https://youtu.be/J-FArPUp16w
COMP90054 AI Planning for Autonomy
Azul Game Project

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1 Introduction

As Azul game is a kind of competitive game which purpose is to grab more points in limited moves, the expected ideal player should not only be able to win the game but also gain as many points as possible. Under such prerequisites, it is necessary for the player to make a rough prediction of the opponent's operation so that more points could be obtained and the score of opponents could be influenced. In each step, the player should pick the optimal option from various predictions under the current situation.

2 Applied Techniques

2.1 Breadth-first Search

In the view of the nature of the Azul game, Breadth-first search was taken the lead in the tentative research and development of blind search. In case of BFS is a general search algorithm, it is easy to implement. However, because of the time limitation, the exploration state space is limited. To ensure that BFS can reach the round-end and return an answer, the state space should be carefully pruning. The moves of the opponent are ordinarily judged by random from some possible good moves, similar to fast move. Besides, the BFS player can only add its move and the move of opponents together to ensure that each state is moving on its own, which causes not as expected performance of BFS.

2.2 Monte Carlo Tree Search

Through a series of previous attempts, we gradually learned that the algorithm we required needs to have the ability to infer the game. After some literature review, it is found that the Monte Carlo Tree Search (MCTS) probably is a suitable method. The basic principle of MCTS is to predict the best strategy through multiple simulations, which is a core component in the implementation of Alpha GO. MCTS will consider the actions of the opponent and make modifications based on the game which is appropriate for the Azul game.

In the actual development process, MCTS is indeed feasible. First of all, the search depth of MCTS is very high, it is capable of quick estimation, and the performance is quite excellent. However, due to the time

limit, MCTS will consume additional time when it is random in the default policy, which allows MCTS to search deeper under simulation, but impossible to converge to the best state desired by state eval in a given budget (search times).

2.3 Alpha-beta Tree Pruning

On this basis, after studying the Deep Blue system, we adopted the Alpha-beta Pruning algorithm, whose search depth is not better than MCTS, but the breadth is wider, and the search is more thorough. This advantage makes the performance and control of the time of min-max players are more optimized than MCTS player.

The designated agent for the final tournament is implemented using the alpha-beta pruning technique which is an optimizing version over the min-max algorithm, the well-known algorithms used quite often in chess-class games. The min-max algorithm has a core based on the idea of a zero-sum game in game theory that for each opposite party within a rivalry, each side maximizes its benefits while affecting the other side losing benefits.

Briefly on min-max, the algorithm searches for the best move, depending on a value denoting the maximum gain of benefits from the opponent's possible following moves. The alpha-beta pruning algorithm improves min-max on eliminating the subtree of that move that is worse than the previous strategy. In other words, it is not necessary to search for the following moves that hardly influence the final result. More efficient on the time factor, the alpha-beta algorithm reaches the same result as min-max algorithms would obtain. The move score is used to determine how valuable each move would be, hence limit the moves selection in the very beginning phases. By doing moves selection, our algorithms performance enhances a lot that the prediction depth increases from 2 to 4 with a reasonable moves limit number.

3 Strengths and Weaknesses

The final tournament agent has multiple strengths. Firstly, the algorithm supports more than two players in one game setting compared to the normal search algorithm which is not designed for this problem scope. Secondly, the nature of pruning extra leaves in the algorithm deduces search time that it is not easy to timeout when an agent makes a decision. Last but not least, the agent has great performance with a fairly high winning rate. Winning factors include the search, state evaluation, and move selection. Although the searching depth in the min-max algorithm is limited, yet having a thorough searching over complete state space ensures the largest state eval within the depth searching range. Since the search depth for our agent is 4 steps in our algorithm that takes advantage of the prediction to ensure the victory.

The final tournament agent has one noticeable weakness on optimizing point gaining when facing weak rivals, and this defect is derived from the min-max algorithm itself. This algorithm is pessimistic and conservative relatively speaking, since the algorithm is based on the assumption that its current opponent

always possesses the same level of strategy as itself. For instance, when confronting a significantly weaker opponent evaluating an objective perspective, the agent notices some greedy moves which are risky yet would yield higher points gaining. As a matter of fact, our agent will disregard such moves, because such local optimal actions would lead to the global minimum, i,e. losing, from agents understanding. For achieving winning as the main task, our agent forfeits chances to take as many advantages over weak opponents. Therefore, this explains the phenomenon that our agent has a great winning rate with weak rivals like random agents, but the scores of the game are not really high.

4 Experienced Challenges

The most significant challenge is the time limit. As there exists restriction for all moves only one second time, nearly 80% of moving time costs on deepcopy. Since simulation is necessary in the step of predicting the opponent, it is must be ensured that one state will not affect the other in the further move. Therefore, deepcopy is crucial for players.

In case of the time limits, the number of deepcopy is restricted. It is essential to improve the algorithm by searching further states with less deepcopy. After that, it has been noticed that the quantity of deepcopy is actually equal to taken moves. Regardless of move execution, the state will not be changed. Hence, move selection is a suitable solution found.

There are also reasonable and unreasonable differences in Moves. There will always be unwise moves to place pieces on the floor line. Besides, moves which take pieces to form a complete assembly is obviously the better option.

Therefore, the introduction of the scoring system is a clever solution dealing with the review of moves. The scoring system will provide each move a corresponding score, which makes it easy to select the optimal solution from the predicting steps. The score gained by a particular move would be recorded after taking the move. Later on, moves selection will be limited to the very beginning serval moves.

