Mitzi - Exercise 3

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January 22, 2014

Contents

1 Our Final Code

1.1 ChessGame.java

```
package mitzi;

import mitzi.IMove;
import mitzi.RandyBrain;

/**
 * The environment for playing chess
 *
 */
public class ChessGame {

  private static GameState game_state;

  public static void main(String[] args) {

    System.out.println("Lets play chess!");

    IMove move;

    game_state = new GameState();

    RandyBrain randy = new RandyBrain();
    HumanBrain human = new HumanBrain();
    //MitziBrain mitzi = new MitziBrain();

    while (true) {
      //Humans turn
      human.set(game_state);
      move = human.search(0, 0, 0, false, null);
      game_state.doMove(move);
      if (game_state.getPosition().isMatePosition()) {
        System.out.println("You won!");
        break;
      }
      if (game_state.getPosition().isStaleMatePosition()) {
        System.out.println("Draw!");
        break;
      }
      System.out.println(game_state.getPosition());

      //Randys turn
```

```
      randy.set(game_state);
      move = randy.search(0, 0, 0, false, null);
      System.out.println("Randy plays:" + move);
      game_state.doMove(move);
      if (game_state.getPosition().isMatePosition()) {
        System.out.println("You lost!");
        break;
      }
      if (game_state.getPosition().isStaleMatePosition()) {
        System.out.println("Draw!");
        break;
      }
      System.out.println(game_state.getPosition());

      /*
      //Mitzis turn
      mitzi.set(game_state);
      move = mitzi.search(100000, 100000, 6, false, null);
      System.out.println("Mitzi plays:" + move);
      game_state.doMove(move);
      if (game_state.getPosition().isMatePosition()) {
        System.out.println("You lost!");
        break;
      }
      if (game_state.getPosition().isStaleMatePosition()) {
        System.out.println("Draw!");
        break;
      }
      System.out.println(game_state.getPosition());
      */
    }

  }

}
```

1.2 Piece.java

```
package mitzi;

/**
 * An enum containing the different Pieces
 */
public enum Piece {
```

```
  PAWN, ROOK, BISHOP, KNIGHT, QUEEN, KING;
}
```

1.3 Side.java

```
package mitzi;

/**
 * An enum containing the two different sides.
 *
 */
public enum Side {
  BLACK, WHITE;

  /**
   * returns the opposite side of the given side
   * @param side the given side
   * @return the opposite side
   */
  public static Side getOppositeSide(Side side) {
    switch (side) {
    case BLACK:
      return WHITE;
    default:
      return BLACK;
    }
  }

  /**
   * returns the side sign of the given side
   * @param side the given side
   * @return -1 if side == black, 1 otherwise.
   */
  public static int getSideSign(Side side) {
    switch (side) {
    case BLACK:
      return -1;
    default:
      return +1;
    }
  }
}
```

1.4 PieceHelper.java

```
package mitzi;

import java.util.Locale;

public final class PieceHelper {

  /**
   * A String for the algebraic names of the pieces. P... Pawn, R... Rook,
   * etc.
   */
  public static final String[] ALGEBRAIC_NAMES = { "P", "R", "N", "B", "Q",
      "K" };

  private PieceHelper() {
  };

  /**
   * Converts a Piece of a given Side into string. Capital letters are white,
   * lower case letters are black.
   *
   * @param side
   *          the gives side
   * @param piece
   *          the given piece
   * @return the string representation of the piece.
   */
  public static String toString(final Side side, final Piece piece) {
    return toString(side, piece, false);
  }

  /**
   * Converts a Piece of a given Side into string. Capital letters are white,
   * lower case letters are black. Additionally, you have the choice to omit
   * writing a P for pawn.
   *
   * @param side
   *          the gives side
   * @param piece
   *          the given piece
   * @param omitPawnLetter
   *          if the pawnletter should be omitted or not.
   * @return the string representation of the piece.
   */
  public static String toString(final Side side, final Piece piece,
```

```
      final boolean omitPawnLetter) {

    if (omitPawnLetter && piece == Piece.PAWN) {
      return "";
    } else if (side == Side.BLACK) {
      return pieceToString(piece).toLowerCase(Locale.ENGLISH);
    } else {
      return pieceToString(piece);
    }
  }

  /**
   * converts a given piece into a string, no distinction which side.
   *
   * @param piece
   *          the given piece
   * @return the string representation.
   */
  private static String pieceToString(final Piece piece) {
    switch (piece) {
    case PAWN:
      return "P";
    case ROOK:
      return "R";
    case KNIGHT:
      return "N";
    case BISHOP:
      return "B";
    case QUEEN:
      return "Q";
    default:
      return "K";
    }

  }

}
```

1.5 SquareHelper.java

```
package mitzi;

import java.util.ArrayList;
import java.util.HashSet;
```

```
import java.util.LinkedList;
import java.util.List;
import java.util.Set;

/**
 * In brief, each square of the chessboard has a two-digit designation. The
 * first digit is the number of the column, from left to right from White's
 * point of view. The second digit is the row from the edge near White to the
 * other edge.
 *
 * @see <a href="https://en.wikipedia.org/wiki/ICCF_numeric_notation">ICCF
 *      numeric notation</a>
 */
public final class SquareHelper {

  /**
   * the letters of the columns of the chessboard
   */
  private static final String[] letters = { "a", "b", "c", "d", "e", "f",
      "g", "h" };

  /**
   * stores all squares in a certain direction for a certain source square
   */
  private static ArrayList<ArrayList<List<Integer>>> squares_direction = new
      ArrayList<ArrayList<List<Integer>>>();

  /**
   * stores all squares reachable for the knight from a certain source square
   */
  private static ArrayList<List<Integer>> squares_direction_knight = new
      ArrayList<List<Integer>>();

  public static LinkedList<Integer> all_squares = new LinkedList<Integer>();

  private SquareHelper() {
  };

  static {
    //initialize with null
    for (int i = 0; i < 89; i++) {
      squares_direction.add(null);
      squares_direction_knight.add(null);
    }

    for (int i = 1; i < 9; i++)
```

```
    for (int j = 1; j < 9; j++) {
      int source_square = getSquare(i, j);
      all_squares.add(source_square);
      ArrayList<List<Integer>> dir_list = new ArrayList<List<Integer>>();
      for (int k = 0; k < 9; k++)
        dir_list.add(null);
      ArrayList<Integer> dir_list_knight = new ArrayList<Integer>();

      // compute squares for pieces except the knight
      for (Direction dir : Direction.values()) {
        ArrayList<Integer> square_list = new ArrayList<Integer>();

        int square = source_square + dir.offset;
        while (isValidSquare(square)) {
          square_list.add(square);
          square += dir.offset;
        }
        dir_list.set(dir.ordinal(), square_list);
      }

      // squares for Knight
      for (Direction dir : Direction.values()) {

        int square = source_square + dir.knight_offset;
        if (isValidSquare(square)) {
          dir_list_knight.add(square);
        }
      }
      squares_direction.set(source_square, dir_list);
      squares_direction_knight.set(source_square, dir_list_knight);
    }

}

/**
 * Returns the integer value of the square's column. Starting with 1 at
 * column a and ending with 8 at column h.
 *
 * @return the integer value of the square's column.
 */
public static int getColumn(int square) {
  return square / 10;
}

/**
 * Returns the integer value of the square's row. Where row 1 is row 1 and
```

```
 * so forth, obviously.
 *
 * @return the integer value of the square's row.
 */
public static int getRow(int square) {
  return square % 10;
}

/**
 * Returns the square-number for a given row and column. Row 1 and column 2
 * results in 12.
 *
 * @return the integer value of the square
 */
public static int getSquare(int row, int column) {
  return 10 * column + row;
}

/**
 * Check if the square is white on a traditional chess board.
 *
 * @param square
 *           the integer code of the square
 *
 * @return true if the square is white and false otherwise
 */
public static boolean isWhite(int square) {
  return (square / 10 + square % 10) % 2 != 0;
}

/**
 * Check if the square is black on a traditional chess board.
 *
 * @param square
 *           the integer code of the square
 *
 * @return true if the square is black and false otherwise
 */
public static boolean isBlack(int square) {
  return !isWhite(square);
}

/**
 * returns all squares in all possible directions for a given source square
 *
 * @param square
```

```
     *           the source square
     * @return an ArrayList, indexed by the ordinal of the direction, containing
     *         a List of squares in the desired direction
     */
    public static ArrayList<List<Integer>> getSquaresAllDirections(int square) {
      return squares_direction.get(square);
    }

    public static List<Integer> getAllSquaresInDirection(
        ArrayList<List<Integer>> squares, Direction direction) {
      return squares.get(direction.ordinal());
    }

    /**
     * Gives an ordered List of squares going in a straight line from the source
     * square.
     *
     * @param source_square
     *           the square from where to start
     * @param direction
     *           one of the values SquareHelper.EAST, SquareHelper.NORTHEAST,
     *           SquareHelper.NORTH,
     * @return the list of squares ordered from the source_square to the boards
     *         edge
     */
    public static List<Integer> getAllSquaresInDirection(int source_square,
        Direction direction) {

      return squares_direction.get(source_square).get(direction.ordinal());
    }

    /**
     * Gives a List of squares reached by a knight from the source square (in no
     * specific order).
     *
     * @param source_square
     *           the square from where to start
     * @return the list of squares a knight can reach
     */
    public static List<Integer> getAllSquaresByKnightStep(int source_square) {

      return squares_direction_knight.get(source_square);
    }

    /**
     * Checks if the integer value of the square is inside the board's borders.
```

```
 *
 * @param square
 *          the square to be checked
 * @return true if the square is on the board
 */
public static boolean isValidSquare(int square) {
  int row = getRow(square);
  int column = getColumn(square);
  return (row >= 1 && row <= 8 && column >= 1 && column <= 8);
}

/**
 * Returns a string representation of the square in algebraic notation.
 *
 * Each square is traditionally identified by a unique coordinate pair
 * consisting of a letter and a number. The vertical columns from White's
 * left (the queenside) to his right (the kingside) are labeled a through h.
 * The horizontal rows are numbered 1 to 8 starting from White's side of the
 * board. Thus, each square has a unique identification of a letter followed
 * by a number. For example, the white king starts the game on square e1,
 * while the black knight on b8 can move to open squares a6 or c6.
 *
 * @return a string representation of the square in algebraic notation.
 */
public static String toString(int square) {
  return letters[getColumn(square) - 1]
      + Integer.toString(getRow(square));
}

/**
 * converts the string representation of a square into a the ICCF notation.
 *
 * @param notation
 *          the given square in string notation
 * @return the square in integer representation.
 */
public static int fromString(String notation) {
  int i = 0;
  while (letters[i].charAt(0) != notation.charAt(0)) {
    i++;
  }
  return (i + 1) * 10 + Character.getNumericValue(notation.charAt(1));
}

/**
 * returns the number for the i_th row seen from a given side. i.e. the last
```

```
   * row for black is 1, the 3rd row for white is 3, the 3rd row for black is
   * 6;
   *
   * @param side
   *           the given side
   * @param i_th
   *           the i_th row, where the (global) row number is wanted.
   * @return the (global) row number.
   */
  public static int getRowForSide(Side side, int i_th) {
    if (side == Side.BLACK)
      return 9 - i_th;
    else
      return i_th;
  }

}
```

1.6 IBrain.java

```
package mitzi;

import java.util.List;

public interface IBrain {

  /**
   * Before the engine is asked to search on a game state, there will always
      be
   * this command to tell the engine about the current game state.
   *
   * @param game_state
   *           the current game state
   */
  public void set(GameState game_state);

  /**
   * Start calculating on the current position.
   *
   * @param movetime
   *           search for exactly this time in milliseconds
   * @param maxMoveTime
   *           search for at most this time in milliseconds
   * @param searchDepth
```

```
   *           the maximum search depth in plys
   * @param infinite
   *           If set to true, search until the "stop" command. Do not exit
   *           the search without being told so in this mode!
   * @param searchMoves
   *           Restrict search to this moves only. If null, the engine may
   *           search any moves.
   * @return the hopefully best move
   */
  public IMove search(int movetime, int maxMoveTime, int searchDepth,
      boolean infinite, List<IMove> searchMoves);

  /**
   * Stop calculating immediately and return the best move.
   *
   * @return the currently best move
   */
  public IMove stop();

}
```

1.7 IMove.java

```
package mitzi;

public interface IMove {

  /**
   *
   * @return the source of the move
   */
  public int getFromSquare();

  /**
   *
   * @return the destination of the move
   */
  public int getToSquare();

  /**
   *
   * @return the promotion of the pawn. EMPTY if no promotion.
   */
  public Piece getPromotion();
```

```
  /**
   *
   * @return the string representation of the move
   */
  public String toString();

}
```

