Outlook

- Exercise 9: Solution discussion
- Exercise 10: Overview (Mergsort, Hanoi Towers, Reversi)
U9.A1 – Game Theory

- Components of a game tree
  - Root → Beginning (state before any move)
  - Node → Possible state of the game
  - Edge → Move
  - Leaf → End of the game (final state)
L9.A1a,b,c – Game Tree Min-Max

MAX strategy

Height: 4
Search Depth: 3
Best path: left
L9.A1d – The α-β algorithm

- The α-β algorithm
  - Reduces the game tree through pruning, but delivers the MinMax value of the root in the same way as the MinMax 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 largest known value of all MAX treatments of the MIN nodes
  - 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 largest known value of all MIN treatments of the MAX nodes
  - 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

MAX

MIN

MAX

MIN
**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
class BestMove {
    public Coordinates coord;
    public int value;
    public boolean cut;
    // whether it was cut at the maximum recursion depth
}

public Coordinates nextMove(GameBoard gb) {
    BestMove bestMove = null;
    bestMove = max(d, gb, 0);
    return bestMove.coord;
}
```
L9.A2a – Min-Max – max(…)  

```java
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);
    }

    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
  - `nextMove()`

```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");
        return null;
    }
    try {
        for (int i = 2; bestMove.cut; i++)
            bestMove = max(i, timeout, gb, 0);
    } catch (Timeout e) {} } return bestMove.coord;
```

L9.A2b – timeLimit – Timeout

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.A3c – 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)
Outlook

- Exercise 9: Solution discussion
- Exercise 10: Overview (Megsort, Hanoi Towers, Reversi)
Mergesort

- Is a recursive and stable sort algorithm, which is based on the divide and conquer principle
- 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
U10.A1a – Manual work

- 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

http://upload.wikimedia.org/wikipedia/commons/c/cc/Merge-sort-example-300px.gif
**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
10 "measured points"
- Make sure that the random arrays are built beyond 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
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 not necessary.
  - When shifting a tower of height 4 in 15 steps, give the sequence of tower number that is 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?
<table>
<thead>
<tr>
<th></th>
<th>HumanPlayer</th>
<th>RandomPlayer</th>
<th>GreedyPlayer</th>
<th>MinMaxPlayer</th>
<th>α-β-Player</th>
</tr>
</thead>
<tbody>
<tr>
<td>nextMove()</td>
<td>nextMove()</td>
<td>nextMove()</td>
<td>nextMove()</td>
<td>nextMove()</td>
<td>nextMove()</td>
</tr>
<tr>
<td></td>
<td>Waits for entry from command line</td>
<td>Chooses a random (but valid!) next move</td>
<td>Chooses the next move by means of an easy and non-recursive evaluation function</td>
<td>Choose the next move by means of a Minimax analysis through a new evaluation function</td>
<td>Chooses the next move by means of the α-β analysis with your own evaluation function</td>
</tr>
</tbody>
</table>

**Excersie 7**

**Excersie 8**

**Excersie 9**

**Excersie 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 Minmax 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

- Tournament: Wednesday 28, 2014, 14:15, CABinett (Stuz2).
- Submission:
  - Deadline: Wednesday, May 21, 2014, 23:59 (Zürich Time)
  - Send to Leyna Sadamori (leyna.sadamori@inf.ethz.ch)
  - You can work alone or in groups of two

A few pieces of advice concerning the tournament
- Start with writing the Idea for the evaluation function in pseudo-code
- Keep developing the pseudo-code
- The pseudo-code yields hints about how the information about the next move should be computed
- Keep implementing the different versions of the pseudo-code for the tournament player
Have Fun!