Auction Game

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I. Introduction

This report will be discussing and evaluating different strategies and the implementation of an agent-based system which is being coded in Python3 to be able to outbid other agents in an Auction Game. An agent is defined as intelligent if it can act on heuristics to carry out a set of actions which change based on different game states to complete a goal [1]. The development of these strategies will under this definition make these intelligent agents. The strategies will be created on game theory a field which has been increasing in interest over many different fields of work (political, economic, biology and more) [2]. There are four auction games each with there own winning conditions and with different levels of information available. The rough domain of these games is as follows. There are 1000 pounds available to each player to bid on one of four artists paintings. The first two games are based on collecting 5 paintings from one artist. The second two games are based on collecting as much art as possible. The more specifics of the games are shown in figure 1.

- Game 1: First to buy 5 of any artist wins, the highest bidder pays own bid, and the auction order known.
- Game 2: First to buy 5 of any artist wins, the highest bidder pays own bid, but the auction order is not known.
- Game 3: Highest total value at the end wins, the highest bidder pays own bid, and the auction order known.
- Game 4: Highest total value at the end wins, the highest bidder pays the second highest bid, and the auction order known.

Fig. 1. Game Domains.

These variables allow the storing of histories, these histories might not be full but are still very useful in developing strong strategies for outplaying opposing agents. If a winning strategy cannot be developed and followed then an at-least drawing strategy should be a backup; this leaves the worst case being losing. The information on histories is also known as knowledge. There can be an assumption that the other agents will also figure out similar history based knowledge making it general knowledge; this will be further explained with specific examples. Not knowing what everyone bids each round means there is uncertainty and will lead to multiple possible strategies which will also be explained and evaluated throughout this report.

II. Methods

The four artists available to bid on are Picasso, Van Gogh, Rembrandt and Da Vinci. There will be 200 rounds per game to decide a winner if one is not reached a draw will have occurred and the game will be re-run. There are four Python3 files provided which set up the auction server and allow strategies to be coded and tested against others. The bids will be made across the agents simultaneously making this auction a sealed-bid so that a comparison can be made directly [3].

Within the file AuctionClients there are variables which are accessible when creating the strategies which provide information on the other strategies and the game in question. This type of game is an extensive game due to individual actions being played in sequence. There is however a difference between the imperfect information provided for them making the agent uncertain about the actions others are taking. Because of this imperfect information risks will have to be made the reduction of the risks will be easier if more information is calculated and stored from the variables provided. Some of the more important variables are standings; a data structure that provides how many of each painting every strategy has won along with the money they have spare. The number of bidders, which provides the number of strategies within the game. Arguably the most important, itemsinauction providing a list of the items in the game and depending on the domain gives the order in which they come up in. These variables are used directly in creating strategies based on knowledge of the game domain and the other agents to give the best chance of winning.

III. Discussion

This section of the report will be describing the four different games in more depth along with evaluating the strategies chosen to be implemented for each along with reasons why others were not used. These agents, in general, are partially cooperative which is being happy with what you want but even happier with what you do not. Games 1 and 2 have very similar problem domains, with the only differences being in 2 you cannot see the auction order which reduces the amount of information that can be derived and implemented into the strategy. Both of these two games are first to collect 5 of certain artists work. If two or more agents bid the same amount it is randomly distributed to one of them.

A. Game 1

Game 1 is the first to buy 5 of any artist where the highest bidder pays their own bid and the auction order is known. The strategy for this was split into three sections depending on the number of bidders. When there are lots of players, being more than 25 there is one strategy; when there is a medium amount of players being less than 25 and more than 7 there is another. A final strategy is also implemented when there are less than 7 players. These three sections will be different because the number of players directly relates to how patient you should be and how consistent your bidding should be. Zermelo states there is a Nash Equilibrium for

every extensive game for this game it would be for everyone to bid 200 on an artist there will be deviations but sticking to this for lots of players will strategically better than others.