1.8 IPosition.java

```
package mitzi;

import java.util.List;
import java.util.Set;

/**
 * This class provides an interface for a generic chess for the positions on a
 * chess board.
 *
 */
public interface IPosition {

  /**
   * Sets the board to the initial position at the start of a game.
   */
  public void setToInitial();

  /**
   * Sets the board to a position given in Forsyth-Edwards Notation (FEN).
   *
   * @see <a
   *
      href="https://en.wikipedia.org/wiki/Forsyth-Edwards_Notation">Wikipedia
   *      - Forsyth-Edwards Notation</a>
   */
  public void setToFEN(String fen);

  /**
   * Return an independent copy of the IPosition.
   *
   * @return the copy
   */
  public IPosition returnCopy();
```

```
/**
 * Performs the given move and returns a new position. There is no check,
 * that the performed move is legal!
 *
 * @param move
 *           the move, which should be performed. Please note, that the
 *           move must be valid, no checking is done.
 * @return the new board and a boolean, if the half_move_clock should be
 *         reseted.
 */
public IPosition doMove_copy(IMove move);

/**
 * Performs the given move on the actual board. There is no check, that the
 * performed move is legal!
 *
 * @param move
 *           the move, which should be performed. Please note, that the
 *           move must be valid, no checking is done.
 */
public void doMove(IMove move);

/**
 * Reverts the given move. In addition a stack is used to recover the whole
 * information. There is no check, that the performed move is legal!
 *
 * @param move
 *           the move, which should be performed. Please note, that the
 *           move must be valid, no checking is done.
 */
public void undoMove(IMove move);

/**
 * Returns, which side has to move.
 *
 * @return the active Side of the actual position
 */
public Side getActiveColor();

/**
 * En passant target square. If there's no en passant target square, this is
 * -1. If a pawn has just made a two-square move, this is the position
 * "behind" the pawn. This is recorded regardless of whether there is a pawn
 * in position to make an en passant capture.
 *
```

```
     * @return the square "behind" the pawn which can be take en passant
     */
    public int getEnPassant();

    /**
     * Check if the king can use castling to get to a specified square.
     *
     * @param king_to
     *           the square to be checked
     *
     * @return true if the king is allowed to move to the square by castling
     *
     * @see <a href="http://www.fide.com/fide/handbook?id=124&view=article">FIDE
     *      Rule 3.8</a>
     */
    public boolean canCastle(int king_to);

    /**
     * The position stores also an eventual analysis result from board
     * evaluation.
     *
     * @return the analysis result of the board.
     */
    public AnalysisResult getAnalysisResult();

    /**
     * Sets/update the actual analysis result.
     *
     * @param new_result
     *           the new analysis result.
     */
    public void updateAnalysisResult(AnalysisResult new_result);

    /**
     * Checks if a given side, can still castle.
     *
     * @param color
     *           the given side
     * @return true, if the given side can castle, false else.
     */
    public Boolean colorCanCastle(Side color);

    /**
     * Returns all squares, occupied by a given side.
     *
     * @param color
```

```
     *           the given side
     * @return a set of integers, containing all squares, where a piece of this
     *         side is placed.
     */
    public Set<Integer> getOccupiedSquaresByColor(Side color);

    /**
     * Returns all squares, occupied by a given piece.
     *
     * @param type
     *           the given piece
     * @return a set of integers, containing all squares, where this piece is
     *         placed.
     */
    public Set<Integer> getOccupiedSquaresByType(Piece type);

    /**
     * Returns all squares, occupied by a given piece and side.
     *
     * @param color
     *           the given side
     * @param type
     *           the given piece
     * @return a set of integers, containing all squares, where the piece of
     *         this side is placed.
     */
    public Set<Integer> getOccupiedSquaresByColorAndType(Side color, Piece
        type);

    /**
     * returns the square, where the king for a side is positioned.
     *
     * @param side
     *           the given side
     * @return the square where the king is
     */
    public int getKingPos(Side side);

    /**
     * Returns the number of occupied squares by a given side.
     *
     * @param color
     *           the given side
     * @return the number of squares, where a piece of the given side is placed.
     */
    public int getNumberOfPiecesByColor(Side color);
```

```java
/**
 * Returns the number of occupied squares by a given piece.
 *
 * @param type
 *          the given piece
 * @return the number of squares, where the piece is placed.
 */
public int getNumberOfPiecesByType(Piece type);

/**
 * Returns the number of occupied squares by a given piece and side.
 *
 * @param color
 *          the given side
 * @param type
 *          the given piece
 * @return the number of squares, where the piece of this side is placed.
 */
public int getNumberOfPiecesByColorAndType(Side color, Piece type);

/**
 * Computes all possible moves for the active side. Moves, where the active
 * color is check, are invalid and got deleted.
 *
 * @return a set of all valid and possible moves.
 */
public List<IMove> getPossibleMoves();

/**
 * Computes all possible moves for the active side from a specific square.
 * Moves, where the active color is check, are invalid and got deleted.
 *
 * @param square
 *          the given square
 * @return a set of all valid and possible moves from the given square.
 */
public List<IMove> getPossibleMovesFrom(int square, boolean pseudolegal);

/**
 * Computes all possible moves for the active side to a specific square.
 * Moves, where the active color is check, are invalid and got deleted.
 * Please note, that this functions calls getPossibleMoves() and extracts
 * the desired ones.
 *
 * @param square
```

```
     *           the given square
     * @return a set of all valid and possible moves to the given square.
     */
    public List<IMove> getPossibleMovesTo(int square);

    /**
     * returns the side of the piece on a given square
     *
     * @param square
     *           the given square
     * @return the side, if this square is occupied by a side and null if it is
     *         empty.
     */
    public Side getSideFromBoard(int square);

    /**
     * returns the piece on a given square
     *
     * @param square
     *           the given square
     * @return the piece, if this square is occupied and null if it is empty.
     */
    public Piece getPieceFromBoard(int square);

    /**
     * checks if the actual position is a check position.
     *
     * @return true if the position is a check position
     */
    public boolean isCheckPosition();

    /**
     * checks if the actual position is a mate position.
     *
     * @return true if the position is a mate position
     */
    public boolean isMatePosition();

    /**
     * checks if the actual position is a stalemate position.
     *
     * @return true if the position is a stalemate position
     */
    public boolean isStaleMatePosition();

    /**
```

```
     * checks if a given move is a valid move. Note, that this function calls
     * first getPossibleMoves() and then searches the given move in all possible
     * moves
     *
     * @param move
     *          the move to be checked
     * @return true, if the move is possible
     */
    public boolean isPossibleMove(IMove move);

    /**
     * converts the given position in fen notation
     *
     * @return a string of the actual position in fen notation
     */
    public String toFEN();

    /**
     * searches all moves, which are a capture and promotions
     *
     * @return the desired set of moves of all captures and promotions.
     */
    public List<IMove> generateCaptures();

    /**
     * Since AnalysisResults are stored in the Transposition Tables
     * (ResultCache), it is important to ensure that the AnalysisResult
     * corresponding to the actual position should be used, if there are
     * collisions with hashvalues. Therefore a second one (this one) is created
     * to identify the position and these problems unlikely.
     *
     * @return a different hashvalue
     */
    public long hashCode2();

    /**
     * computes all information and stores them, which is needed for fast board
     * evaluation.
     */
    public void cacheOccupiedSquares();

    public void setHalfMoveClock(int parseInt);

    public int getHalfMoveClock();

    boolean isCheckAfterMove(IMove move);
```

```
  void getPotentialAttackersTo(int square, Piece attacking_dir,
      List<IMove> result);

  List<IMove> getPotentialAttackersTo(int square, Piece attacking_dir);

  List<IMove> getPotentialAttackersTo(int square);

  List<IMove> getPossibleMoves(boolean pseudolegal);
}
```

1.9 IPositionAnalyzer.java

```
package mitzi;

public interface IPositionAnalyzer {

  /**
   * Evaluates the given board and returns a value in centipawns, this
   * function should not include further increase of search depth.
   *
   * @param board
   *           the board to be analyzed
   * @return a analysisResult, containing the value in centipawns
   */
  public AnalysisResult eval0(IPosition board);

  /**
   * Evaluates the given board and returns a value in centipawns, this
   * function should/can include further increase of search depth.
   *
   * @param board
   *           the board to be analyzed
   * @param alpha
   *           the alpha value of the alpha-beta algorithm
   * @param beta
   *           the beta value of the alpha-beta algorithm
   * @return a analysisResult, containing the value in centipawns and the
   *         selective depth
   * @throws InterruptedException
   */
  public AnalysisResult evalBoard(IPosition board, int alpha, int beta)
      throws InterruptedException;
```

```
  /**
   * stores the castling rights
   * @param position the actual position
   */
  public void setCastling(IPosition position);

}
```

1.10 RandyBrain.java

```
package mitzi;

import java.util.List;
import java.util.Random;

/**
 * This class implements the most basic search engine, the random move
 * selection. All possible moves of the actual game state are computed and one
 * of them is randomly selected.
 *
 */
public class RandyBrain implements IBrain {

  /**
   * The current game state
   */
  private GameState game_state;

  @Override
  public void set(GameState game_state) {
    this.game_state = game_state;
  }

  @Override
  public IMove search(int movetime, int maxMoveTime, int searchDepth,
      boolean infinite, List<IMove> searchMoves) {

    List<IMove> moves = game_state.getPosition().getPossibleMoves();

    int randy = new Random().nextInt(moves.size());
    int i = 0;
    for (IMove move : moves) {
      if (i == randy)
        return move;
```

```
      i = i + 1;
    }

    return null; // cannot not happen anyway
  }

  @Override
  public IMove stop() {
    // no need to implement the stop function, since RandyBrain is fast
    // enough.
    return null;
  }

}
```

1.11 HumanBrain.java

```
package mitzi;

import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStreamReader;
import java.util.List;

import mitzi.GameState;

public class HumanBrain implements IBrain {

  /**
   * The current game state
   */
  private GameState game_state;

  @Override
  public void set(GameState game_state) {
    this.game_state = game_state;
  }


  @Override
  public IMove search(int movetime, int maxMoveTime, int searchDepth,
      boolean infinite, List<IMove> searchMoves) {

    //Read in the move as string
```

```
    BufferedReader reader = new BufferedReader(new
        InputStreamReader(System.in));
    String string_move = null;
    try {
      string_move = reader.readLine();
    } catch (IOException e) {
      // TODO Auto-generated catch block
      e.printStackTrace();
    }

    //convert it to an object move.
    IMove move = new Move(string_move);
    //if the move was illegal, the player has to choose another one.
    while(!game_state.getPosition().isPossibleMove(move)){
      System.out.println("Illegal move, choose another one!");
      try {
        string_move = reader.readLine();
      } catch (IOException e) {
        // TODO Auto-generated catch block
        e.printStackTrace();
      }
      move = new Move(string_move);
    }
    //return the choosen move.
    return move;
  }

  @Override
  public IMove stop() {
    return null;
  }

}
```

1.12 Move.java

```
package mitzi;

import java.util.Locale;
import java.util.Set;

public final class Move implements IMove {

  /**
```

```
 * the source square of the move
 */
private final short src;

/**
 * the destination square of the move
 */
private final short dest;

/**
 * the piece, resulting from promotion. null if no promotion
 */
private final Piece promotion;

/**
 * Move constructor
 *
 * @param src
 *           Source
 * @param dest
 *           Destination
 * @param promotion
 *           Promotion (if no, then omit)
 */
public Move(int src, int dest, Piece promotion) {
  this.src = (short) src;
  this.dest = (short) dest;
  this.promotion = promotion;
}

/**
 * Move constructor (no promotion)
 *
 * @param src
 *           Source square
 * @param dest
 *           Destination square
 */
public Move(int src, int dest) {
  this(src, dest, null);
}

/**
 * Move constructor from string notation
 *
 * @param notation
```

```
     *           the string representation of the move
     */
    public Move(String notation) {
      String[] squares = new String[2];

      squares[0] = notation.substring(0, 2);
      squares[1] = notation.substring(2, 4);

      src = (short) SquareHelper.fromString(squares[0]);
      dest = (short) SquareHelper.fromString(squares[1]);

      if (notation.length() > 4) {
        String promo_string = notation.substring(4, 5).toLowerCase(
            Locale.ENGLISH);
        if (promo_string.equals("q")) {
          promotion = Piece.QUEEN;
        } else if (promo_string.equals("r")) {
          promotion = Piece.ROOK;
        } else if (promo_string.equals("n")) {
          promotion = Piece.KNIGHT;
        } else if (promo_string.equals("b")) {
          promotion = Piece.BISHOP;
        } else {
          promotion = null;
        }
      } else {
        promotion = null;
      }
    }

    /**
     *
     * Checks if a move is in a given List of moves
     *
     * @param moves
     *           List of moves
     * @param move
     *           the move to be searched
     * @return true if move is in moves, else false
     */
    public static boolean MovesListIncludesMove(Set<Move> moves, Move move) {
      return moves.contains(move);

    }

    @Override
```

```
public int getFromSquare() {
  return src;
}

@Override
public int getToSquare() {
  return dest;
}

@Override
public Piece getPromotion() {
  return promotion;
}

@Override
public String toString() {
  String promote_to;
  if (getPromotion() != null) {
    promote_to = PieceHelper.toString(Side.WHITE, getPromotion());
  } else {
    promote_to = "";
  }
  return SquareHelper.toString(getFromSquare())
      + SquareHelper.toString(getToSquare()) + promote_to;
}

@Override
public int hashCode() {
  final int prime = 31;
  int result = 1;
  result = prime * result + dest;
  result = prime * result
      + ((promotion == null) ? 0 : promotion.hashCode());
  result = prime * result + src;
  return result;
}

@Override
public boolean equals(Object obj) {
  if (this == obj) {
    return true;
  }
  if (obj == null) {
    return false;
  }
  if (getClass() != obj.getClass()) {
```

```
      return false;
    }
    Move other = (Move) obj;
    if (dest != other.dest || promotion != other.promotion
        || src != other.src) {
      return false;
    }
    return true;
  }
}
```

1.13 Direction.java

```
package mitzi;

import java.util.EnumSet;

/**
 * This class represents stores the information about the offset for moving a
 * piece from a square in a specific direction. The offset for a knight is
 * different for the other figures.
 */
public enum Direction {
  EAST(10, 21), NORTHEAST(11, 12), NORTH(1, -8), NORTHWEST(-9, -19), WEST(
      -10, -21), SOUTHWEST(-11, -12), SOUTH(-1, 8), SOUTHEAST(9, 19);

  /**
   * Add to a square value to go one step in the specified direction.
   *
   * White is South, Black is North.
   */
  public final int offset;

  /**
   * Add to a square value to go one knight-step in the specified direction.
   *
   * One up and two right is East. Two up one right is Northeast. Basically,
   * the orientation is shifted a bit counterclockwise.
   */
  public final int knight_offset;

  Direction(int offset, int knight_offset) {
    this.offset = offset;
    this.knight_offset = knight_offset;
```

```
  }

  /**
   * Returns the direction in which a pawn of the specified color can move
   * (without capturing).
   *
   * @param color
   *          the color of the piece
   * @return NORTH for white and SOUTH for black
   */
  public static Direction pawnDirection(Side color) {
    if (color == Side.WHITE) {
      return NORTH;
    } else {
      return SOUTH;
    }
  }

  /**
   * Returns a set of directions in which a pawn of the specified color can
   * capture other pieces.
   *
   * @param color
   *          the color of the piece
   * @return the set of directions allowed
   */
  public static EnumSet<Direction> pawnCapturingDirections(Side color) {
    if (color == Side.WHITE) {
      return EnumSet.of(NORTHEAST, NORTHWEST);
    } else {
      return EnumSet.of(SOUTHEAST, SOUTHWEST);
    }
  }

}
```

