Mancala (Awele)

Year 2023-2024

Sara-Ştefania Cojocaru, Alexandra-Ioana Moldovan, Tudor-Florin Râpă-Bălan, Maria-Alexandra Groza, Rebeca Sturz, Cristian Chiriac, Petru Lungu
Abdessamie Belaziz Sanae, Delaporte Léa, Palau Gabriel

Teachers: Ariana Stanca Văcăreţu, Hubert Proal
Schools: Colegiul Național Emil Racoviţă, Romania ; Lycée Val de Durance, France
Researcher: Yves Papegay, INRIA - Sophia Antipolis Méditerranée Research Center

I. Introducing the research topic

Mancala is a strategy game where two players take turns to move pieces on a wooden board. There are many variants of this game played worldwide, the rules being slightly different in each of them. In this article, we will focus on the version of Mancala called Awele. The game is played on a wooden board with 12 pits distributed in two rows and requires 48 seeds, each pit containing, at the beginning of the game, 4 seeds. Therefore in order to win you have to collect at least 25 seeds (half of 48 +1).On the sides there are 2 additional bigger pits named houses- these are where each player will try their best to have as many seeds as possible. Our problem was to find a solution to this game, to create a strategy with 100% chance of success.

Fig. 1 Practical project made by the Romanian students for their fair

II. RULES

In order to state the rules, some terms we used must be defined. *Sowing* refers to the action of distributing seeds throughout the board. The term *mancalas* refers to the bigger pits in which the seeds you win are collected.

The basic rules of the version of Mancala we had to solve are:

1. Play always moves around the board in a counter-clockwise circle (to the right);
2. The mancala on your right belongs to you. That is where you keep the seeds you win;
3. The six pits near you are your pits;
4. Once you touch the seeds in a pit, you must move those seeds;
5. Only put seeds in your own store, not your opponent's store.

Special rules for this specific version:

1. On a turn, a player picks up all the seeds in one pit and sows them in a counter-clockwise manner, placing one seed in each of the pits along the way. If you pass by the mancala, you add a seed to your store and continue. You may end up putting seeds in your opponent's pits along the way.
2. When the last seed in your hand lands in your mancala, you receive a free turn;
3. When the last seed in your hand lands in one of your own pits, if that pit is empty you get to keep all of the seeds in your opponent's pit on the opposite side. Put those captured seeds, as well as the last seed that you just played on your side, into the mancala.

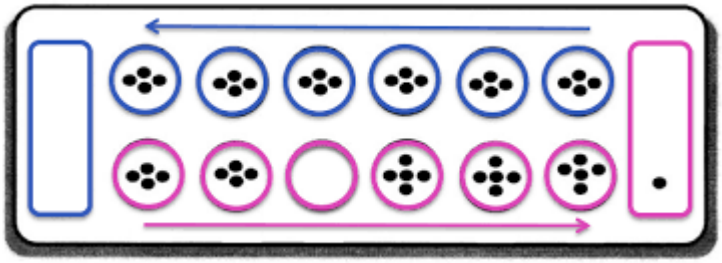

Fig. 2 Mancala board

III. APPROACH

At first, we wanted to understand the game better, therefore we tried all sorts of online apps. After a few days we saw how many different versions there are, some are solvable while others are not yet completed. All of the teams who contributed to this research decided to use an app as a first reference. We analysed the algorithm of the AI which the app was using and tried to optimise it. In order to do this, we needed to find some basic strategies to create our starting point.

So, we competed with our teammates and tried to solve the puzzles the app had to offer, which helped us make the best moves in certain situations and develop some techniques.

While the Romanian teams used the app in order to construct strategies and analyse the software trained to win Mancala, the French team spent a good amount of time calculating specific positions. They considered that because the value of a strategy is very positional, an absolute statement for the best strategies is not what we should strive for, all of them are useful if given the right position. Therefore, the teams focused their research on establishing a hierarchy to value each and every move and therefore the value of the position and of the future positions.

IV. ALGORITHM AND STRATEGIES

i TECHNIQUES

In order to be able to start developing a strategy, we needed to find certain techniques that would help us solve this game. Of course, we soon realised there is not a singular way towards the win, but we discovered that if you combine the following 5 steps you have a high chance to win:

- **Overstacking**
- **Empty next to your house**
- **Maximum free moves**
- **Gathering seeds**
- **Capturing seeds / forcing move**

Over stacking:

• The strategy is to give your opponent as many seeds as possible.
• Your opponent will be forced to redistribute the seeds on your side.
• This strategy only works if we keep the number of "gifted" seeds under 7 in one of the spaces to prevent the seeds from returning to his side of the board.

Empty next to your house:

• This strategy involves intentionally leaving the spaces next to your house empty or almost empty, aiming to maximise the number of free moves.
• You will need to gather your seeds in the spaces farther away from your house.
(French group) Consequences : You need more seed in the spaces farther away to be able to play again (free move)

At the end of your turn (and especially if the opponent is forced to play a “giving” move) you should always have in as many spaces as possible n-1 seeds to maximise your maximum free moves.

Maximum free moves:

• In situations where there is an opportunity to make moves that provide free moves, in most of the cases it's the best chance you've got.
• If there are multiple such moves, you should do them in the order that offers you maximum free moves. (French group) In other words in a manner that takes into account

the proximity of the “free move” space with your house the closest should then be the first to be sowed. We called this the chain rule.

Gathering seeds:

• Towards the end of the game, when your opponent has exhausted all available moves, you will strategically make moves that keep the seeds on your side of the board.
• This only works if you have more available moves than the opponent.