The strategy discovered was implemented for more than or equal to 25 players. This strategy was to pick an artist based off of a data structure created to store the next artist to occur 5 times in the auction order. This information was found by calculating the index positions of each artist and updating it each round. Once a piece of art was owned that would be the only art the agent would bid for. Not only will the agent be exclusively bidding on an artist but the bid will only be 200 due to the negatives from unilaterally deviating, which would instantly put the agent at a disadvantage. The only downside to this strategy is there will be a fair amount of luck involved as it is likely a lot of other agents will be using this same strategy. This is very simple however when the numbers of players are large simple is more effective and harder to counter. This was tested against random strategies and against other strategies based off more patient ideologies however this proved best. There is a fail safe in place for the very low likelihood of reaching the final round, which bids the rest of the agents money.

For in between 25 and 7 the strategy implemented was slightly more aggressive but also slightly more tactful. The aim was to bid for the most unlikely to be bid upon as this gives the greatest chance of satisfying the win condition. The artist which occurs 5 times second from last from round 0 was to be the artist this agent would commit to. This was because it was believed others would be being more aggressive aiming for the first 2, and if trying to counter the aggressiveness selecting the last. However, selecting the third to occur was probably the least likely to be bid on by more than 2-3 players. The bidding for this would start at 201 to secure a piece of art hopefully deterring others from going for it; this would be followed up by 3 bids of 200 and finishing with a bid of 199. This strategy would hopefully pick up a final bit of art for cheaper because it is less popular and would be more aggressive in the first round of the artist occurring to scare off others. This strategy seemed to work really well for the upper half of the medium ground; which would have been split up again if this project would be carried out again. Whereas the lower half would need to have a slightly altered version.

For less than or equal to 7 players, an even more aggressive strategy was chosen, followed by a much more patient one which would be implemented if the aggressive one fell through. Firstly, a bid of 200 would be made on the artist to first occur 5 times like this with such few numbers would be the most likely to be the artist the agent who wins the game would bid for. If this worked and the first bid of 200 the artist became your it would be followed up by constantly bidding 200 on that specific artist looking for a quick win. However, if another agent owns the artist that our agent is trying to obtain it would deviate. This deviation would be to all of the three others bidding an amount lower than 100 but constantly upping opponents waiting to collect as much of the other artists as possible and saving to outbid the others by 1 once they reach 4 of a certain artist. It is important to keep in mind not to outbid yourself in this situation as that would be wasting your money. This counters constantly bidding 200 on anything and as there are fewer people to rely on to outbid someone when they reach 4 the strategy will make sure the agent attempts the outbidding. Less than or equal to 7 is an important boundary due to this meaning if everyone selects and commits to one piece of art there will be at least one artist only one agent will bid for. This is why the strategy for countering the constant 200 is implemented here.

This strategy as a whole was tested and proved to perform quite well, beating all other more basic less thought out strategies. The risk of letting someone else do the outbidding with a large number of players is much more likely to occur hence why it is not implemented in any world with more than 7 players.

B. Game 2

This game is very similar to 1, the only difference being the order of the auction items is not known. This reduces the amount of information that can be concluded and used to implement the artist which is first to occur. However, there is still information on how many of each item occurs within the auction, this will be used as the scale as to select a most or least likely artist. This strategy is also split into more than 25, in between 25 and 7 and less than or equal to 7. These three boundaries hold for the same reasons as in game 1. The strategies are just variations of the ones carried out by the agent in the previous game. For greater than or equal to 25 players the agent will bid a constant 200 risking that others will not bid on this artist and that they also deviate to save money ruining their chances to be distributed a piece of art. This comes down to chance more than anything.