1.14 Position.java

```
package mitzi;

import java.util.ArrayList;
import java.util.Arrays;
import java.util.EnumSet;
import java.util.HashMap;
```

```
import java.util.HashSet;
import java.util.Iterator;
import java.util.List;
import java.util.Map;
import java.util.Set;

import mitzi.IrreversibleMoveStack.MoveInfo;

/**
 * The class implements the position of the figures on a chess board. The
    board
 * is represented as two 8*8 +1 arrays - one for the sides, one for the
    pieces.
 * All accesses to a square outside the chessboard are mapped to the 65th
    entry
 * of the board, which is always null. This map from square to array index is
 * performed by the function <code>squareToArrayIndex(square) </code>, which
 * looks up in the <code>square_to_array_index array</code>. For informations
 * about the <code>int</code> value of a square, see
 * <code>SqaureHelper.java</code>.
 *
 */
public class Position implements IPosition {

  /**
   * the initial position of the sides
   */
  protected static Side[] initial_side_board = { Side.BLACK, Side.BLACK,
      Side.BLACK, Side.BLACK, Side.BLACK, Side.BLACK, Side.BLACK,
      Side.BLACK, Side.BLACK, Side.BLACK, Side.BLACK, Side.BLACK,
      Side.BLACK, Side.BLACK, Side.BLACK, Side.BLACK, null, null, null,
      null, null, null, null, null, null, null, null, null, null,
      null, null, null, null, null, null, null, null, null, null,
      null, null, null, null, null, null, null, Side.WHITE, Side.WHITE,
      Side.WHITE, Side.WHITE, Side.WHITE, Side.WHITE, Side.WHITE,
      Side.WHITE, Side.WHITE, Side.WHITE, Side.WHITE, Side.WHITE,
      Side.WHITE, Side.WHITE, Side.WHITE, Side.WHITE, null };

  /**
   * the initial position of the pieces
   */
  protected static Piece[] initial_piece_board = { Piece.ROOK, Piece.KNIGHT,
      Piece.BISHOP, Piece.QUEEN, Piece.KING, Piece.BISHOP, Piece.KNIGHT,
      Piece.ROOK, Piece.PAWN, Piece.PAWN, Piece.PAWN, Piece.PAWN,
      Piece.PAWN, Piece.PAWN, Piece.PAWN, Piece.PAWN, null, null, null,
      null, null, null, null, null, null, null, null, null, null,
```

```
    null, null, null, null, null, null, null, null, null, null,
    null, null, null, null, null, null, null, Piece.PAWN, Piece.PAWN,
    Piece.PAWN, Piece.PAWN, Piece.PAWN, Piece.PAWN, Piece.PAWN,
    Piece.PAWN, Piece.ROOK, Piece.KNIGHT, Piece.BISHOP, Piece.QUEEN,
    Piece.KING, Piece.BISHOP, Piece.KNIGHT, Piece.ROOK, null };

/**
 * this array maps the integer value of an square to the array index of
 * array representation of the board in this class
 */
protected static int[] square_to_array_index = { 64, 64, 64, 64, 64, 64,
    64, 64, 64, 64, 64, 56, 48, 40, 32, 24, 16, 8, 0, 64, 64, 57, 49,
    41, 33, 25, 17, 9, 1, 64, 64, 58, 50, 42, 34, 26, 18, 10, 2, 64,
    64, 59, 51, 43, 35, 27, 19, 11, 3, 64, 64, 60, 52, 44, 36, 28, 20,
    12, 4, 64, 64, 61, 53, 45, 37, 29, 21, 13, 5, 64, 64, 62, 54, 46,
    38, 30, 22, 14, 6, 64, 64, 63, 55, 47, 39, 31, 23, 15, 7, 64, 64,
    64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64,
    64, 64, 64 };

/**
 * the array of Sides, containing the information about the position of the
 * sides of the pieces
 */
private Side[] side_board = new Side[65];

/**
 * the array of Pieces, containing the information about the position of the
 * pieces
 */
private Piece[] piece_board = new Piece[65];

/**
 * squares c1, g1, c8 and g8 in ICCF numeric notation. do not change the
 * squares' order or bad things will happen! set to -1 if castling not
 * allowed.
 */
private int[] castling = { -1, -1, -1, -1 };

/**
 * the square of the en_passant_target, -1 if none.
 */
private int en_passant_target = -1;

/**
 * the side, which has to move
 */
```

```
private Side active_color;

/**
 * contains the information about the value of the position.
 */
private AnalysisResult analysis_result = null;

/**
 * This is the number of halfmoves since the last pawn advance or capture.
 * This is used to determine if a draw can be claimed under the fifty-move
 * rule.
 */
public int half_move_clock;

// The following class members are used to prevent multiple computations
/**
 * caching of the possible moves
 */
private List<IMove> possible_moves = new ArrayList<IMove>(50);

/**
 * true if, the possible moves were not computed for this position.
 */
private boolean possible_moves_is_null = true;

/**
 * caching if the current position is check.
 */
private Boolean is_check;

/**
 * caching if the current position is mate.
 */
private Boolean is_mate;

/**
 * caching if the current position is stalemate.
 */
private Boolean is_stale_mate;

// the following maps takes and Integer, representing the color, type or
// PieceValue and returns the set of squares or the number of squares!
/**
 * this map maps the PieceValue, i.e. 10*side.ordinal + piece.ordinal, to
 * the set of squares where the pieces of the side are positioned.
 */
```

```
private Map<Integer, Set<Integer>> occupied_squares_by_color_and_type = new
    HashMap<Integer, Set<Integer>>();

/**
 * this map maps the side, i.e. side.ordinal, to the set of squares where
 * the side has pieces.
 */
private Map<Side, Set<Integer>> occupied_squares_by_color = new
    HashMap<Side, Set<Integer>>();

/**
 * this map maps the piece, i.e. piece.ordinal, to the set of squares where
 * the pieces are positioned.
 */
private Map<Piece, Set<Integer>> occupied_squares_by_type = new
    HashMap<Piece, Set<Integer>>();

/**
 * caching the number of occupied squares for each side of an piece in an
 * small array.
 */
private int[] num_occupied_squares_by_color_and_type = new int[16];

/**
 * caching the positions of the kings. (indexed by the ordinal of the side)
 */
private int[] king_pos = new int[2];

/**
 * saves the side, which got captured by the last tinyDoMove
 */
private Side side_capture;

/**
 * saves the piece, which got captured by the last tinyDoMove
 */
private Piece piece_capture;

/**
 * saves if the old position after tinyDoMove was check or not
 */
Boolean old_check;

private Boolean pseudolegal_moves;
```

```
//
    ----------------------------------------------------------------------------

/**
 * Resets and clears the stored class members.
 */
private void resetCache() {
  possible_moves.clear();
  possible_moves_is_null = true;
  pseudolegal_moves = null;
  is_check = null;
  is_mate = null;
  is_stale_mate = null;
  analysis_result = null;
  occupied_squares_by_color_and_type.clear();
  occupied_squares_by_type.clear();
  occupied_squares_by_color.clear();
}

/**
 * computes the index for the internal array representation of an square
 *
 * @param square
 *           the given square
 * @return the index
 */
private int squareToArrayIndex(int square) {
  if (square < 0)
    return 64;
  return square_to_array_index[square];
}

/**
 * computes a copy of the actual board, only the necessary informations are
 * copied, plus <code>num_occupied_squares_by_color_and_type</code>
 *
 * @return a incomplete copy of the board.
 */
@Override
public Position returnCopy() {
  Position newBoard = new Position();

  newBoard.active_color = active_color;
  newBoard.en_passant_target = en_passant_target;
  System.arraycopy(castling, 0, newBoard.castling, 0, 4);
```

```
    System.arraycopy(side_board, 0, newBoard.side_board, 0, 65);
    System.arraycopy(piece_board, 0, newBoard.piece_board, 0, 65);

    System.arraycopy(num_occupied_squares_by_color_and_type, 0,
        newBoard.num_occupied_squares_by_color_and_type, 0, 16);

    System.arraycopy(king_pos, 0, newBoard.king_pos, 0, 2);
    return newBoard;
  }

  /**
   * returns the Side, which occupies a given square
   *
   * @return the side of the piece which is on the square
   */
  public Side getSideFromBoard(int square) {
    int i = squareToArrayIndex(square);
    return side_board[i];
  }

  /**
   * returns the piece, which occupies a given square
   *
   * @return the piece which is on the square
   */
  public Piece getPieceFromBoard(int square) {
    int i = squareToArrayIndex(square);
    return piece_board[i];
  }

  /**
   * sets a piece on the board.
   *
   * @param square
   *          the square, were the piece should be set
   * @param side
   *          the given side
   * @param piece
   *          the given piece
   */
  private void setOnBoard(int square, Side side, Piece piece) {
    int i = squareToArrayIndex(square);
    side_board[i] = side;
    piece_board[i] = piece;
  }
```

```
/**
 * returns the opponents side of the actual board
 *
 * @return the side of the opponent
 */
public Side getOpponentsColor() {
  if (active_color == Side.BLACK)
    return Side.WHITE;
  else
    return Side.BLACK;
}

/**
 * returns the eventual result of the position evaluation
 */
public AnalysisResult getAnalysisResult() {
  return analysis_result;
}

/**
 * updates the result of the board. (only if it more valuable, i.e.
 * comparison of the depth)
 *
 * @param analysis_result
 *           the new analysis result
 */
public void updateAnalysisResult(AnalysisResult analysis_result) {
  if (analysis_result == null)
    throw new NullPointerException();

  if (this.analysis_result == null
      || this.analysis_result.compareQualityTo(analysis_result) <= 0) {
    this.analysis_result = analysis_result;
  }
}

/**
 * checks is a move is a hit. there is no check, that the move is legal!.
 *
 * @param move
 *           the move to be checked
 * @return true, if it is a hit, false otherwise
 */
public boolean isHit(IMove move) {
  int dest = move.getToSquare();
  int src = move.getFromSquare();
```

```
    // a hit happens iff the dest is an enemy or its en passant
    if (getSideFromBoard(dest) == Side.getOppositeSide(active_color)
        || (getPieceFromBoard(src) == Piece.PAWN && dest == this
            .getEnPassant()))
      return true;
    return false;
  }

  @Override
  public void setToInitial() {
    System.arraycopy(initial_side_board, 0, side_board, 0, 65);
    System.arraycopy(initial_piece_board, 0, piece_board, 0, 65);

    castling[0] = 31;
    castling[1] = 71;
    castling[2] = 38;
    castling[3] = 78;

    half_move_clock = 0;
    en_passant_target = -1;
    active_color = Side.WHITE;

    num_occupied_squares_by_color_and_type[Side.WHITE.ordinal() * 10
        + Piece.KING.ordinal()] = 1;
    num_occupied_squares_by_color_and_type[Side.WHITE.ordinal() * 10
        + Piece.QUEEN.ordinal()] = 1;
    num_occupied_squares_by_color_and_type[Side.WHITE.ordinal() * 10
        + Piece.ROOK.ordinal()] = 2;
    num_occupied_squares_by_color_and_type[Side.WHITE.ordinal() * 10
        + Piece.BISHOP.ordinal()] = 2;
    num_occupied_squares_by_color_and_type[Side.WHITE.ordinal() * 10
        + Piece.KNIGHT.ordinal()] = 2;
    num_occupied_squares_by_color_and_type[Side.WHITE.ordinal() * 10
        + Piece.PAWN.ordinal()] = 8;
    num_occupied_squares_by_color_and_type[Side.BLACK.ordinal() * 10
        + Piece.KING.ordinal()] = 1;
    num_occupied_squares_by_color_and_type[Side.BLACK.ordinal() * 10
        + Piece.QUEEN.ordinal()] = 1;
    num_occupied_squares_by_color_and_type[Side.BLACK.ordinal() * 10
        + Piece.ROOK.ordinal()] = 2;
    num_occupied_squares_by_color_and_type[Side.BLACK.ordinal() * 10
        + Piece.BISHOP.ordinal()] = 2;
    num_occupied_squares_by_color_and_type[Side.BLACK.ordinal() * 10
        + Piece.KNIGHT.ordinal()] = 2;
    num_occupied_squares_by_color_and_type[Side.BLACK.ordinal() * 10
```

```
      + Piece.PAWN.ordinal()] = 8;

  king_pos[Side.WHITE.ordinal()] = 51;
  king_pos[Side.BLACK.ordinal()] = 58;
  resetCache();
}

@Override
public void setToFEN(String fen) {
  side_board = new Side[65];
  piece_board = new Piece[65];

  castling[0] = -1;
  castling[1] = -1;
  castling[2] = -1;
  castling[3] = -1;
  en_passant_target = -1;

  resetCache();

  String[] fen_parts = fen.split(" ");

  // populate the squares
  String[] fen_rows = fen_parts[0].split("/");
  char[] pieces;
  for (int row = 1; row <= 8; row++) {
    int offset = 0;
    for (int column = 1; column + offset <= 8; column++) {
      pieces = fen_rows[8 - row].toCharArray();
      int square = (column + offset) * 10 + row;
      switch (pieces[column - 1]) {
      case 'P':
        setOnBoard(square, Side.WHITE, Piece.PAWN);
        num_occupied_squares_by_color_and_type[Side.WHITE.ordinal()
            * 10 + Piece.PAWN.ordinal()]++;
        break;
      case 'R':
        setOnBoard(square, Side.WHITE, Piece.ROOK);
        num_occupied_squares_by_color_and_type[Side.WHITE.ordinal()
            * 10 + Piece.ROOK.ordinal()]++;
        break;
      case 'N':
        setOnBoard(square, Side.WHITE, Piece.KNIGHT);
        num_occupied_squares_by_color_and_type[Side.WHITE.ordinal()
            * 10 + Piece.KNIGHT.ordinal()]++;
        break;
```

```
case 'B':
  setOnBoard(square, Side.WHITE, Piece.BISHOP);
  num_occupied_squares_by_color_and_type[Side.WHITE.ordinal()
      * 10 + Piece.BISHOP.ordinal()]++;
  break;
case 'Q':
  setOnBoard(square, Side.WHITE, Piece.QUEEN);
  num_occupied_squares_by_color_and_type[Side.WHITE.ordinal()
      * 10 + Piece.QUEEN.ordinal()]++;
  break;
case 'K':
  setOnBoard(square, Side.WHITE, Piece.KING);
  king_pos[Side.WHITE.ordinal()] = (byte) square;
  num_occupied_squares_by_color_and_type[Side.WHITE.ordinal()
      * 10 + Piece.KING.ordinal()]++;
  break;
case 'p':
  setOnBoard(square, Side.BLACK, Piece.PAWN);
  num_occupied_squares_by_color_and_type[Side.BLACK.ordinal()
      * 10 + Piece.PAWN.ordinal()]++;
  break;
case 'r':
  setOnBoard(square, Side.BLACK, Piece.ROOK);
  num_occupied_squares_by_color_and_type[Side.BLACK.ordinal()
      * 10 + Piece.ROOK.ordinal()]++;
  break;
case 'n':
  setOnBoard(square, Side.BLACK, Piece.KNIGHT);
  num_occupied_squares_by_color_and_type[Side.BLACK.ordinal()
      * 10 + Piece.KNIGHT.ordinal()]++;
  break;
case 'b':
  setOnBoard(square, Side.BLACK, Piece.BISHOP);
  num_occupied_squares_by_color_and_type[Side.BLACK.ordinal()
      * 10 + Piece.BISHOP.ordinal()]++;
  break;
case 'q':
  setOnBoard(square, Side.BLACK, Piece.QUEEN);
  num_occupied_squares_by_color_and_type[Side.BLACK.ordinal()
      * 10 + Piece.QUEEN.ordinal()]++;
  break;
case 'k':
  setOnBoard(square, Side.BLACK, Piece.KING);
  king_pos[Side.BLACK.ordinal()] = (byte) square;
  num_occupied_squares_by_color_and_type[Side.BLACK.ordinal()
      * 10 + Piece.KING.ordinal()]++;
```

```
        break;
      default:
        offset += Character.getNumericValue(pieces[column - 1]) - 1;
        break;
      }
    }
  }

  // set active color
  switch (fen_parts[1]) {
  case "b":
    active_color = Side.BLACK;
    break;
  case "w":
    active_color = Side.WHITE;
    break;
  }

  // set possible castling moves
  if (!fen_parts[2].equals("-")) {
    char[] castlings = fen_parts[2].toCharArray();
    for (int i = 0; i < castlings.length; i++) {
      switch (castlings[i]) {
      case 'K':
        castling[1] = 71;
        break;
      case 'Q':
        castling[0] = 31;
        break;
      case 'k':
        castling[3] = 78;
        break;
      case 'q':
        castling[2] = 38;
        break;
      }
    }
  }

  // set en passant square
  if (!fen_parts[3].equals("-")) {
    en_passant_target = SquareHelper.fromString(fen_parts[3]);
  }
}

@Override
```

```
public IPosition doMove_copy(IMove move) {
  Position newBoard = this.returnCopy();

  int src = move.getFromSquare();
  int dest = move.getToSquare();

  Piece piece = getPieceFromBoard(src);
  Piece capture = getPieceFromBoard(dest);
  boolean resets_half_move_clock = false;
  // if promotion
  if (move.getPromotion() != null) {
    newBoard.setOnBoard(src, null, null);
    newBoard.setOnBoard(dest, active_color, move.getPromotion());
    resets_half_move_clock = true;
    newBoard.num_occupied_squares_by_color_and_type[active_color
        .ordinal() * 10 + Piece.PAWN.ordinal()]--;
    newBoard.num_occupied_squares_by_color_and_type[active_color
        .ordinal() * 10 + move.getPromotion().ordinal()]++;
  }
  // If castling
  else if (piece == Piece.KING && Math.abs((src - dest)) == 20) {
    newBoard.setOnBoard(dest, active_color, Piece.KING);
    newBoard.setOnBoard(src, null, null);
    newBoard.setOnBoard((src + dest) / 2, active_color, Piece.ROOK);
    if (SquareHelper.getColumn(dest) == 3)
      newBoard.setOnBoard(src - 40, null, null);
    else
      newBoard.setOnBoard(src + 30, null, null);

  }
  // If en passant
  else if (piece == Piece.PAWN && dest == this.getEnPassant()) {
    newBoard.setOnBoard(dest, active_color, Piece.PAWN);
    newBoard.setOnBoard(src, null, null);
    if (active_color == Side.WHITE) {
      capture = getPieceFromBoard(dest - 1);
      newBoard.setOnBoard(dest - 1, null, null);
    } else {
      capture = getPieceFromBoard(dest + 1);
      newBoard.setOnBoard(dest + 1, null, null);
    }
    resets_half_move_clock = true;
  }
  // Usual move
  else {
    Side side = getSideFromBoard(src);
```

```
    newBoard.setOnBoard(dest, side, piece);
    newBoard.setOnBoard(src, null, null);
    if (this.getSideFromBoard(dest) != null || piece == Piece.PAWN)
      resets_half_move_clock = true;
  }

  if (resets_half_move_clock)
    newBoard.half_move_clock = 0;

  // update counters
  if (capture != null) {
    newBoard.num_occupied_squares_by_color_and_type[Side
        .getOppositeSide(active_color).ordinal()
        * 10
        + capture.ordinal()]--;
  }

  // Change active_color after move
  newBoard.active_color = Side.getOppositeSide(active_color);

  // Update en_passant
  if (piece == Piece.PAWN && Math.abs(dest - src) == 2)
    newBoard.en_passant_target = (dest + src) / 2;
  else
    newBoard.en_passant_target = -1;

  // Update castling
  if (piece == Piece.KING) {
    newBoard.king_pos[active_color.ordinal()] = (byte) dest;
    if (active_color == Side.WHITE && src == 51) {
      newBoard.castling[0] = -1;
      newBoard.castling[1] = -1;
    } else if (active_color == Side.BLACK && src == 58) {
      newBoard.castling[2] = -1;
      newBoard.castling[3] = -1;
    }
  } else if (piece == Piece.ROOK) {
    if (active_color == Side.WHITE) {
      if (src == 81)
        newBoard.castling[1] = -1;
      else if (src == 11)
        newBoard.castling[0] = -1;
    } else {
      if (src == 88)
        newBoard.castling[3] = -1;
      else if (src == 18)
```

```
        newBoard.castling[2] = -1;
      }
    }
    if (capture == Piece.ROOK) {
      if (active_color == Side.BLACK) {
        if (dest == 81)
          newBoard.castling[1] = -1;
        else if (dest == 11)
          newBoard.castling[0] = -1;
      } else {
        if (dest == 88)
          newBoard.castling[3] = -1;
        else if (dest == 18)
          newBoard.castling[2] = -1;
      }
    }

    return newBoard;
  }

  @Override
  public int getEnPassant() {
    return en_passant_target;
  }

  @Override
  public boolean canCastle(int king_to) {
    if ((king_to == 31 && castling[0] != -1)
        || (king_to == 71 && castling[1] != -1)
        || (king_to == 38 && castling[2] != -1)
        || (king_to == 78 && castling[3] != -1)) {
      return true;
    } else {
      return false;
    }
  }

  @Override
  public Boolean colorCanCastle(Side color) {

    // Set the right color
    if (active_color != color)
      active_color = getOpponentsColor();

    // check for castling
    if (!isCheckPosition()) {
```

```
int off = 0;
int square = 51;

if (color == Side.BLACK) {
  off = 2;
  square = 58;
}

for (int i = 0; i < 2; i++) {
  int castle_flag = 0;
  Integer new_square = castling[i + off];
  // castling must still be possible to this side
  if (new_square != -1) {

    Direction dir;
    if (i == 0)
      dir = Direction.WEST;
    else
      dir = Direction.EAST;

    List<Integer> line = SquareHelper.getAllSquaresInDirection(
        square, dir);

    // Check each square if it is empty
    for (Integer squ : line) {
      if (getSideFromBoard(squ) != null) {
        castle_flag = 1;
        break;
      }
      if (squ == new_square)
        break;
    }
    if (castle_flag == 1)
      continue;

    // Check each square if the king on it would be check
    for (Integer squ : line) {
      setOnBoard(squ, active_color, Piece.KING);
      setOnBoard(square, null, null);

      if (isCheckPosition()) {
        setOnBoard(square, active_color, Piece.KING);
        setOnBoard(squ, null, null);
        break;
      }
      setOnBoard(square, active_color, Piece.KING);
```

```
          setOnBoard(squ, null, null);
          if (squ == new_square) {
            // If the end is reached, then stop checking.

            // undoing change of color
            if (active_color == color)
              active_color = getOpponentsColor();

            return true;
          }
        }
      }
    }
  }

  // undoing change of color
  if (active_color == color)
    active_color = getOpponentsColor();

  return false;
}

@Override
public Set<Integer> getOccupiedSquaresByColor(Side color) {

  if (occupied_squares_by_color.containsKey(color) == false) {
    Set<Integer> set = new HashSet<Integer>();

    for (int square : SquareHelper.all_squares)
      if (getSideFromBoard(square) == color)
        set.add(square);

    occupied_squares_by_color.put(color, set);
    return set;
  }
  return occupied_squares_by_color.get(color);
}

@Override
public Set<Integer> getOccupiedSquaresByType(Piece type) {

  if (occupied_squares_by_type.containsKey(type) == false) {
    Set<Integer> set = new HashSet<Integer>();

    for (int square : SquareHelper.all_squares)
      if (getPieceFromBoard(square) == type)
```

```
        set.add(square);

    occupied_squares_by_type.put(type, set);
    return set;
  }
  return occupied_squares_by_type.get(type);

}

@Override
public Set<Integer> getOccupiedSquaresByColorAndType(Side color, Piece
    type) {

  int value = color.ordinal() * 10 + type.ordinal();

  if (occupied_squares_by_color_and_type.containsKey(value) == false) {
    Set<Integer> set = new HashSet<Integer>();
    if (type == Piece.KING)
      set.add((int) king_pos[color.ordinal()]);
    else {
      for (int square : SquareHelper.all_squares)
        if (type == getPieceFromBoard(square)
            && color == getSideFromBoard(square))
          set.add(square);
    }
    occupied_squares_by_color_and_type.put(value, set);
    return set;
  }
  return occupied_squares_by_color_and_type.get(value);
}

@Override
public int getNumberOfPiecesByColor(Side side) {
  int result = 0;
  for (Piece piece : Piece.values()) {
    result += num_occupied_squares_by_color_and_type[side.ordinal()
        * 10 + piece.ordinal()];
  }
  return result;
}

@Override
public int getNumberOfPiecesByType(Piece piece) {
  int result = 0;
  for (Side side : Side.values()) {
    result += num_occupied_squares_by_color_and_type[side.ordinal()
```

```
        * 10 + piece.ordinal()];
    }
    return result;
  }

  @Override
  public int getNumberOfPiecesByColorAndType(Side color, Piece type) {
    int value = color.ordinal() * 10 + type.ordinal();
    return num_occupied_squares_by_color_and_type[value];
  }

  @Override
  public List<IMove> getPossibleMoves() {
    return getPossibleMoves(false);
  }

  @Override
  public List<IMove> getPossibleMoves(boolean pseudolegal) {

    if (possible_moves_is_null == true ) {

      // loop over all squares
      for (int square : SquareHelper.all_squares) {
        if (getSideFromBoard(square) == active_color)
          possible_moves.addAll(getPossibleMovesFrom(square,
              pseudolegal));
      }
      pseudolegal_moves = pseudolegal;
      possible_moves_is_null = false;
    }
    else if(!pseudolegal && pseudolegal_moves)
    {
      Iterator<IMove> iter = possible_moves.iterator();
      while(iter.hasNext())
      {
        IMove m = iter.next();
        if(isCheckAfterMove(m))
          iter.remove();
      }
      pseudolegal_moves = false;
    }

    return possible_moves;

  }
```

```
@Override
public List<IMove> getPossibleMovesFrom(int square, boolean pseudolegal) {
  // The case, that the destination is the opponents king cannot happen.

  Piece type = getPieceFromBoard(square);
  Side opp_color = getOpponentsColor();

  ArrayList<List<Integer>> all_squares = SquareHelper
      .getSquaresAllDirections(square);
  List<Integer> squares;
  List<IMove> moves = new ArrayList<IMove>(35);
  Move move;

  // Types BISHOP, QUEEN, ROOK
  if (type == Piece.BISHOP || type == Piece.QUEEN || type == Piece.ROOK) {

    // Loop over all directions and skip not appropriate ones
    for (Direction direction : Direction.values()) {

      // Skip N,W,E,W with BISHOP and skip NE,NW,SE,SW with ROOK
      if (((direction == Direction.NORTH
          || direction == Direction.EAST
          || direction == Direction.SOUTH || direction == Direction.WEST) &&
              type == Piece.BISHOP)
          || ((direction == Direction.NORTHWEST
              || direction == Direction.NORTHEAST
              || direction == Direction.SOUTHEAST || direction ==
                  Direction.SOUTHWEST) && type == Piece.ROOK)) {

        continue;
      } else {
        // do stuff
        squares = SquareHelper.getAllSquaresInDirection(
            all_squares, direction);

        for (Integer new_square : squares) {
          Piece piece = getPieceFromBoard(new_square);
          Side color = getSideFromBoard(new_square);
          if (piece == null || color == opp_color) {

            move = new Move(square, new_square);
            moves.add(move);
            if (piece != null && color == opp_color)
              // not possible to go further
              break;
          } else
```

```
            break;
        }
      }

    }

  }

  if (type == Piece.PAWN) {
    // If Pawn has not moved yet (steps possible)
    if ((SquareHelper.getRow(square) == 2 && active_color == Side.WHITE)
        || (SquareHelper.getRow(square) == 7 && active_color ==
            Side.BLACK)) {

      if (getSideFromBoard(square
          + Direction.pawnDirection(active_color).offset) == null) {
        move = new Move(square, square
            + Direction.pawnDirection(active_color).offset);
        moves.add(move);
        if (getSideFromBoard(square + 2
            * Direction.pawnDirection(active_color).offset) == null) {
          move = new Move(square, square + 2
              * Direction.pawnDirection(active_color).offset);
          moves.add(move);
        }
      }

      Set<Direction> pawn_capturing_directions = Direction
          .pawnCapturingDirections(active_color);
      for (Direction direction : pawn_capturing_directions) {
        if (getSideFromBoard(square + direction.offset) ==
            getOpponentsColor()) {
          move = new Move(square, square + direction.offset);
          moves.add(move);
        }
      }

    }
    // if Promotion will happen
    else if ((SquareHelper.getRow(square) == 7 && active_color ==
        Side.WHITE)
        || (SquareHelper.getRow(square) == 2 && active_color ==
            Side.BLACK)) {
      if (getSideFromBoard(square
          + Direction.pawnDirection(active_color).offset) == null) {
        move = new Move(square, square
```

```
            + Direction.pawnDirection(active_color).offset,
            Piece.QUEEN);
        moves.add(move);
        move = new Move(square, square
            + Direction.pawnDirection(active_color).offset,
            Piece.KNIGHT);
        moves.add(move);

        move = new Move(square, square
            + Direction.pawnDirection(active_color).offset,
            Piece.ROOK);
        moves.add(move);
        move = new Move(square, square
            + Direction.pawnDirection(active_color).offset,
            Piece.BISHOP);
        moves.add(move);

      }
      Set<Direction> pawn_capturing_directions = Direction
          .pawnCapturingDirections(active_color);
      for (Direction direction : pawn_capturing_directions) {
        if (getSideFromBoard(square + direction.offset) ==
            getOpponentsColor()) {
          move = new Move(square, square + direction.offset,
              Piece.QUEEN);
          moves.add(move);
          move = new Move(square, square + direction.offset,
              Piece.KNIGHT);
          moves.add(move);

          move = new Move(square, square + direction.offset,
              Piece.ROOK);
          moves.add(move);
          move = new Move(square, square + direction.offset,
              Piece.BISHOP);
          moves.add(move);
        }
      }

    }
    // Usual turn and en passant is possible, no promotion
    else {
      if (getSideFromBoard(square
          + Direction.pawnDirection(active_color).offset) == null) {
        move = new Move(square, square
            + Direction.pawnDirection(active_color).offset);
```

```
        moves.add(move);
      }
      Set<Direction> pawn_capturing_directions = Direction
          .pawnCapturingDirections(active_color);
      for (Direction direction : pawn_capturing_directions) {
        if ((getSideFromBoard(square + direction.offset) ==
            getOpponentsColor())
            || square + direction.offset == getEnPassant()) {
          move = new Move(square, square + direction.offset);
          moves.add(move);
        }
      }
    }

  }
  if (type == Piece.KING) {
    for (Direction direction : Direction.values()) {
      Integer new_square = square + direction.offset;

      if (SquareHelper.isValidSquare(new_square)) {
        move = new Move(square, new_square);
        Side side = getSideFromBoard(new_square);
        // if the new square is empty or occupied by the opponent
        if (side != active_color)
          moves.add(move);
      }
    }

    // Castle Moves
    // If the King is not check now, try castle moves
    if (!isCheckPosition()) {
      int off = 0;
      if (active_color == Side.BLACK)
        off = 2;

      for (int i = 0; i < 2; i++) {
        int castle_flag = 0;
        Integer new_square = castling[i + off];
        // castling must still be possible to this side
        if (new_square != -1) {

          Direction dir;
          if (i == 0)
            dir = Direction.WEST;
          else
            dir = Direction.EAST;
```

```
        List<Integer> line = SquareHelper
            .getAllSquaresInDirection(square, dir);

        // Check each square if it is empty
        int last_squ = line.get(line.size() - 1);
        for (Integer squ : line) {
          if (squ == last_squ)
            break;
          if (getSideFromBoard(squ) != null) {
            castle_flag = 1;
            break;
          }

        }
        if (castle_flag == 1)
          continue;

        // Check each square if the king on it would be check
        for (Integer squ : line) {

          setOnBoard(squ, active_color, Piece.KING);
          setOnBoard(square, null, null);
          is_check = null;
          king_pos[active_color.ordinal()] = squ;
          if (isCheckPosition()) {
            setOnBoard(square, active_color, Piece.KING);
            setOnBoard(squ, null, null);
            is_check = false; // king is not check in the
                     // original position
            king_pos[active_color.ordinal()] = square;
            break;
          }
          setOnBoard(square, active_color, Piece.KING);
          setOnBoard(squ, null, null);
          is_check = false;
          king_pos[active_color.ordinal()] = squ;
          if (squ == new_square) {
            // if everything is right, then add the move
            move = new Move(square, squ);
            moves.add(move);
            break;
          }

        }
      }
```

```
      }
    }
  }
  if (type == Piece.KNIGHT) {
    squares = SquareHelper.getAllSquaresByKnightStep(square);
    for (Integer new_square : squares) {
      Side side = getSideFromBoard(new_square);
      if (side != active_color) {
        move = new Move(square, new_square);
        moves.add(move);
      }
    }
  }

  if (!pseudolegal) {
    // remove invalid positions
    Iterator<IMove> iter = moves.iterator();
    IMove mv;
    while (iter.hasNext()) {
      mv = iter.next();
      if (isCheckAfterMove(mv))
        iter.remove();
    }
  }
  return moves;
}

@Override
public List<IMove> getPotentialAttackersTo(int square) {
  List<IMove> result = new ArrayList<IMove>();

  for (Piece p : Piece.values())
    getPotentialAttackersTo(square, p, result);

  // TODO: en passant

  return result;
}

@Override
public List<IMove> getPossibleMovesTo(int square) {

  List<IMove> result = new ArrayList<IMove>();
  Side s = getSideFromBoard(square);
  if (s == active_color)
    return result;
```

```
Side side = active_color;
Side opp_side = Side.getOppositeSide(side);

IMove move;

EnumSet<Piece> dirs = EnumSet.of(Piece.BISHOP, Piece.ROOK,
    Piece.KNIGHT, Piece.KING);
if (s == opp_side)
  getPotentialAttackersTo(square, Piece.PAWN, result);

for (Piece p : dirs)
  getPotentialAttackersTo(square, p, result);

// en passant
if (s == null
    && (square + Direction.pawnDirection(opp_side).offset ==
        en_passant_target)) {
  for (Direction dir : Direction.pawnCapturingDirections(opp_side)) {
    int squ = square + dir.offset;
    if (getPieceFromBoard(squ) == Piece.PAWN
        && getSideFromBoard(squ) == active_color) {
      move = new Move(squ, square);
      if (!isCheckAfterMove(move))
        result.add(move);
    }
  }
}

// Castling moves
if (canCastle(square)) {
  if (!isCheckPosition()) {

    int old_king_pos = king_pos[active_color.ordinal()];
    int castle_flag = 0;

    Direction dir;
    if (square < king_pos[active_color.ordinal()])
      dir = Direction.WEST;
    else
      dir = Direction.EAST;

    List<Integer> line = SquareHelper.getAllSquaresInDirection(
        old_king_pos, dir);

    // Check each square if it is empty
```

```
      int last_squ = line.get(line.size() - 1);
      for (Integer squ : line) {
        if (squ == last_squ)
          break;
        if (getSideFromBoard(squ) != null) {
          castle_flag = 1;
          break;
        }

      }
      if (castle_flag != 1) {

        // Check each square if the king on it would be check
        for (Integer squ : line) {

          setOnBoard(squ, active_color, Piece.KING);
          setOnBoard(old_king_pos, null, null);
          is_check = null;
          king_pos[active_color.ordinal()] = squ;
          if (isCheckPosition()) {
            setOnBoard(old_king_pos, active_color, Piece.KING);
            setOnBoard(squ, null, null);
            is_check = false; // king is not check in the
                     // original position
            king_pos[active_color.ordinal()] = old_king_pos;
            break;
          }
          setOnBoard(old_king_pos, active_color, Piece.KING);
          setOnBoard(squ, null, null);
          is_check = false;
          king_pos[active_color.ordinal()] = old_king_pos;
          if (squ == square) {
            // if everything is right, then add the move
            move = new Move(old_king_pos, squ);
            result.add(move);
            break;
          }

        }
      }

    }
  }
  // usual pawn move (1 square)
  int new_square = square + Direction.pawnDirection(opp_side).offset;
  if (s == null && getPieceFromBoard(new_square) == Piece.PAWN
```

```
      && getSideFromBoard(new_square) == active_color) {
    if (SquareHelper.getRow(square) == SquareHelper.getRowForSide(
        active_color, 8)) {
      // promotion
      move = new Move(new_square, square);
      if (!isCheckAfterMove(move)) {
        move = new Move(new_square, square, Piece.QUEEN);
        result.add(move);
        move = new Move(new_square, square, Piece.KNIGHT);
        result.add(move);
        move = new Move(new_square, square, Piece.BISHOP);
        result.add(move);
        move = new Move(new_square, square, Piece.ROOK);
        result.add(move);
      }
    } else {
      // usual move
      move = new Move(new_square, square);
      if (!isCheckAfterMove(move))
        result.add(move);
    }
  }
  // usual pawn move (2 squares)
  new_square += Direction.pawnDirection(opp_side).offset;
  if (SquareHelper.getRow(square) == SquareHelper.getRowForSide(side, 4)
      && s == null && getPieceFromBoard(new_square) == Piece.PAWN
      && getSideFromBoard(new_square) == active_color) {
    move = new Move(new_square, square);
    if (!isCheckAfterMove(move))
      result.add(move);
  }

  return result;
}

@Override
public List<IMove> getPotentialAttackersTo(int square, Piece attacking_dir)
    {
  List<IMove> result = new ArrayList<IMove>();
  getPotentialAttackersTo(square, attacking_dir, result);
  return result;

}

@Override
public void getPotentialAttackersTo(int square, Piece attacking_dir,
```

```
    List<IMove> result) {

  Side side = active_color;
  Side opp_side = Side.getOppositeSide(active_color);
  List<Integer> squares;
  IMove move;

  if (attacking_dir == Piece.PAWN) {
    for (Direction dir : Direction.pawnCapturingDirections(opp_side)) {
      int new_square = square + dir.offset;
      if (getPieceFromBoard(new_square) == Piece.PAWN
          && getSideFromBoard(new_square) == side) {

        move = new Move(new_square, square);
        if (SquareHelper.getRow(square) == SquareHelper
            .getRowForSide(side, 8)) {
          // promotion
          if (!isCheckAfterMove(move)) {
            move = new Move(new_square, square, Piece.QUEEN);
            result.add(move);
            move = new Move(new_square, square, Piece.KNIGHT);
            result.add(move);
            move = new Move(new_square, square, Piece.BISHOP);
            result.add(move);
            move = new Move(new_square, square, Piece.ROOK);
            result.add(move);
          }
        } else if (!isCheckAfterMove(move))
          result.add(move);
      }
    }
  } else if (attacking_dir == Piece.KNIGHT) {
    squares = SquareHelper.getAllSquaresByKnightStep(square);
    for (int squ : squares) {
      if (getPieceFromBoard(squ) == Piece.KNIGHT
          && getSideFromBoard(squ) == side) {
        move = new Move(squ, square);
        if (!isCheckAfterMove(move))
          result.add(move);
      }
    }
  } else if (attacking_dir == Piece.KING) {
    for (Direction dir : Direction.values()) {
      if (getPieceFromBoard(square + dir.offset) == Piece.KING
          && getSideFromBoard(square + dir.offset) == side) {
        move = new Move(square + dir.offset, square);
```

```
        if (!isCheckAfterMove(move)) {
          result.add(move);
          break;
        }
      }
    }
  }
  EnumSet<Direction> dirs = null;
  if (attacking_dir == Piece.ROOK)
    dirs = EnumSet.of(Direction.NORTH, Direction.SOUTH, Direction.WEST,
        Direction.EAST);
  else if (attacking_dir == Piece.BISHOP)
    dirs = EnumSet.of(Direction.NORTHEAST, Direction.SOUTHEAST,
        Direction.NORTHWEST, Direction.SOUTHWEST);

  if (attacking_dir == Piece.ROOK || attacking_dir == Piece.BISHOP) {
    ArrayList<List<Integer>> all_squares = SquareHelper
        .getSquaresAllDirections(square);
    for (Direction dir : dirs) {
      squares = all_squares.get(dir.ordinal());
      for (int squ : squares)
        if (getSideFromBoard(squ) == opp_side)
          break;
        else if (getSideFromBoard(squ) == side) {

          Piece p = getPieceFromBoard(squ);
          if (p == Piece.QUEEN || p == attacking_dir) {

            move = new Move(squ, square);
            if (!isCheckAfterMove(move))
              result.add(move);
          }
          break;
        }
    }
  }

}

@Override
public boolean isCheckAfterMove(IMove move) {

  boolean is_check = false;

  tinyDoMove(move);
  active_color = Side.getOppositeSide(active_color);
```

```
    if (isCheckPosition())
      is_check = true;
    active_color = Side.getOppositeSide(active_color);
    tinyUndoMove(move);

    return is_check;

  }

  @Override
  public boolean isCheckPosition() {
    if (is_check == null) {
      is_check = true;
      int king_pos = getKingPos(active_color);
      ArrayList<List<Integer>> all_squares = SquareHelper
          .getSquaresAllDirections(king_pos);
      // go in each direction
      for (Direction direction : Direction.values()) {
        List<Integer> line = SquareHelper.getAllSquaresInDirection(
            all_squares, direction);
        // go until
        int iter = 0;
        for (int square : line) {
          iter++;
          // some piece is found
          Piece piece = getPieceFromBoard(square);
          if (piece != null) {
            Side side = getSideFromBoard(square);
            if (side == active_color) {
              break;
            } else {
              if (piece == Piece.PAWN && iter == 1) {
                if (((direction == Direction.NORTHEAST || direction ==
                    Direction.NORTHWEST) && active_color == Side.WHITE)
                    || ((direction == Direction.SOUTHEAST || direction ==
                        Direction.SOUTHWEST) && active_color == Side.BLACK)) {
                  return true;
                }
              } else if (piece == Piece.ROOK) {
                if (direction == Direction.EAST
                    || direction == Direction.WEST
                    || direction == Direction.NORTH
                    || direction == Direction.SOUTH) {
                  return true;
                }
              } else if (piece == Piece.BISHOP) {
```

```
            if (direction == Direction.NORTHEAST
                || direction == Direction.NORTHWEST
                || direction == Direction.SOUTHEAST
                || direction == Direction.SOUTHWEST) {
              return true;
            }
          } else if (piece == Piece.QUEEN) {
            return true;
          } else if (piece == Piece.KING && iter == 1) {
            return true;
          }
          break;
        }
      }
    }
  }

  // check for knight attacks
  List<Integer> knight_squares = SquareHelper
      .getAllSquaresByKnightStep(king_pos);
  for (int square : knight_squares) {
    Piece piece = getPieceFromBoard(square);
    if (piece== Piece.KNIGHT) {
      Side side = getSideFromBoard(square);
      if (side != active_color) {
        return true;
      }
    }
  }
  is_check = false;
 }
 return is_check.booleanValue();

}

@Override
public boolean isMatePosition() {
 if (is_mate == null) {
  is_mate = true;
  List<IMove> moves = getPossibleMoves();
  if (moves.isEmpty() && isCheckPosition())
    return true;
  is_mate = false;
 }
 return is_mate.booleanValue();
}
```

```
@Override
public boolean isStaleMatePosition() {
  if (is_stale_mate == null) {
    is_stale_mate = true;
    List<IMove> moves = getPossibleMoves();
    if (moves.isEmpty())
      return true;
    is_stale_mate = false;
  }
  return is_stale_mate.booleanValue();
}

@Override
public boolean isPossibleMove(IMove move) {

  List<IMove> possible_moves = getPossibleMoves();

  return possible_moves.contains(move);
}

public String toString() {
  return toFEN();
}

@Override
public String toFEN() {
  StringBuilder fen = new StringBuilder();

  // piece placement
  for (int row = 0; row < 8; row++) {

    int counter = 0;

    for (int column = 0; column < 8; column++) {

      if (side_board[row * 8 + column] == null) {
        counter++;
      } else {
        if (counter != 0) {
          fen.append(counter);
          counter = 0;
        }
        fen.append(PieceHelper.toString(
            side_board[row * 8 + column], piece_board[row * 8
                + column]));
```

```
      }
      if (column == 7 && counter != 0) {
        fen.append(counter);
      }
    }

    if (row != 7) {
      fen.append("/");
    }
  }
  fen.append(" ");

  // active color
  if (active_color == Side.WHITE) {
    fen.append("w");
  } else {
    fen.append("b");
  }
  fen.append(" ");

  // castling availability
  boolean castle_flag = false;
  if (castling[1] != -1) {
    fen.append("K");
    castle_flag = true;
  }
  if (castling[0] != -1) {
    fen.append("Q");
    castle_flag = true;
  }
  if (castling[3] != -1) {
    fen.append("k");
    castle_flag = true;
  }
  if (castling[2] != -1) {
    fen.append("q");
    castle_flag = true;
  }
  if (!castle_flag) {
    fen.append("-");
  }
  fen.append(" ");

  // en passant target square
  if (en_passant_target == -1) {
    fen.append("-");
```

```
    } else {
      fen.append(SquareHelper.toString(en_passant_target));
    }

    return fen.toString();
  }

  @Override
  public Side getActiveColor() {
    return active_color;
  }

  @Override
  public int hashCode() {
    final int prime = 31;
    int result = 1;

    for (Side element : side_board)
      result = prime * result
          + (element == null ? 0 : element.ordinal() + 1);

    for (Piece element : piece_board)
      result = prime * result
          + (element == null ? 0 : element.ordinal() + 1);

    for (int element : castling)
      result = prime * result + element;

    result = prime * result + active_color.ordinal();

    result = prime * result + en_passant_target;

    return result;
  }

  @Override
  public boolean equals(Object obj) {
    if (this == obj) {
      return true;
    }
    if (obj == null) {
      return false;
    }
    if (getClass() != obj.getClass()) {
      return false;
    }
```

```
    Position other = (Position) obj;
    if (!Arrays.equals(side_board, other.side_board)
        || !Arrays.equals(piece_board, other.piece_board)
        || !Arrays.equals(castling, other.castling)
        || en_passant_target != other.en_passant_target
        || active_color != other.active_color) {
      return false;
    }
    return true;
  }

  @Override
  public List<IMove> generateCaptures() {
    List<IMove> poss_moves = getPossibleMoves();
    List<IMove> result = new ArrayList<IMove>(poss_moves.size());

    for (IMove move : poss_moves)
      if (isHit(move) || move.getPromotion() != null)
        result.add(move);
    return result;
  }

  @Override
  public long hashCode2() {
    final int prime = 23;
    long result = 1;

    for (Side element : side_board)
      result = prime * result
          + (element == null ? 0 : element.ordinal() + 1);

    for (Piece element : piece_board)
      result = prime * result
          + (element == null ? 0 : element.ordinal() + 1);

    for (int element : castling)
      result = prime * result + element;

    result = prime * result + active_color.ordinal();

    result = prime * result + en_passant_target;

    return result;
  }

  @Override
```

```
public int getKingPos(Side side) {
  return king_pos[side.ordinal()];
}

@Override
public void cacheOccupiedSquares() {

  Side s;
  Piece p;
  Set<Integer> w_pawn = new HashSet<Integer>();
  Set<Integer> w_rook = new HashSet<Integer>();
  Set<Integer> w_bishop = new HashSet<Integer>();
  Set<Integer> w_knight = new HashSet<Integer>();
  Set<Integer> w_queen = new HashSet<Integer>();

  Set<Integer> b_pawn = new HashSet<Integer>();
  Set<Integer> b_rook = new HashSet<Integer>();
  Set<Integer> b_bishop = new HashSet<Integer>();
  Set<Integer> b_knight = new HashSet<Integer>();
  Set<Integer> b_queen = new HashSet<Integer>();

  for (int square : SquareHelper.all_squares) {

    s = getSideFromBoard(square);
    if (s == null)
      continue;
    p = getPieceFromBoard(square);
    switch (s) {
    case WHITE:
      switch (p) {
      case PAWN:
        w_pawn.add(square);
        break;
      case ROOK:
        w_rook.add(square);
        break;
      case BISHOP:
        w_bishop.add(square);
        break;
      case KNIGHT:
        w_knight.add(square);
        break;
      case QUEEN:
        w_queen.add(square);
        break;
      default:
```

```
        break;
      }
      break;
    case BLACK:
      switch (p) {
      case PAWN:
        b_pawn.add(square);
        break;
      case ROOK:
        b_rook.add(square);
        break;
      case BISHOP:
        b_bishop.add(square);
        break;
      case KNIGHT:
        b_knight.add(square);
        break;
      case QUEEN:
        b_queen.add(square);
        break;
      default:
        break;
      }
      break;
    }

  }

  occupied_squares_by_color_and_type.put(Side.WHITE.ordinal() * 10
      + Piece.PAWN.ordinal(), w_pawn);
  occupied_squares_by_color_and_type.put(Side.WHITE.ordinal() * 10
      + Piece.ROOK.ordinal(), w_rook);
  occupied_squares_by_color_and_type.put(Side.WHITE.ordinal() * 10
      + Piece.BISHOP.ordinal(), w_bishop);
  occupied_squares_by_color_and_type.put(Side.WHITE.ordinal() * 10
      + Piece.KNIGHT.ordinal(), w_knight);
  occupied_squares_by_color_and_type.put(Side.WHITE.ordinal() * 10
      + Piece.QUEEN.ordinal(), w_queen);

  occupied_squares_by_color_and_type.put(Side.BLACK.ordinal() * 10
      + Piece.PAWN.ordinal(), b_pawn);
  occupied_squares_by_color_and_type.put(Side.BLACK.ordinal() * 10
      + Piece.ROOK.ordinal(), b_rook);
  occupied_squares_by_color_and_type.put(Side.BLACK.ordinal() * 10
      + Piece.BISHOP.ordinal(), b_bishop);
  occupied_squares_by_color_and_type.put(Side.BLACK.ordinal() * 10
```

```
      + Piece.KNIGHT.ordinal(), b_knight);
  occupied_squares_by_color_and_type.put(Side.BLACK.ordinal() * 10
      + Piece.QUEEN.ordinal(), b_queen);

}

@Override
public void doMove(IMove move) {

  int src = move.getFromSquare();
  int dest = move.getToSquare();

  Piece piece = getPieceFromBoard(src);
  Piece capture = getPieceFromBoard(dest);

  setOnBoard(dest, active_color, piece);
  setOnBoard(src, null, null);

  boolean resets_half_move_clock = false;

  // if promotion
  if (move.getPromotion() != null) {
    setOnBoard(dest, active_color, move.getPromotion());
    resets_half_move_clock = true;
    num_occupied_squares_by_color_and_type[active_color.ordinal() * 10
        + Piece.PAWN.ordinal()]--;
    num_occupied_squares_by_color_and_type[active_color.ordinal() * 10
        + move.getPromotion().ordinal()]++;
  }
  // If castling
  else if (piece == Piece.KING && Math.abs((src - dest)) == 20) {
    setOnBoard((src + dest) / 2, active_color, Piece.ROOK);
    if (SquareHelper.getColumn(dest) == 3)
      setOnBoard(src - 40, null, null);
    else
      setOnBoard(src + 30, null, null);
  }
  // If en passant
  else if (piece == Piece.PAWN && dest == en_passant_target) {
    if (active_color == Side.WHITE) {
      setOnBoard(dest - 1, null, null);
    } else {
      setOnBoard(dest + 1, null, null);
    }
    num_occupied_squares_by_color_and_type[Side.getOppositeSide(
        active_color).ordinal()
```

```
      * 10 + Piece.PAWN.ordinal()]--;
  resets_half_move_clock = true;
}
// Usual move
else {
  if (capture != null || piece == Piece.PAWN)
    resets_half_move_clock = true;
}

// update counters
if (capture != null) {
  num_occupied_squares_by_color_and_type[Side.getOppositeSide(
      active_color).ordinal()
      * 10 + capture.ordinal()]--;
}

IrreversibleMoveStack.addInfo(half_move_clock, castling,
    en_passant_target, capture, is_check);

// reset half move clock
if (resets_half_move_clock)
  half_move_clock = 0;

// Update en_passant
if (piece == Piece.PAWN && Math.abs(dest - src) == 2)
  en_passant_target = (dest + src) / 2;
else
  en_passant_target = -1;

// Update castling
if (piece == Piece.KING) {
  king_pos[active_color.ordinal()] = (byte) dest;
  if (active_color == Side.WHITE && src == 51) {
    castling[0] = -1;
    castling[1] = -1;
  } else if (active_color == Side.BLACK && src == 58) {
    castling[2] = -1;
    castling[3] = -1;
  }
} else if (piece == Piece.ROOK) {
  if (active_color == Side.WHITE) {
    if (src == 81)
      castling[1] = -1;
    else if (src == 11)
      castling[0] = -1;
  } else {
```

```
        if (src == 88)
          castling[3] = -1;
        else if (src == 18)
          castling[2] = -1;
      }
    }
    if (capture == Piece.ROOK) {
      if (active_color == Side.BLACK) {
        if (dest == 81)
          castling[1] = -1;
        else if (dest == 11)
          castling[0] = -1;
      } else {
        if (dest == 88)
          castling[3] = -1;
        else if (dest == 18)
          castling[2] = -1;
      }
    }

    // Change active_color after move
    active_color = Side.getOppositeSide(active_color);

    resetCache();

  }

  @Override
  public void undoMove(IMove move) {

    resetCache();

    int src = move.getFromSquare();
    int dest = move.getToSquare();

    Piece piece = getPieceFromBoard(dest);

    // Change active_color after move
    active_color = Side.getOppositeSide(active_color);

    // get the missing information
    MoveInfo inf = IrreversibleMoveStack.irr_move_info.removeLast();

    en_passant_target = inf.en_passant_square;
    Piece capture = inf.capture;
    half_move_clock = inf.half_move_clock;
```

```
System.arraycopy(inf.castling, 0, castling, 0, 4);
is_check = inf.is_check;

setOnBoard(src, active_color, piece);
if (capture != null)
  setOnBoard(dest, Side.getOppositeSide(active_color), capture);
else
  setOnBoard(dest, null, null);

// if promotion
if (move.getPromotion() != null) {
  setOnBoard(src, active_color, Piece.PAWN);
  num_occupied_squares_by_color_and_type[active_color.ordinal() * 10
      + Piece.PAWN.ordinal()]++;
  num_occupied_squares_by_color_and_type[active_color.ordinal() * 10
      + move.getPromotion().ordinal()]--;
}
// If castling
else if (piece == Piece.KING && Math.abs((src - dest)) == 20) {
  setOnBoard((src + dest) / 2, null, null);
  if (SquareHelper.getColumn(dest) == 3)
    setOnBoard(src - 40, active_color, Piece.ROOK);
  else
    setOnBoard(src + 30, active_color, Piece.ROOK);

}
// If en passant
else if (piece == Piece.PAWN && dest == en_passant_target) {
  if (active_color == Side.WHITE) {
    setOnBoard(dest - 1, Side.getOppositeSide(active_color),
        Piece.PAWN);
  } else {
    setOnBoard(dest + 1, Side.getOppositeSide(active_color),
        Piece.PAWN);
  }
  num_occupied_squares_by_color_and_type[Side.getOppositeSide(
      active_color).ordinal()
      * 10 + Piece.PAWN.ordinal()]++;
}

// update counters
if (capture != null) {
  num_occupied_squares_by_color_and_type[Side.getOppositeSide(
      active_color).ordinal()
      * 10 + capture.ordinal()]++;
}
```

```
    if (piece == Piece.KING) {
      king_pos[active_color.ordinal()] = (byte) src;
    }

    is_mate = false;
    is_stale_mate = false;

  }

  /**
   * Performs a incomplete version of doMove. This function only sets the new
   * figure, deletes the captures ones (are saved in side_capture and
   * piece_capture) and changes the active color. Note that it is not possible
   * to perform tinyDoMove twice, because the captured figure of the first
   * application will be lost.
   *
   * @param move
   *           the move to be performed, must be a legal move
   */
  private void tinyDoMove(IMove move) {

    int src = move.getFromSquare();
    int dest = move.getToSquare();

    Piece piece = getPieceFromBoard(src);
    Side s_piece = getSideFromBoard(src);
    piece_capture = getPieceFromBoard(dest);
    side_capture = getSideFromBoard(dest);

    setOnBoard(dest, s_piece, piece);
    setOnBoard(src, null, null);

    // if promotion
    if (move.getPromotion() != null) {
      setOnBoard(dest, s_piece, move.getPromotion());
    }
    // If castling
    else if (piece == Piece.KING && Math.abs((src - dest)) == 20) {
      setOnBoard((src + dest) / 2, s_piece, Piece.ROOK);
      if (SquareHelper.getColumn(dest) == 3)
        setOnBoard(src - 40, null, null);
      else
        setOnBoard(src + 30, null, null);

    }
```

```
    // If en passant
    else if (piece == Piece.PAWN && dest == en_passant_target) {
      if (active_color == Side.WHITE)
        setOnBoard(dest - 1, null, null);
      else
        setOnBoard(dest + 1, null, null);
    }

    // Update castling
    if (piece == Piece.KING)
      king_pos[s_piece.ordinal()] = dest;

    // Change active_color after move
    active_color = Side.getOppositeSide(active_color);

    old_check = is_check;

    is_check = null;
    is_mate = null;
    is_stale_mate = null;

  }

  /**
   * inverts the function tinyDoMove(), note that only one application can be
   * inverted!
   *
   * @param move
   *           the move to be inverted.
   */
  private void tinyUndoMove(IMove move) {

    int src = move.getFromSquare();
    int dest = move.getToSquare();

    Piece piece = getPieceFromBoard(dest);
    Side s_piece = getSideFromBoard(dest);

    // Change active_color after move
    active_color = Side.getOppositeSide(active_color);

    setOnBoard(dest, side_capture, piece_capture);
    setOnBoard(src, s_piece, piece);
    // if promotion
    if (move.getPromotion() != null) {
      setOnBoard(src, s_piece, Piece.PAWN);
```

```
    }
    // If castling
    else if (piece == Piece.KING && Math.abs((src - dest)) == 20) {
      setOnBoard((src + dest) / 2, null, null);
      if (SquareHelper.getColumn(dest) == 3)
        setOnBoard(src - 40, s_piece, Piece.ROOK);
      else
        setOnBoard(src + 30, s_piece, Piece.ROOK);

    }
    // If en passant
    else if (piece == Piece.PAWN && dest == en_passant_target) {
      if (s_piece == Side.WHITE)
        setOnBoard(dest - 1, Side.getOppositeSide(s_piece), Piece.PAWN);
      else
        setOnBoard(dest + 1, Side.getOppositeSide(s_piece), Piece.PAWN);
    }

    // Update king position
    if (piece == Piece.KING)
      king_pos[s_piece.ordinal()] = src;

    is_check = old_check;
    is_mate = false;
    is_stale_mate = false;

  }

  @Override
  public void setHalfMoveClock(int parseInt) {
    half_move_clock = parseInt;

  }

  @Override
  public int getHalfMoveClock() {
    return half_move_clock;
  }

}
```

