_paintings function). The final bid to complete the set is always the remaining budget of my agent.

With this outline of rational play, there are a number of choices that must be made:

- How to utilize the bid of 126.
- Signs of irrational play and strategies to exploit irrational agents.
- Considering how game size will affect the auction.

A. *Determining when to bid high*

A number of ideas were explored to determine the optimal way to bid 126

- Bidding 126 until successful, then bidding 125.
- Bidding 126 on a painting that will become the second a set of three.
- Bidding 126 on the third painting of a set.
- Bidding 126 on final painting of target collection.
- Bidding 126 on a painting that prevents a drastic increase in minimum rounds to game termination.

As the aim of this game is to terminate early by achieving the terminating condition, it seems natural to use the high bid on the first round to increase the chance of an early lead. However, using the high bid early removes the possibility for strategic play later on once the state of the game is better-known. My agent could also be beaten at a final stage where a winner is determined in the final round.

My final idea was to score the painting for sale based on it's 'importance'. This importance was quantified by seeing how much the sale of this painting changes the state of the game. If all agents can end the game in 10 rounds, a painting is sold and all agents then have 9 rounds until earliest termination this painting is not important (being assigned an importance of 0). If instead the number of rounds until earliest termination increases from 10 to 13 for an agent if the painting is not acquired, it is assigned an importance of 3. This importance parameter characterises how much my agent will regret not acquiring the current painting by finding the smallest number of rounds until the agent can terminate. Painting's deemed very important are bid on with 126. I chose to implement this under the condition that if the importance of a painting was greater than the size of the room, the agent bids 126.

This was chosen as it seemed intuitive to be more patient when there are more bots in the room, as the games are going to be longer. Also, as my agent will always bid it's remaining budget at the terminating round, the high bid can be saved for this critical stage. With testing, the use of this importance parameter outperformed all other decision methods to determine the use of the 126 bid.

B. Irrational and risky play

A good agent must play well against both rational and irrational opponents. Considering the competition of paintings is extremely important, especially when the number of agents is small. For example, in an auction of two agents after a number of rounds it is highly likely that only one of the agents will be interested in a certain painting. My agent's strategy accounts for this, bidding 1 on paintings in which only it is interested in bidding. This behaviour is risky as it assumes the rationality of other agents and it is exploitable by the other agent(s) as they could bid 2 and not lose much budget, but deny a vital painting for me. This counter-exploiting behaviour was ignored by my strategy as I believe expending 2 budget to deny a painting hurts the exploiter, as one of their future bids must be less than or equal to 124.

If a bid of 1 is successful my agent plays the rest of the game with a surplus budget. My agent learns it has gained an advantage changes it's strategy; bidding 127 on paintings it requires, and 2 on paintings it does not require but only has one agent competing for.

C. Losing Position

Due to the random nature of this game, many of the auctions will be unwinnable once chance plays its hand. Unfortunately there is no counter-play to this scenario; however my agent might delay the termination of the game by attempting to outbid an agent that is going to win. However, one can not disregard the potential for bugs in bots that suddenly stop rational play allowing my agent to win in a rationally unwinnable situation. Therefore, win-blocking behaviour was not implemented.

D. Collection Conclusion

In conclusion, this bot has been carefully designed to play well against rational players by exploiting predictable behaviour. Potential problems I can foresee with this agent is that it assumes the other agents are rational, and uses this to exploit them. However, I think it is fair to assume that other agents will first check if a painting gives them an advantage before bidding any more than 0 budget on it. Another strategy I created checked all upcoming paintings and only bid on paintings that will lead to the fastest termination instead of simply checking if a painting moves the agent closer to terminating. Upon testing I found that this strategy was far weaker than the strategy outlined above, especially in large rooms. This is because obtaining this 'optimal' collection, although terminates more quickly, is very improbable especially in larger rooms. I found that it is a better overall strategy to attempt to greedily claim all paintings that improve your immediate position.

Given more time, I would explore incorporating the strategy that only pursues the optimal bundle of paintings as a mixed strategy depending on room size. When there are fewer players the prospect of playing optimally could be considered more seriously as there is less competition for each painting.

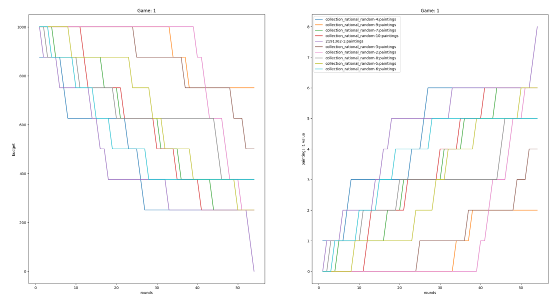

Fig. 1. Collection game of 10 agents, u2191362 playing with 9 rational agents that bid 126 until successful and then 125. Left plot is the budget of each agent against round number, the right plot is each agents painting collection L1 distance from a winning bundle of paintings against round number.

IV. Value Auction

In this auction the agent with the highest total score at the end wins, with the highest bidder of each round paying the second-highest bid. This is known as a Vickrey auction. It has been shown that in the Vickrey auction there is no incentive for counter-speculation and truthful bidding is a dominant strategy meaning if the agent applies this strategy they receive the highest expected utility, no matter the strategy of the other bidders [1] [2]. However, this has the assumption of private values and that all agents are risk neutral; so the applicability of these ideas to this coursework is uncertain. Unlike a standard auction setting where agents payoff functions are their individual profits, as this is a competitive game, rational agents maximize the difference in obtained score.