In between 25 and 7 is again similar, start on 201 to be aggressive followed up by 3 bids of 200 and finished with a bid of 199. The artist bid on will also be the second most common in hopes nobody wants it. If any deviation occurs by more than 1, this strategy will become dominant; something else to hope for. For less than or equal to 7 bidders a test will be carried out using a boolean variable to see if anyone owns the most common artist, if no one owns it then bid 200. However, if someone beats you to it deviate and go for the other three for as cheap as possible whilst upping the other agents' bids by a random integer to reduce the risk of other agents analysing the strategy. This analysing is much more likely when there is less to base the bids off of. The bidding low amounts will allow the agent to attempt to outbid others when they are on the verge of winning hopefully prolonging them long enough to win itself. There is also the last round statement which bids the rest of the agents' money.

Games 1 and 2 use almost identical strategies for good reason, they are almost identical games. The only difference

is what the bids are being based on, either the first time each artist occurs 5 times or the most common; this was due to the increase in imperfect information provided by the domain. The mix between the strategies depending on the number of bidders leads to both performing well. They are implemented in logical manners which take into account many different scenarios.

C. Game 3

Games 3 and 4 both have the same aim for all agents. This aim is to collect the biggest net worth of paintings possible within 200 rounds. For 3 the highest bidder pays their own bid in this and the auction order is known. Whereas the agent pays the second highest bid. The strategies for 3 and 4 were not split into sections for the number of bidders, there is a spit in rounds where a calculation is applied for the last 60 rounds of each game. This is because of the inherent much more patient type of game that is being played.

Game 3, for game three a dictionary was made which contained the prices last paid for each of the artists. This dictionary allowed the agent to outbid the last bidder each time, whilst not outbidding themselves. This strategy is patient and is based on trying to save money so in the later rounds it can outbid others whilst picking up as much art as possible throughout. The maximisation of utility primarily takes into account the price the art is worth not how much you pay for it; if an item is won there is an increase of goal satisfaction to a certain extent due to the increase in net worth. Instead of attempting to analyse and counter other strategies this one leads from the front by following an upper limit to bid below which has been calculated to attempt to find the maximum possible bid for each round without running out of money before the end of the game. The formula which the calculation carries out finds how much the remaining value of the total amount of each artist is and then turns that into a ratio based on how much money is left against the number of bidders. This is done under the assumption they are also all trying to bid on the art. This upper bound that is calculated is used in the first 140 rounds as a limit to bids hopefully getting them for cheaper, and saving some money. Whereas, in the last 60 rounds the upper limit calculation becomes the bidding calculation and bids this peak amount for everything that appears. The number of bidders was tried to be incorporate into this strategy however this seemed much more appropriate due to its efficiency and after it had been tested still performed well. There is a randomness added into the strategy to help prevent the effectiveness of analytical strategies which try to counter the bids being made.

D. Game 4

This game is very similar to 3 it is, however, more aggressive due to the agent paying the second highest bidders price. This will lead to agents attempting to raise the steaks to get others to pay what they are bidding. The assumption that other strategies will be slightly more aggressive leads to the belief that the best approach is to stay patient by only slightly increasing the bidding amount up until this upper boundary which is calculated again. The main difference between the two strategies is larger randomness when carrying out the last 60 rounds adding a random integer between 2 and 12 on top of the upper limit to try and also make others waste money, the maximum random integer raised as to reduce the possible loss. If a Da Vinci is purchased for 12 the extra 12 spent 'breaks even', whereas if a Picasso is won by paying an extra 12 it is losing value. This does not matter in terms of my personal finances however will have an effect on the outcome of the game because the agent will have a bigger pot of money to play with the more tactful financial decisions it carries out. The formula for calculating the upper limit is shown below in figure 2.

```
"""
total = ((itemdict['Van_Gogh'] * 6) + (itemdict['Picasso'] * 4) + (itemdict['Da_Vinci'] * 12) + (itemdict['Rembrandt'] * 8))
mon = standings[mybidderid]['money']
val = values[artist]
num = itemdict[artist]
calc = math.floor((((val * num) / total) * mon) / ((val * num) / numberbidders)) * val)
```

Fig. 2. Upper Limit.