1.15 AnalysisResult.java

```
package mitzi;
```

```
import java.util.LinkedList;

/*
 * Size of the class:
 * Header:    8 bytes
 * short :    2 bytes
 * Boolean:   16 bytes (8 header + 1 boolean + 7 round up to multiple of 8)
 * boolean:   1 byte
 * 2*byte:    2 bytes
 * Flag:    4 bytes (like int? )
 * IMove:     16 bytes ( 8 header + 2 short+ 2 short + 4 Piece (like int) + 0
    round up to multiple of 8)
 * long:      8 bytes
 * linkedList: 24 + (8 + 24 + 16)k = 24 + 48k bytes
 *       (list: 8 header + 8 reference to first elem + 4 size + 8k reference
    to each node + 4 round up 24+ 8k)
 *        (node: 8 header + 8 reference to next node + 8 reference to class =
    24)
 *        (class: 16 byte)
 *
 * round up:  7 byte
 *  total size: 88 + 48k bytes.
 *
 * k = 3 : 232 bytes
 * k = 5 : 328 bytes
 * k =10 : 568 bytes
 *
 * lets assume that a single analysis needs about 500 bytes.
 * Then a 500 MB TranspositionTable can hold about 1 Mio entries.
 *
 * http://www.javamex.com/tutorials/memory/object_memory_usage.shtml
 * http://www.sandeshshrestha.com/blog/memory-used-by-java-data-types/
 */

public final class AnalysisResult {

  /**
   * The boards score in centipawns.
   */
  public short score;

  /**
   * If true, the board is a stalemate position. I. e. no moves are possible
   * but there is no check. If null, then it has not been analyzed.
   */
```

```
public Boolean is_stalemate;

/**
 * If the evaluation method considers this board to be in an unstable state
 * and recommends a deeper evalutation or is simply not sure, this is set to
 * true.
 */
public boolean needs_deeper;
/**
 * The distance to (complete) search depth at which this result was
 * obtained.
 */
public byte plys_to_eval0 = 0;

/**
 * The distance to selective search depth at which this result was obtained.
 */
public byte plys_to_seldepth = 0;

/**
 * The state of the result in alpha-beta search: exact, fail-high or
 * fail-low
 */
public Flag flag;

/**
 * The best move from current board.
 */
public IMove best_move;

/**
 * Since AnalysisResults are stored in the Transposition Tables
 * (ResultCache), it is important to ensure that the AnalysisResult
 * corresponding to the actual position should be used, if there are
 * collisions with hashvalues. Therefore a second one (this one) is created
 * to identify the position and these problems unlikely.
 **/
public long hashvalue;

/**
 * A sorted list of the better moves in reverse order, i.e. the last moves
 * are better, then the first ones.
 */
public LinkedList<IMove> best_moves = new LinkedList<IMove>();

AnalysisResult(int score, Boolean is_stalemate, boolean needs_deeper,
```

```
    int plys_to_eval0, int plys_to_seldepth, Flag flag) {
  this.score = (short) score;
  this.is_stalemate = is_stalemate;
  this.needs_deeper = needs_deeper;
  this.plys_to_eval0 = (byte) plys_to_eval0;
  this.plys_to_seldepth = (byte) plys_to_seldepth;
  this.flag = flag;
}

AnalysisResult(int score, Boolean is_stalemate, boolean needs_deeper,
    int plys_to_eval0, int plys_to_seldepth, Flag flag,
    IMove best_move, long hashvalue) {
  this.score = (short) score;
  this.is_stalemate = is_stalemate;
  this.needs_deeper = needs_deeper;
  this.plys_to_eval0 = (byte) plys_to_eval0;
  this.plys_to_seldepth = (byte) plys_to_seldepth;
  this.flag = flag;
  this.best_move = best_move;
  this.hashvalue = hashvalue;
}

/**
 * computes a copy of the analysis result without the list of good moves and
 * the hashvalue.
 *
 * @return a copy without some elements.
 */
public AnalysisResult tinyCopy() {
  return new AnalysisResult(score, is_stalemate, needs_deeper,
      plys_to_eval0, plys_to_seldepth, null, best_move, 0);
}

/**
 * sets all values of analysis result except the list of good moves and the
 * hashvalue.
 *
 * @param score
 *          the new score
 * @param is_stalemate
 *          the new status of is_stalemate
 * @param needs_deeper
 *          the new status of needs_deeper
 * @param plys_to_eval0
 *          the new number of plys to base case.
 * @param plys_to_seldepth
```

```
     *           the new number of plys to base case of selective depth.
     * @param flag
     *           the new flag
     * @param best_move
     *           the new best move.
     */
    public void tinySet(int score, boolean is_stalemate, boolean needs_deeper,
        int plys_to_eval0, int plys_to_seldepth, Flag flag, IMove best_move) {
      this.score = (short) score;
      this.is_stalemate = is_stalemate;
      this.needs_deeper = needs_deeper;
      this.plys_to_eval0 = (byte) plys_to_eval0;
      this.plys_to_seldepth = (byte) plys_to_seldepth;
      this.flag = flag;
      this.best_move = best_move;
    }

    /**
     * sets all values of analysis result except the list of good moves and the
     * hashvalue.
     *
     * @param ar
     *           the new analysis result
     */
    public void tinySet(AnalysisResult ar) {
      tinySet(ar.score, ar.is_stalemate, ar.needs_deeper, ar.plys_to_eval0,
          ar.plys_to_seldepth, ar.flag, ar.best_move);
    }

    /**
     * enables a comparison of two results.
     *
     * @param o
     *           the other result.
     * @return 0 if there are the same or have the same value, 1 if the actual
     *         one is more valuable then the other one, -1 else.
     */
    public int compareQualityTo(AnalysisResult o) {
      if (o == null)
        throw new NullPointerException();

      if (this == o)
        return 0;

      // (deeper results)
      if (this.plys_to_eval0 > o.plys_to_eval0)
```

```
      return 1;

    if (this.plys_to_eval0 == o.plys_to_eval0
        && this.plys_to_seldepth == o.plys_to_seldepth)
      return 0;

    return -1;
  }

  /**
   * returns the Principal Variation, i.e. a sequence of best moves moves. It
   * may be cut off, if entries in the ResultCache are overridden.
   *
   * @param pos
   *           the position, where the PV starts
   * @return a linked list with the PV
   */
  public LinkedList<IMove> getPV(IPosition pos, int counter) {
    LinkedList<IMove> pv = new LinkedList<IMove>();
    IPosition best_child;
    AnalysisResult ar;
    if (best_move != null && counter >=0) {
      pv.add(best_move);
      best_child = pos.doMove_copy(best_move);
      ar = ResultCache.getResult(best_child);
      counter--;
      if (ar != null)
        pv.addAll(ar.getPV(best_child, counter));
    }
    return pv;
  }

  @Override
  public String toString() {
    return "cp: " + score + " depth: " + plys_to_eval0
        + (flag != null ? " flag: " + flag : "");
  }
}
```