Capturing seeds:

• During the final stages of the game, it is advisable to leave empty spaces on your side corresponding to spaces where your opponent still has seeds.
• Capturing them consists of having the last seed end up in an empty space matching a space with multiple seeds on your opponent's side of the board.

Still, we managed to find an algorithm that has helped us win many times.
First, you over stack the seeds on the other side of the board. Then, you try to empty the spaces right next to your house to maximise the number of free moves. During the final stages of the game, you should start gathering seeds and capturing your opponent's seeds, making it easy to obtain multiple points in only one turn.
Obviously, there are numerous variables when playing a game of mancala. Each person has its own unique way of playing, so it’s never guaranteed you’ll win with only one strategy.

ii PARTICULAR STRATEGIES

After numerous attempts at trying to find the best strategy for player 1, we figured that the starting move we considered as being optimal can be replaced with a better move. Initially, the strategy implied that player 1 should always start with pit number 3, so that a free move is granted from the beginning. Later we realised that the free move gained from this is not really useful and can lead to blunders in player 1’s game. A better method we found suggests that the best starting move for player 1 is pit number 1. Surely, this will not grant a free move from the start, but it allows player 1 to block player 2’s potential winning moves. After analysing the way certain artificial intelligences play Mancala, we noticed that player 2, in this case, will most likely play pit number 5, earn a free move, and then play pit number 6. Here, player 1 starts to gain consecutive advantages. By playing pit number 4, followed by pit number 1, and then finally pit number 5, player 1 forces player 2 to deposit his seeds on the opponent’s side. This strategy assures in most cases that the player who starts the game will also win it, but we’ve only tested it against AIs and it is possible that with strategic thinking, player 2 can win against it.
Another strategy found by the French team was using an opening that combines both advantages; by playing first pit number 3 then number 6 there are occurring substantial improvements in the winning percentages as the player 1 (72%), this move allows to play again and “blocking” the opponent’s pit number 4 “forcing him” to play pit number 5.

iii ALGORITHM DEVELOPMENT

Some versions of Mancala have been solved with the help of computers in the past (most notably Awari, Kalah and Ohvalhu). Awale however still stands as an unsolved variant of the Mancala game. We were able to come up with two possible reasons for this: either the general interest in this variant of the game is much lower than in others, and therefore no one has devoted significant computational resources to calculate deep move trees, or the amount of board states and plays in Awale is much larger than those in other variants of Mancala due to the extra-turn rule. Since we couldn't really evaluate the first theory, we decided to try and see for ourselves how complicated the game really gets for a computer.

In order to get a simple program going that could look ahead, we decided to implement a minmax algorithm, optimised with AB-pruning. Minmax is a conceptually simple algorithm that involves descending into the tree of all possible moves up to a certain set depth (8-10 moves in our case) using recursive calls of the minmax function on each possible move in a board state. Once the maximum depth is reached, the function returns the current score (the difference between the number of pebbles in each house), and then each function call, depending on the player whose move it's evaluating tries to either minimise or maximise this difference.

Minmax itself is definitely not a very fast or optimised algorithm, quite the contrary actually. Therefore, in order to avoid a full-on brute-force solution we attempted to optimise the algorithm using AB-pruning, which is, in essence, a way of discarding branches that are evaluated as suboptimal at a lower depth without losing precision, thereby allowing a shrinkage in the number of states that require calculation on each level. Surprisingly, this was so effective in our case that it enabled us to extend our computation depth by 4-5 moves with no significant increase in computation time.

In the same spirit the French group has tried creating a neuron system using AI. This system uses the same concept as a reward reinforcement system in AI learning also known as reinforcement learning or RL. By giving coefficients, we evaluate the value of each move and therefore the value of each position so we can maximise the gains. We just have to adjust the depth of the AI to see the move forcing the best course of option. One use of this evaluation would be to establish a graph modelling the evolution of the game, as in chess or the development of an AI that, if given enough time using RL, will know what to choose to win.

V. RESULTS AND CONCLUSIONS

To conclude our research, we wrote some final thoughts about the best way to play the game, the possible ways to gain an advantage and future development directions and areas, as well as whether there was a first player advantage, and if there were a way to fully solve the game, similar to Tic-Tac-Toe.

First of all, Player 1 seems to have an obvious advantage as he moves first, respectively his first choice can totally unbalance the game. The right strategic moves would enable the acquisition of a number of free moves, respectively gaining an advantage early on in the match.

Second of all, as in any other game from the tactical and strategic point of view, calculating a couple of possible variations and moves ahead is a requirement to form a good understanding of a

certain position and to be sure of what to play next. This can be done by thinking of ways to achieve the scenarios described before, in **IV.i ALGORITHM AND STRATEGIES – TECHNIQUES**.

As of now a mathematical formula or a specific algorithm was not discovered by us to develop in any way to completely solve the game. Most current full-algorithmic solutions fail to reach a sufficient amount of future-sight to prevent any miscalculations, as a lot of techniques can be easily used throughout a whole game, requiring a lot of moves for preparation. Only efficient strategies more or less seem attainable for now. As such, following the afore-mentioned stratagems and potentially memorising certain small-case scenarios is to date the only proper way of playing the game well.

In the future, with increased computational power, a solution could be created with the use of a software that will be able to reach an increased depth of analysis, solving to a certain degree the game, and eventually, with supercomputers with near-unlimited computing abilities, transform Mancala into a fully solved game.