Informatik II (D-ITET)

Tutorial 10

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L9.A1a,b,c – Game Tree Min-Max

MAX strategy

Height: 4
Search Depth: 3
Best path: left
L9.A1d – The \( \alpha \)-\( \beta \) algorithm

- The \( \alpha \)-\( \beta \) algorithm
  - Reduces the game tree through pruning, but delivers the MiniMax value of the root in the same way as the MiniMax algorithm
  - The MinMax algorithm evaluates the whole search tree. In this case, nodes that don't influence the outcome (choice of the branch at the root) are also evaluated. The Alpha-Beta search ignores those nodes.

- \( \alpha \)
  - The maximum lower bound of possible solutions
  - Is relevant for the evaluation of Min nodes (Evaluation of the successors can be aborted as soon as the computed return value is below \( \alpha \))

- \( \beta \)
  - The minimum upper bound of possible solutions
  - Is relevant for the evaluation of Max nodes (Evaluation of the successors can be aborted as soon as the computed return value is above \( \beta \))
L9.A1d – The Tree

\[ \alpha \]

\[ \beta \]

\[ \alpha \]

\[ \beta \]
L9.A2a – Min-Max

- Two helping methods:
  - `max(...)`
  - `min(...)`

- Idea: `max()` and `min()` call each other in turns

- Until we reach depth `d`
  - `nextMove()`

```java
public Coordinates nextMove(GameBoard gb){
    BestMove bestMove = null;

    bestMove = max(min(d, gb, 0));

    return bestMove.coord;
}
```

```java
class BestMove {
    public Coordinates coord;
    public int value;
    public boolean cut;
    //whether it was cut at the maximum recursion depth
}
```
private BestMove max(int maxDepth, GameBoard gb, int depth) {
    if (depth == maxDepth) return new BestMove(eval(gb), null, true);

    ArrayList<Coordinates> availableMoves = getMovesFor(myColor, gb);
    if (availableMoves.isEmpty()) {
        if (gb.isMoveAvailable(otherColor)) {
            BestMove result = min(maxDepth, gb, depth + 1);
            return new BestMove(result.value, null, false);
        } else
            return new BestMove(finalResult(gb), null, false);
    }

    // initialize bestMove with worst possible values
    BestMove bestMove = new BestMove(minEval(gb) - 1, null, false);
    for (Coordinates coord : availableMoves) {
        GameBoard hypothetical = gb.clone();
        hypothetical.checkMove(myColor, coord);
        hypothetical.makeMove(myColor, coord);

        BestMove result = min(maxDepth, hypothetical, depth + 1);
        bestMove.cut = bestMove.cut || result.cut;

        if (result.value > bestMove.value) {
            bestMove.coord = coord;
            bestMove.value = result.value;
        }
    }
    return bestMove;
}
L9.A2b – timeLimit

- Timeout per move:
  - `nextMove()` has to return a valid move before the time-out of `timeLimit` milliseconds

```java
public Coordinates nextMove(GameBoard gb) {
    long timeout = System.currentTimeMillis() + timeLimit - 10;
    BestMove bestMove = null;
    try {
        bestMove = max(1, timeout, gb, 0);
    } catch (Timeout e) {
        throw new AssertionError("oh oh, not enough time for depth 1");
    } catch (AssertionError e) {
        throw new AssertionError("oh oh, not enough time for depth 1");
    }
    return null;
}
```

class Timeout extends Throwable{
}

private BestMove max(int maxDepth, long timeout, GameBoard gb, int depth) throws Timeout
{
    if( System.currentTimeMillis() > timeout )
        throw new Timeout();

    if( depth == maxDepth ){
        return new BestMove( eval(gb), null, true );
    }

    ... 

    return bestMove;
}
L9.A2c – Evaluation function

- Propositions for possible, static evaluations:
  - **Agility**
    - How many moves are possible for me / my opponent?
  - **Rows**
    - How many rows of connected counters are there?
    - How long are they? Their location is also interesting!
    - A fully occupied border is really good, while a long sequence in the opponent's can potentially allow for good moves
  - **How many counters...**
    - Will be flipped by a given move and in how many directions? Are the counters lying inside the board or in the borders?
  - **How many counters...**
    - Of a specific color are lying on the board? (That might be the evaluation function for the final game, when a thorough analysis of the search tree is possible. In the middle of the game, this might be inappropriate.)
  - **Positions**
    - To be evaluated on the field (e.g. corner points)
HINTS FOR EXERCISE SHEET 10

A1 – Mergesort
A2 – Towers of Hanoi
A3 – Reversi (Part 4)
Mergesort

- Is a recursive and stable sort algorithm, which is based on the divide and conquer principle
- It was developed in 1945 by John von Neumann

Divide and conquer principle

- Separate the enemies to vanquish them
- Political and military strategy
- Was already applied in the Roman empire

John von Neumann
1903 Budapest – 1957 Washington
Mergesort

Consider the data to be sorted as a list and decompose it into smaller lists, which will have to be sorted.