1.16 BasicMoveComparator.java

```
package mitzi;

import java.util.Comparator;
```

```
import java.util.HashMap;
import java.util.Map;

public class BasicMoveComparator implements Comparator<IMove> {

  /**
   * saves the actual board, where the moves should be compared
   */
  private IPosition board;

  /**
   * map, which maps a move to its value. Initial size set to 35 to prevent
   */
  private Map<IMove, Integer> move_values = new HashMap<IMove, Integer>(35,
      1);

  /**
   * contains values for move comparison
   */
  private static final int[] piece_values = { 100, 500, 325, 325, 975, 000 };

  /**
   * value of a square where a piece moves to or from.
   */
  private static final int[] center_values = { -1, -1, -1, -1, -1, -1, -1,
      -1, -1, -1, -1, 0, 2, 4, 7, 7, 4, 3, 0, -1, -1, 1, 5, 8, 12, 12, 8,
      5, 1, -1, -1, 3, 8, 12, 17, 17, 12, 8, 3, -1, -1, 6, 10, 15, 20,
      20, 15, 10, 6, -1, -1, 6, 10, 15, 20, 20, 15, 10, 6, -1, -1, 3, 8,
      12, 17, 17, 12, 8, 3, -1, -1, 1, 5, 8, 12, 12, 8, 5, 1, -1, -1, 0,
      2, 4, 7, 7, 4, 2, 0, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1,
      -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1 };


  public BasicMoveComparator(IPosition board) {
    this.board = board;
  }

  /**
   * Grades an IMove by some heuristics.
   *
   * Ignoring special situations like en passant and castling.
   *
   * @param move the current move
   */
  private void computeValue(IMove move) {
    int value = 0;
```

```
    // moved figure
    Piece src_piece = board.getPieceFromBoard(move.getFromSquare());

    // captured figure
    Piece dest_piece = board.getPieceFromBoard(move.getToSquare());

    if (dest_piece != null) {
      // try to get advantage in exchange
      value += (piece_values[dest_piece.ordinal()]
          - piece_values[src_piece.ordinal()] + 1) * 16;
    }
    // move with more powerful pieces
    value += piece_values[src_piece.ordinal()];

    // move to the center (but away with the king)
    value += (center_values[move.getToSquare()] - center_values[move
        .getFromSquare()]) * (src_piece == Piece.KING ? -1 : 1);

    move_values.put(move, value);
  }

  /**
   * compares two moves by there value.
   */
  @Override
  public int compare(IMove m1, IMove m2) {
    if (!move_values.containsKey(m1))
      computeValue(m1);
    if (!move_values.containsKey(m2))
      computeValue(m2);

    return Integer.compare(move_values.get(m1), move_values.get(m2));
  }

}
```