Figure 2 defines the upper limit as calc and rounds it down to the nearest integer as to not cross this limit. This technique proved to be very effective when coming across strategies which were not as adaptive and self-sufficient. There is a final fail safe to bid the rest of the agents' money from round 198 onwards, this is because there is no point in saving any money and it may as well be gambled on an attempt to pick up a last minute piece of art. Another smaller strategy to save money is if everyone else is out of money, bid 1 for everything to make the money go as far as possible.

IV. Conclusion

To conclude these extensive form games have to be approached very differently with all the other agents in mind. The first two games have to be approached with a much more aggressive strategy due to the speed of the game, competing under a round constraint; especially for low numbers of bidders. The strategies for both are split into the number of bidders which is the variable which will affect the length of the game the most. Other more adaptive strategies were used and tested which scaled with the number of bidders and analysed the other agents' strategies to figure out the least favourite artist. These, however, did not perform as well due to their lack of urgency to bid. For these two games, it is best to bid as early as possible. This lead to the belief that manually splitting them by the number of bidders would give an opportunity to hard code very different strategies for very different lengths of games. For a large number of players everyone bidding 200 for a specific artist is as close to a Nash Equilibrium (NE) that will occur, hence why on average it is most likely the best strategy; selecting which artist is the hard bit.

As the numbers reduce for these two games the strategies get much more specific, trying to counter what was assumed to be the most likely strategy to be carried out by all other agents. For less than or equal to 7 players the strategy to play patient for all art rather than only 3 was a major option and was very nearly taken, however if the difference between the first and second artist to occur 5 times is greater or equal to the number of all other players then you are likely to win if you can secure the best artist. This is the main reasoning behind aiming for the best and then deviating to bidding low for others if that does not go well. The key to these first two games is being sensible when there are lots of players and following the NE because of the increased chance of others trying to outbid people. Where was for low numbers is to outplay people, which comes from a bit of guesswork at what their strategy is.

For games 3 and 4, the strategies perform well because of this formula which scales; which is useful because the strategies of the game will not change dramatically for a small number of players. The strategy of sticking to and below a best upper bound plays well in almost all situations, the only strategy which would compete with this is bidding slightly more on the two most expensive paintings (Da Vinci, Rembrandt) and ignoring the least expensive. This would be the dominating strategy to compete against the one the agent is carrying out, however, the strategy, in general, is dominating. With these games there will almost always be a way to counter a strategy, the difficulty is trying to dominate as many as possible. The first 140 rounds being more passive improved the testing of the strategy as it saves money which allows the upper limit to increase for the last 60 rounds making a bigger impact. The randomness in increasing the bids each time prevents other strategies from working out how the agent acts to a certain extent, another very effective method. The strategies for 3 and 4 are likely to perform better than 1 and 2 due to the formula being based on the best case. The likelihood of others implementing strategies which have not found this upper bound is relatively high, hence the confidence in it. The fact that these games have imperfect information makes it harder to predict other strategies and to, therefore, counter them. On the other hand, all the data provided is common knowledge which is useful for this prediction.

If this project was carried out again with a slightly longer time scale an attempt at using reinforcement learning would have been carried out on the strategies, getting them to compete originally against a random one and then against strategies that it comes up with. It would come up with these strategies by analysing the utility payoff of moves and certain bids. For the first two games, it is likely the agent would learn to pay around 200, the hard bit will be having slight variations in the learning approach for a different number of bidders. Or in a perfect world, the learning would take into account a different number of players. Q-learning would be more appropriate due to it learning its own policy, this would still use a tree search and trial a move and see if the 'reward' was good or bad. The other positive of Q-learning is the balance between exploitation and exploration, if it finds a good tactic in its learning process it will favour it but will not settle on it. This exploration is basically trial and error however and can be floored.

The possible strategies and actions for each of the games are hard to visualise and keep track of by a human, even though the attempt to create heuristical strategies is effective and well thought Q-learning might be more appropriate as this would let the computer store analyse and deal with data on a much larger scale. Another interesting concept would be saving information between games to see if evolutionary learning could be applied.

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