The smaller sorted lists are merged together in a zipper way, until one common list is achieved.
U10.A1b – Implementation

- **ISort** defines an interface
  - *ISort.sort* takes an *ArrayList* and return a new sorted *ArrayList*

- **MergeSort.java** (build)
  - Implement the **ISort** interface
  - Tip: recursive helping method
  - Tip: one does not always build a new list, but one can play with beginning-end indices
U10.A1c,d – Measure.java

- 10 "measured points"
  - Make sure that the random arrays are built outside the time measurements!

- Repeat the measurements
  - Ignore both min and max (extreme values)
  - Take the average of n measurements (overall n+2 measurement runs)

- Build a diagram
  - Your favorite tool (e.g.: GNUplot, Excel, Matlab, …)
  - Deliver a graphic
  - Interpretation must add up!
U10.A2 – Hanoi Towers

- In the lecture
  - Recursive solution to the problem

- The only possibility is to move the bottommost (largest) disc from tower 1 to tower 3:
  - (a) There is nothing else on tower 1
  - (b) Tower 3 is empty

- From (a) and (b) derives:
  - All other discs are on tower 2!
  - At first, the n-1 other discs must be moved from tower 1 to tower 2
U10.A2 – Hanoi Towers

- Solution for the 3-disc case
  - Name the 3 towers from left to right 1, 2, 3 and the discs from the smallest to the largest A, B, C
  - Then use the number-letter pair to indicate where a disc has to be moved
  - C2 means for example that the largest disc has to be moved to the tower in the middle.

- Steps for the solution:
  - A3, B2, A2, C3, A1, B3, A3 (7 steps)
U10.A2.a/b

- Identify regularities:
  - For each step in the execution of the recursive algorithm of the lecture, exactly one tower is \textbf{not} necessary.
  - When shifting a tower of height 4 in 15 steps, give the sequence of tower number that is \textbf{not} used.
U10.A2b,c – Pseudo-code

- Describe all "developed" algorithms in pseudo-code
  - For the starting tower of height 4
  - Are adaptations necessary when starting with a tower of height 5?
# Hints for U10.A3 – Reversi (Part 4)

<table>
<thead>
<tr>
<th>Player Type</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HumanPlayer</td>
<td>nextMove()</td>
<td>Waits for entry from command line</td>
</tr>
<tr>
<td>RandomPlayer</td>
<td>nextMove()</td>
<td>Chooses a random (but valid!) next move</td>
</tr>
<tr>
<td>GreedyPlayer</td>
<td>nextMove()</td>
<td>Chooses the next move by means of an easy and non-recursive evaluation function</td>
</tr>
<tr>
<td>MinMaxPlayer</td>
<td>nextMove()</td>
<td>Choose the next move by means of a Minimax analysis through a new evaluation function</td>
</tr>
<tr>
<td>α-β-Player</td>
<td>nextMove()</td>
<td>Chooses the next move by means of the α-β analysis with your own evaluation function</td>
</tr>
</tbody>
</table>

Download | Übung 7 | Übung 8 | Übung 9 | Übung 10
Hints for U10.A3a – Reversi (Part 4)

- Build an evaluation function, which follows the $\alpha$-$\beta$ process, which produces the same result as the pure Minimax method of the previous exercise sheet.

- $\alpha$-$\beta$ algorithm
  - Beware that in this exercise, the algorithm of the lecture is requested, not one of its adaptation.
  - Implement a move abort through a throwable timeout.
Reversi Tournament

- Wednesday, June 01, 2016, 12:30, CABinett (Stuz2).
- Submission:
  - Deadline: Wednesday, May 25, 2016, 23:59 (Zürich Time)
  - Submit on the Reversi Platform
    http://www.vs.inf.ethz.ch/edu/FS2016/I2/reversi/#platform
  - You can work alone or in groups of two
- Cool prizes!
Have fun!