1.17 CaptureComparator.java

```
package mitzi;

import java.util.ArrayList;
import java.util.Comparator;
import java.util.EnumSet;
```

```
import java.util.HashMap;
import java.util.Iterator;
import java.util.List;
import java.util.Map;

public class CaptureComparator implements Comparator<IMove> {

  /**
   * saves the actual board, where the moves should be compared
   */
  private IPosition board;

  /**
   * map, which maps a move to its value. Initial size set to 35 to prevent
   */
  private Map<IMove, Integer> move_values = new HashMap<IMove, Integer>(35,
      1);

  private static final int[] piece_values = { 100, 500, 325, 325, 975, 000 };

  private ArrayList<List<IMove>> attackers = new ArrayList<List<IMove>>(2);

  public CaptureComparator(IPosition board) {
    this.board = board.returnCopy();
  }

  private int seeCapture(IMove m) {
    int value = 0;
    int square = m.getToSquare();
    Side side = board.getActiveColor();

    Piece piece = board.getPieceFromBoard(square);
    if (piece == null
        && SquareHelper.getRow(square) != SquareHelper.getRowForSide(
            board.getActiveColor(), 8))
      piece = Piece.PAWN; // en_passant
    else if (piece == null)
      piece = Piece.KING; // promotion, no capture - value of King is 0

    if (attackers.size() < 2) {
      attackers.add(null);
      attackers.add(null);
    }

    List<IMove> captures = board.getPotentialAttackersTo(square);
    captures.remove(m);
```

```
    attackers.set(side.ordinal(), captures);

    board.doMove(m);

    value = (piece_values[piece.ordinal()] - see(square, m));

    board.undoMove(m);

    attackers.clear();
    move_values.put(m, value);
    return value;
  }

  private int see(int square, IMove m) {

    int value = 0;
    Side side = board.getActiveColor();
    update_attackers(square, m);
    IMove move = get_smallest_attacker(side);
    /* skip if the square isn't attacked anymore by this side */
    if (move != null) {
      Piece piece = board.getPieceFromBoard(move.getToSquare());
      board.doMove(move);

      // Do not consider captures if they lose material, therefore max
      // zero
      value = Math.max(0,
          piece_values[piece.ordinal()] - see(square, move));

      board.undoMove(move);
    }
    return value;
  }

  @Override
  public int compare(IMove m1, IMove m2) {
    if (!move_values.containsKey(m1))
      seeCapture(m1);
    if (!move_values.containsKey(m2))
      seeCapture(m2);

    return Integer.compare(move_values.get(m1), move_values.get(m2));
  }

  public IMove get_smallest_attacker(Side side) {
```

```
    Piece p;
    int val = 1001;
    IMove best_move = null;
    List<IMove> captures = attackers.get(side.ordinal());

    if(captures.isEmpty())
      return null;

    piece_values[Piece.KING.ordinal()] = 1000;
    for (IMove move : captures) {
      p = board.getPieceFromBoard(move.getFromSquare());
      if (piece_values[p.ordinal()] < val) {
        best_move = move;
        val = piece_values[p.ordinal()];

        if (val == 100) {
          captures.remove(move);
          return best_move;
        }
      }

    }
    piece_values[Piece.KING.ordinal()] = 0;
    captures.remove(best_move);

    return best_move;
  }

  private void update_attackers(int square, IMove last_move) {

    Side just_computed_side = null;
    if(attackers.get(board.getActiveColor().ordinal())==null){
      List<IMove> captures2 = board.getPotentialAttackersTo(square);
      attackers.set(board.getActiveColor().ordinal(), captures2);
      if(captures2.isEmpty())
        return;
      just_computed_side = board.getActiveColor();
    }

    if(last_move.getPromotion() != null){
      Iterator<IMove> it =
          attackers.get(Side.getOppositeSide(board.getActiveColor()).ordinal()).iterator();
      while(it.hasNext())
        if(it.next().getPromotion()!=null)
          it.remove();
    }
```

```
Piece p = board.getPieceFromBoard(square);

// find attacking direction
if (p == Piece.KNIGHT)
  return;
if (p == Piece.KING)
  return; // should be changed maybe...

int squ_from = last_move.getFromSquare();

int diff = squ_from - square;

Direction direction = null;
EnumSet<Direction> dir_pos = EnumSet.of(Direction.NORTHEAST,
    Direction.EAST, Direction.SOUTHEAST);
EnumSet<Direction> dir_neg = EnumSet.of(Direction.SOUTHWEST,
    Direction.WEST, Direction.NORTHWEST);

if (diff > 0) {
  for (Direction dir : dir_pos) {
    if (diff % dir.offset == 0) {
      direction = dir;
    }
  }
  if (diff < 8)
    direction = Direction.NORTH;
} else {
  for (Direction dir : dir_neg) {
    if (diff % dir.offset == 0) {
      direction = dir;
    }
  }
  if (diff > -8)
    direction = Direction.SOUTH;
}
int new_square = squ_from + direction.offset;
IMove move;
EnumSet<Direction> dir_lines = EnumSet.of(Direction.EAST,
    Direction.SOUTH, Direction.NORTH, Direction.WEST);
EnumSet<Direction> dir_diag = EnumSet.of(Direction.SOUTHEAST,
    Direction.SOUTHWEST, Direction.NORTHEAST, Direction.NORTHWEST);
while (SquareHelper.isValidSquare(new_square)) {
  Side s = board.getSideFromBoard(new_square);
  if (s != null) {
```

```
        if(s==just_computed_side)
          return;
        p = board.getPieceFromBoard(new_square);
        if (p == Piece.QUEEN) {
          move = new Move(new_square, square);
          if (!board.isCheckAfterMove(move))
            attackers.get(s.ordinal()).add(move);
        } else if (p == Piece.BISHOP) {
          if (dir_diag.contains(direction)) {
            move = new Move(new_square, square);
            if (!board.isCheckAfterMove(move))
              attackers.get(s.ordinal()).add(move);
          }
        } else if (p == Piece.ROOK) {
          if (dir_lines.contains(direction)) {
            move = new Move(new_square, square);
            if (!board.isCheckAfterMove(move))
              attackers.get(s.ordinal()).add(move);
          }
        }
        return;
      }

      new_square += direction.offset;
    }
  }
}
```