On the other hand, parameter adjustment is also a major difficulty in this project. Every game is exactly the same when the random seed is identical. In each game, both players have to play on the red side and the blue side respectively, and finally find the side with the highest overall win rate as the winner. Different parameters are assumed as opponents in the game and seek out the parameters of the winner to further adjust the parameters.

5 Evaluate Performance

Techniques we experimented in this project are BFS, MCTS, and Alpha-beta tree pruning. Performance for each technique is measured and evaluated as wining rate and game score against each other, naive player as baseline, and pre-tournament over 100 games. As a result, overall Alpha-beta tree pruning has the best

overall performance among candidates, thereby we can conclude that alpha-beta tree pruning outplays other algorithms.

BFS	Baseline	MCTS	ABTP
Winning Rate	72%	4%	0%
Tie	1%	1%	0%
Score	40.59	26.96	23.29

Table 1: BSF vs others over 100 games.

MCTS	Baseline	BFS	ABTP
Winning Rate	98%	95%	29%
Tie	0%	1%	3%
Score	50.37	57.58	31.93

Table 2: MCTS vs others over 100 games.

ABTP	Baseline	BFS	MCTS
Winning Rate	100%	100%	68%
Tie	0%	0%	3%
Score	51.89	59.52	39.84

Table 3: ABTP vs others over 100 games.

6 Possible Improvements

In the long history of the match between humans and ai, most of the artificial intelligence that can compete with the world champions have a complete data system, allowing them to train a set of accurate models from the endless self-play. A neural network trained from a large amount of data enables world-class artificial intelligence to analyze the current situation to the extreme. The same is true for the artificial intelligence of Azul games. A huge game data set can train a set of accurate neural networks.

As the initiative of performance depends on the choice of move, A more detailed and professional scoring system will result in more accurate results. In spite of that, an obviously advanced method is to improve the move scoring system by applying deep learning, which would hold much better property than the artificial setting. Using neural networks to conduct a more in-depth analysis of the current situation makes each method as expected. However, the same as the state evaluation, due to the lack of computing power of the game competition and the extremely high complexity of coding, artificially scoring is a last resort.

Self-Reflection

Zhecheng Liu

- I realize the significant of teamwork in this project. My teammates are reliable and when there is something I think is very troublesome my teammates will give me a hand and show his professional. Also, I will try my best to provide any help I can if my teammates have any problems.
- In this project, I review some algorithms that I used before. In this project, I learned MCTS and alpha-beta pruning, which are very efficient and practical. Since I am not so proficient in algorithms, some advanced algorithms are a little bit hard for me to realize and that practice me a lot.
- I played a role in the coordination of team project work and team members and realize part of the code. When there is a problem in the team, I can respond in time and discuss the solution with my teammates. Besides, I think I played a role in regulating the atmosphere in the team's communication.
- I think my programming skills and logical thinking skills need to be improved. Sometimes I cant fulfill my teammates idea on algorithm, which influence the project schedule. In addition, my knowledge reserve is not sufficient enough to discover more and better algorithm.

De Zhang

- Recall from past experience, team working was a bit tricky for me that I was unable to find myself a comfortable place, i.e. role and existence, in the team environment. However, in this wonderful team, my teammates support me and encourage me to take the tasks that I would like to devote my energy into. The outcome is great that I am not only accomplishing the tasks with quality but also finding myself within the team.
- Artificial intelligence is a hot and broad field of study currently that even non-professionals would like to refer it in daily conversation about their understanding upon the future and meaning of AI, and some people might make an unintended joke that the research of AI needs to be stopped so that it wont threaten human future. To be honest, I once was one of those people, due to ignorance. However, in this semester, after digging deeper into the field, I have totally different opinions towards AI as a future practitioner. AI has great potential to accomplish something that either is challenging or trivial for a human to execute. It is a great tool that the technology itself allowed the agent to accomplish certain fields of tasks without explicitly programming for each of them. The future of Ai is worth anticipating, and I am willing to contribute as part of it.
- My best aspect of performance is cooperation that I am confident the teamwork between my teammates is efficient due to well cooperate with each other functioning like gears in a machine. I am fully aware of what position and roles that I am in this team, and I know what benefits I could provide to this

team. Therefore, I trust my teammates that they could finish the tasks well, and they have faith in me as well.

- The area that I need to improve the most is a startup the job earlier than planning in order to manage the time more reasonable. There are multiple assignments due concurrently at the end of the semester, and obviously, the workload is high. I feel that even this time I started to do my jobs in a reasonable early time, yet I could still improve upon it so that the stress would relieve a bit and become more calmly within the tempest.

Xiaoyue Liu

- This project made me realize the significance of teamwork. Sometimes, depending on my personal ability, it may be difficult to accomplish some things. However, in the case of teammates reliable, some difficulties can be solved. I think some tasks are very troublesome, but the teammates will happen to be an expert. For some tasks, teammates will feel powerless and I will help. Teamwork is very fun.

- In this project, I learned some algorithms that I would not normally use. Since I am not proficient in algorithms, some advanced algorithms are hard for me to understand, and I rarely think of it actively. In this project, I learned MCTS and alpha-beta pruning, which are very fashionable and efficient.

- I played a role in the coordination of team project work and team members. Especially when there is a problem with the operation, I can respond in time and discuss the solution. Besides, I think I played a role in regulating the atmosphere in the team's communication.

- I think my programming skills and logical thinking skills need to be improved. Sometimes I cant keep up with my teammates thinking, which slows down the project very much. In addition, my knowledge reserve is not sufficient. I need to learn some new knowledge.