A. General Idea

My plan approaching this work was to create a very rational bot that approximates Nash equilibrium / rational play as closely as possible, then introduce the ability for the agent to detect and exploit irrational play in order to get an advantage. Following this, parameters summarising the state of the game were devised so that strategies that play rationally may be found through self-play.

To find rational play, my agent calculates a dynamically changing aimed_score that is dependent on the state of the game, and bids according to this. The smallest score that guarantees having the largest valuation by the end of the auction is

$$\frac{\sum_{i=1}^{n} item\_value_i}{2} + 1 \tag{1}$$

However the winning score will nearly always be less than this in rooms with more than two bots, especially in rooms with many agents. Aiming for this as an aimed_score may result in low bids that are never successful as the agent is playing too ambitiously. In the case when all agents are rational, the minimum score required to win is

$$\frac{\sum_{i=1}^{n} item\_value_i}{N} + 1 \tag{2}$$

where N is the total number of agents participating in the auction. The aimed score should lie within the values calculated in equations 1 and 2. The agents aimed_score should move towards 2 when rational opponents are detected and 1 when irrational opponents are detected.

B. Considerations

Ideas derived from intuition in this auction are

- Because of the selection of painting prices, the majority of score ($\sim 60\%$) is held in the Picassos. Large-value items should therefore be prioritised. These items disrupt the game.
- Every item should be bid on as this prevents opponents from obtaining paintings while expending no budget.
- My agent should bid high on items my agent decides to prioritise, balanced by bidding below an optimal value on items my agent is indifferent towards.
- The game changes drastically as the number of agents changes. My agent should adapt well to different sizes of rooms.
- Low numbers of agents require careful play to guarantee success as very simple strategies become powerful against overly-aggressive play.

C. Strategy

The aimed_score parameter is initialised to the highest_score_cap as this makes the agent assume the opponents are rational before the auction starts, preventing initial over-bidding.

High-value paintings are prioritised by looking through the painting order to find upcoming paintings, sorting through them in value-order, and prioritising the high-value paintings until aimed_score is found. This is performed in every round. If the painting currently on offer is in this prioritised set of paintings, a bid of

$$\text{bid} = \text{budget} * \frac{\text{painting\_score}}{\text{aimed\_score} - \text{current\_score}} \tag{3}$$

is given. If the item on sale is not a prioritised item a bid should still be given. In this case, a very conservative bid is submitted, characterised by a parameter called tolerance.

In all rounds where prioritised paintings are offered a bid is submitted by my agent. If my agent is outbid for this prioritised painting, aimed_score is multiplied by a factor decrease_factor (< 1) to induce larger bids from my agent. Likewise, if my agent was successful in obtaining the prioritised painting, the aimed_score is multiplied by a factor increase_factor (> 1) to induce lower bidding.

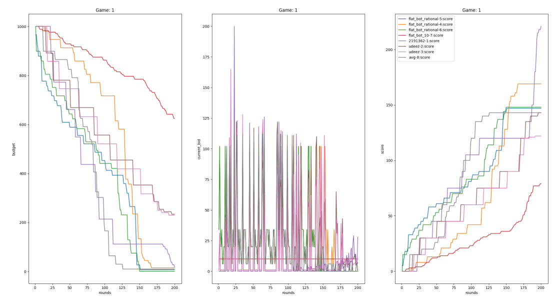

Fig. 2. u2191362 playing in a room of 8 in a mixture of rational and irrational agents. The left plot shows each agents budget, the middle plot each bots bid, and the right plot the score of each agent. My agent plays well against rooms of a mixture of rational and irrational strategies.

Towards the end of the game, a more careful agent is rewarded as many agents will have used all of their budget through over-bidding. To exploit this behaviour once the budget of my agent is below

$$\frac{500}{num\_of\_bots} + 100 \tag{4}$$

bids of

$$\frac{painting\_value}{remaining\_score} * budget \tag{5}$$

are given in each round. This exploits agents that have ran out of budget, as it ensures small bids are always given until the end of the game. For the final painting a bid of the agents remaining budget is given.

Finally, if my agent misses a prioritised item the agent's next priority bid will be multiplied by a regret factor that compounds after multiple failures.

D. Testing

Self-play was used to determine optimal values for the agent's parameters (increase_factor, decrease_factor, regret, tolerance). Games with every combination of room size and factors between the values of 0.7 to 1.3 were played. Using this, I found that increase_factor = 1.1, decrease_factor = 0.75, regret = 1.1, and tolerance = 0.1 gave the best results overall.

E. Value Conclusion

In conclusion, my agent following this strategy plays well against rooms from sizes 2 through 10 of rational agents, irrational agents and mixtures of both. Given more time to work on this strategy, I would have performed more thorough testing through self-play, especially under different scenarios of irrational agents with simple strategies.

References

[1] Brandt, Felix, and Gerhard Weiß. "Antisocial agents and Vickrey auctions." International Workshop on Agent Theories, Architectures, and Languages. Springer, Berlin, Heidelberg, 2001.

[2] Vickrey, William. "Counterspeculation, auctions, and competitive sealed tenders." The Journal of finance 16.1 (1961): 8-37.