1.18 BasicBoardAnalyzer.java

```
package mitzi;

public class BasicBoardAnalyzer implements IPositionAnalyzer {

  private int[] start_castling;

  private int[] piece_values = { 100, 500, 325, 325, 975, 000 };

  @Override
  public AnalysisResult eval0(IPosition board) {

    int score = 0;
    int bishop_pair_value = 50;
```

```
    // basic evaluation
    for (Side side : Side.values()) {
      int side_sign = Side.getSideSign(side);

      // piece values
      for (Piece piece : Piece.values()) {
        score += board.getNumberOfPiecesByColorAndType(side, piece)
            * piece_values[piece.ordinal()] * side_sign;
      }

      // bishop pair gives bonus
      if (board.getNumberOfPiecesByColorAndType(side, Piece.BISHOP) == 2) {
        score += bishop_pair_value * side_sign;
      }
    }
    AnalysisResult result = new AnalysisResult(score, null, true, 0, 0, null);
    return result;
  }

  @Override
  public AnalysisResult evalBoard(IPosition board,int alpha, int beta){

    return eval0(board);
  }

  @Override
  public void setCastling(IPosition position){
    start_castling[0] = position.canCastle(31) ? 31 : -1;
    start_castling[1] = position.canCastle(71) ? 71 : -1;
    start_castling[2] = position.canCastle(38) ? 38 : -1;
    start_castling[3] = position.canCastle(78) ? 78 : -1;
  }
}
```

1.19 BoardAnalyzer.java

```
package mitzi;

import static mitzi.MateScores.NEG_INF;

import java.util.ArrayList;
import java.util.Collections;
import java.util.List;
import java.util.Set;
```

```
/**
 *
 * This class computes the value of a board in a proper way, see
 * http://philemon.cycovery.com/site/part2.html for more details.
 *
 */
public class BoardAnalyzer implements IPositionAnalyzer {

  /**
   * the square to array index from Position.java
   */
  protected static int[] square_to_array_index = { 64, 64, 64, 64, 64, 64,
      64, 64, 64, 64, 64, 56, 48, 40, 32, 24, 16, 8, 0, 64, 64, 57, 49,
      41, 33, 25, 17, 9, 1, 64, 64, 58, 50, 42, 34, 26, 18, 10, 2, 64,
      64, 59, 51, 43, 35, 27, 19, 11, 3, 64, 64, 60, 52, 44, 36, 28, 20,
      12, 4, 64, 64, 61, 53, 45, 37, 29, 21, 13, 5, 64, 64, 62, 54, 46,
      38, 30, 22, 14, 6, 64, 64, 63, 55, 47, 39, 31, 23, 15, 7, 64, 64,
      64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64, 64,
      64, 64, 64 };

  /**
   * the material value of a piece.
   */
  static private int[] piece_values = { 100, 500, 325, 325, 975, 000 };

  // The following arrays contains the value of a piece on a specific square,
  // always in favor of white. Since the arrays are symmetric w.r.t. the
  // columns, BLACK uses 63-i entry with opposite sign.
  /**
   * value of squares for bishop and knight, in favor of white
   */
  static private int[] piece_activity_b_k = { -16, -16, -8, -8, -8, -8, -16,
      -16, -16, -16, -4, -4, -4, -4, -16, -16, -8, 2, 6, 6, 6, 6, 2, -8,
      -8, 2, 6, 6, 6, 6, 2, -8, -8, 2, 4, 4, 4, 4, 2, -8, -8, 2, 2, 2, 2,
      2, 2, -8, -8, -8, 0, 0, 0, 0, -8, -8, -16, -8, -8, -8, -8, -8, -8,
      -16 };
  /**
   * value of squares for rook, in favor of white
   */
  static private int[] piece_activity_r = { 0, 0, 4, 6, 6, 4, 0, 0, 0, 0, 4,
      6, 6, 4, 0, 0, 0, 0, 4, 6, 6, 4, 0, 0, 0, 0, 4, 6, 6, 4, 0, 0, 0,
      0, 4, 6, 6, 4, 0, 0, 0, 0, 4, 6, 6, 4, 0, 0, 0, 0, 4, 6, 6, 4, 0,
      0, 0, 0, 4, 6, 6, 4, 0, 0, };

  /**
```

```
 * value of squares for queen, in favor of white
 */
static private int[] piece_activity_q = { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4,
    5, 5, 4, 0, 0, 0, 2, 4, 10, 10, 4, 2, 0, 0, 2, 10, 12, 12, 10, 2,
    0, -10, 2, 10, 12, 12, 10, 2, -10, -10, -10, 4, 10, 10, 4, -10,
    -10, -10, 2, 8, 8, 8, 8, 2, -10, -10, -8, 0, 0, 0, 0, -8, -10, };

/**
 * value of squares, which are weak/strong squares for bishop and knight
 */
static private int[] weak_positions = { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 8, 12, 12, 8, 0, 0, 0, 2, 12, 16, 16, 12, 2, 0,
    0, 2, 12, 20, 20, 12, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, };

/**
 * value of squares for white pawns. (not symmetric)
 */
static private int[] pawn_positions_w = { 0, 0, 0, 0, 0, 0, 0, 0, 28, 28,
    35, 42, 45, 35, 28, 28, -9, -3, 7, 12, 15, 7, -3, -9, -10, -10, 6,
    9, 10, 6, -11, -10, -11, -11, 4, 5, 6, 2, -11, -11, -11, -11, 0, 0,
    1, 0, -11, -11, -6, -6, 4, 5, 5, 4, -6, -6, 0, 0, 0, 0, 0, 0, 0, 0 };

/**
 * value of squares for black pawns. (not symmetric)
 */
static private int[] pawn_positions_b = { 0, 0, 0, 0, 0, 0, 0, 0, -6, -6,
    4, 5, 5, 4, -6, -6, -11, -11, 0, 0, 1, 0, -11, -11, -11, -11, 4, 5,
    6, 2, -11, -11, -10, -10, 6, 9, 10, 6, -11, -10, -9, -3, 7, 12, 15,
    7, -3, -9, 28, 28, 35, 42, 45, 35, 28, 28, 0, 0, 0, 0, 0, 0, 0, 0 };

/**
 * value of squares for white king, not valid in endgame. (not symmetric)
 */
static private int[] king_positions_w = { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -10, -15,
    -10, 0, 0, 5, 10, 18, -8, -3, -8, 23, 10 };

/**
 * value of squares for black king, not valid in endgame. (not symmetric)
 */
static private int[] king_positions_b = { 5, 10, 18, -8, -3, -8, 23, 10, 0,
    0, 0, -10, -15, -10, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 };
```

```
/**
 * value for twin pawns for different rows.
 */
static private int[] twin_pawns = { 0, 0, 1, 2, 3, 4, 7, 0 };

/**
 * value for covered pawns for different rows.
 */
static private int[] covered_pawns = { 0, 0, 4, 6, 8, 12, 16, 0 };

/**
 * value for passed pawns for different rows.
 */
static private int[] passed_pawn = { 0, 2, 10, 20, 40, 60, 70, 0 };

/**
 * value for passed pawns, where in front of the pawn is a king for
 * different rows.
 */
static private int[] passed_pawn_with_king = { 0, 0, 0, 0, 10, 50, 80, 0 };

/**
 * value for blocked passed pawns
 */
static private int[] blocked_passed_pawn = { 0, 0, -8, -16, -32, -45, -58,
    0 };

/**
 * if not all Bishop and Knight has moved, moving the queen results in
 * negative score
 */
static private int PREMATURE_QUEEN = -17;

/**
 * bonus, if the rook is on an open line (no other pawns)
 */
static private int ROOK_OPEN_LINE = 20;

/**
 * bonus if the rook is on an halfopen line (only opponents pawns)
 */
static private int ROOK_HALFOPEN_LINE = 5;

/**
 * bonus if the rook is in the 7th row and opponents king is in the 8th or
```

```
 * pawn in the 7th
 */
static private int ROOK_7TH_2ND = 25;

/**
 * bonus if the previous bonus holds and the 7th row is empty.
 */
static private int ROOK_7TH_2ND_ABSOLUTE = 15;

/**
 * bonus if a rook covers the other rook, this replaces the ROOK_7TH_2ND and
 * counts for each rook (both on the 7th row)
 */
static private int REINFORCED_ROOK_7TH_2ND = 40;

/**
 * bonus if a rook is behind a passed pawn
 */
static private int PASSED_ROOK_SUPPORT = 10;

/**
 * gives a bonus if both bishops are still available in the endgame
 */
static private int ENDGAME_BISHOP_BONUS = 10; // not yet implemented

/**
 * bonus/malus if the bishop is caged on he baseline (the pawn in front of
 * the bishop has moved and the two pawns left and right of the bisop have
 * not moved )
 */
static private int BISHOP_BASELINE_CAGED = -12;

/**
 * bonus if a queen is covered on the 7th row by a rook
 */
static private int REINFORCING_QUEEN_7TH_2ND = 20;

/**
 * The player receives a bonus if the 2 bishops are alive.
 */
static private int bishop_pair_value = 25;

/**
 * multiple pawns in a columns get a malus.
 */
static private int MULTI_PAWN = -10;
```

```
/**
 * a isolated pawns (no pawn on the neighboring colums) get a malus
 */
static private int ISOLATED_PAWN = -20;

/**
 * bonus for coverd passed pawns on the 7th row
 */
static private int COVERED_PASSED_7TH_PAWN = 90;

/**
 * malus if castling is loss (needs to be fixed and optimized)
 */
static private int CASTLING_LOSS = -40;

/**
 * the number of pieces when the endgame starts (a first draft, needs to be
 * optimized)
 */
static public int ENDGAME_THRESHOLD = 12;

/**
 * counts the number of board evaluations in quiesce().
 */
static public long eval_counter_seldepth = 0;

/**
 * counts the number of found positions in Transposition Table
 */
static public long table_counter = 0;

private int[] start_castling = new int[4];

@Override
public AnalysisResult eval0(IPosition board) {
  int score = 0;
  // compute all the information needed by the evaluation function once.
  board.cacheOccupiedSquares();

  // Evaluate the pieces
  score += evalPieces(board);

  // Evaluate Pawn Stucture
  score += evalPawns(board);
```

```
    // Evaluate Diagonals and lines
    score += evalLinesAndDiagonals(board);

    // Evaluate position - activity
    score += evalPieceActivity(board);

    // Evaluate weak/strong position
    score += evalWeakPosition(board);

    // Evaluate the King's position (not in endgame)
    score += evalKingPos(board);

    AnalysisResult result = new AnalysisResult(score, false, false, 0, 0,
        Flag.EXACT);
    return result;
  }

  @Override
  public AnalysisResult evalBoard(IPosition position, int alpha, int beta)
      throws InterruptedException {
    AnalysisResult result = quiesce(position, alpha, beta);

    // The analysis result should always contain the pure value (not
    // perturbed via side_sign)
    return result;
  }

  /**
   * Implements Quiescence search to avoid the horizon effect. The function
   * increase the search depth until no capture is possible, where only
   * captures are analyzed. The optimal value is found using the negamax
   * algorithm.
   *
   * @see <a
   *
      href="http://chessprogramming.wikispaces.com/Quiescence+Search">http://chessprogrammi
   *
   * @param position
   *            the position to be analyzed
   * @param alpha
   *            the alpha value of alpha-beta search
   * @param beta
   *            the beta value of alpha-beta search
   * @return the value of the board ( in favor of white)
   *
   * @throws InterruptedException
```

```
 */
private AnalysisResult quiesce(IPosition position, int alpha, int beta)
    throws InterruptedException {

  if (Thread.interrupted()) {
    throw new InterruptedException();
  }

  int side_sign = Side.getSideSign(position.getActiveColor());

  // Cache lookup
  AnalysisResult entry = ResultCache.getResult(position);
  if (entry != null) {
    table_counter++;
    if (entry.flag == Flag.EXACT) {
      AnalysisResult new_entry = entry.tinyCopy();
      return new_entry;
    } else if (entry.flag == Flag.LOWERBOUND)
      alpha = Math.max(alpha, entry.score * side_sign);
    else if (entry.flag == Flag.UPPERBOUND)
      beta = Math.min(beta, entry.score * side_sign);

    if (alpha >= beta) {
      AnalysisResult new_entry = entry.tinyCopy();
      return new_entry;
    }
  }

  // generate moves
  List<IMove> moves = position.getPossibleMoves();

  // check for mate and stalemate
  if (moves.isEmpty()) {
    eval_counter_seldepth++;
    if (position.isCheckPosition()) {
      return new AnalysisResult(NEG_INF * side_sign, false, false, 0,
          0, Flag.EXACT);
    } else {
      return new AnalysisResult(0, true, false, 0, 0, Flag.EXACT);
    }
  }

  // evaluation of the current board.
  AnalysisResult standing_pat = eval0(position);
  eval_counter_seldepth++;
```

```
int negaval = standing_pat.score * side_sign;

// alpha beta cutoff
if (negaval >= beta)
  return standing_pat;
alpha = Math.max(alpha, negaval);

// Generate possible Captures
List<IMove> captures = position.generateCaptures();
if (captures.size()>1) {
  // Generate MoveComperator
  BasicMoveComparator move_comparator = new BasicMoveComparator(position);

  //CaptureComparator move_comparator = new CaptureComparator(position);
  Collections.sort(captures,
      Collections.reverseOrder(move_comparator));
}

AnalysisResult result = null;
int best_value = NEG_INF;

for (IMove move : captures) {

  position.doMove(move);
  AnalysisResult result_temp = quiesce(position, -beta, -alpha);
  position.undoMove(move);

  negaval = result_temp.score * side_sign;

  // find the best result
  if (negaval > best_value) {
    best_value = negaval;
    result = result_temp;
  }

  // cut-off
  if (negaval >= beta) {
    result.plys_to_seldepth++;
    return result;
  }
  alpha = Math.max(alpha, negaval);
}

// the standing_pat was computed in this depth
if (result == null)
  return standing_pat;
```

```
    // the result comes from a depth below
    result.plys_to_seldepth++;
    return result;

  }

  /**
   * Evaluates only the material value of the board.
   *
   * @param board
   *           the actual board
   * @return the material value ( in favor of white)
   */
  private int evalPieces(IPosition board) {
    int score = 0;

    // basic evaluation
    for (Side side : Side.values()) {
      int side_sign = Side.getSideSign(side);

      // piece values
      for (Piece piece : Piece.values()) {
        score += board.getNumberOfPiecesByColorAndType(side, piece)
            * piece_values[piece.ordinal()] * side_sign;
      }

      // bishop pair gives bonus
      if (board.getNumberOfPiecesByColorAndType(side, Piece.BISHOP) == 2) {
        score += bishop_pair_value * side_sign;
      }
    }

    return score;
  }

  /**
   * Computes the value of the possible activity of the pieces, e.g.
   * centralization,...
   *
   * @param board
   *           the board to be analyzed
   * @return the score for the activity of Rook, Bishop, Knight, Queen ( in
   *         favor of white)
   */
  private int evalPieceActivity(IPosition board) {
```

```
int score = 0;
Set<Integer> squares;
boolean queen_moved_last, queen_startpos;

for (Side side : Side.values()) {
  int side_sign = Side.getSideSign(side);
  queen_moved_last = true;
  queen_startpos = false;

  // Queen
  squares = board.getOccupiedSquaresByColorAndType(side, Piece.QUEEN);
  if (side == Side.WHITE)
    for (int squ : squares)
      score += piece_activity_q[square_to_array_index[squ]];
  else
    for (int squ : squares)
      score -= piece_activity_q[63 - square_to_array_index[squ]];

  if ((squares.contains(SquareHelper.getSquare(
      SquareHelper.getRowForSide(side, 1), 4))))
    queen_startpos = true;

  // Bishop
  squares = board
      .getOccupiedSquaresByColorAndType(side, Piece.BISHOP);
  if (side == Side.WHITE)
    for (int squ : squares)
      score += piece_activity_b_k[square_to_array_index[squ]];
  else
    for (int squ : squares)
      score -= piece_activity_b_k[63 - square_to_array_index[squ]];

  if (!queen_startpos
      && (squares.contains(SquareHelper.getSquare(
          SquareHelper.getRowForSide(side, 1), 3)) || squares
          .contains(SquareHelper.getSquare(
              SquareHelper.getRowForSide(side, 1), 3))))
    queen_moved_last = false;

  // Knight
  squares = board
      .getOccupiedSquaresByColorAndType(side, Piece.KNIGHT);
  if (side == Side.WHITE)
    for (int squ : squares)
      score += piece_activity_b_k[square_to_array_index[squ]];
  else
```

```
      for (int squ : squares)
        score -= piece_activity_b_k[63 - square_to_array_index[squ]];

    if (!queen_startpos
        && (squares.contains(SquareHelper.getSquare(
            SquareHelper.getRowForSide(side, 1), 2)) || squares
            .contains(SquareHelper.getSquare(
                SquareHelper.getRowForSide(side, 1), 2))))
      queen_moved_last = false;

    // Rook
    squares = board.getOccupiedSquaresByColorAndType(side, Piece.ROOK);
    if (side == Side.WHITE)
      for (int squ : squares)
        score += piece_activity_r[square_to_array_index[squ]];
    else
      for (int squ : squares)
        score -= piece_activity_r[63 - square_to_array_index[squ]];

    if (!queen_startpos && !queen_moved_last)
      score += side_sign * PREMATURE_QUEEN;

  }
  return score;
}

/**
 * this function evaluates the weak position of an outpost, however only for
 * bishop and knight. If a knight is covered by pawn, the value increases.
 *
 * @param board
 *          the board to be analyzed
 * @return the score w.r.t. weak/ strong positions ( in favor of white)
 */
private int evalWeakPosition(IPosition board) {

  int score = 0;
  Set<Integer> squares;

  for (Side side : Side.values()) {

    // Bishop
    squares = board
        .getOccupiedSquaresByColorAndType(side, Piece.BISHOP);
    if (side == Side.WHITE)
      for (int squ : squares)
```

```
        score += weak_positions[square_to_array_index[squ]];
      else
        for (int squ : squares)
          score -= weak_positions[63 - square_to_array_index[squ]];

      // Knight (value get multiplied times the number of pawn covering
      // the knight, if no cover no bonus is added)
      squares = board
          .getOccupiedSquaresByColorAndType(side, Piece.BISHOP);
      int count = 0;
      if (side == Side.WHITE) {
        for (int squ : squares) {
          for (Direction dir : Direction
              .pawnCapturingDirections(Side.BLACK))
            if (board.getPieceFromBoard(squ + dir.offset) == Piece.PAWN)
              count++;
          score += count * weak_positions[square_to_array_index[squ]];
        }
      } else {
        for (int squ : squares) {
          for (Direction dir : Direction
              .pawnCapturingDirections(Side.WHITE))
            if (board.getPieceFromBoard(squ + dir.offset) == Piece.PAWN)
              count++;
          score -= count
              * weak_positions[63 - square_to_array_index[squ]];
        }
      }

    }

    return score;
  }

  /**
   * Evaluates if rooks occupies open/halfopen lines, if they occupies the
   * 7-th row or are covered there and if the bishop is caged on the baseline
   * (the pawn in front of him has moved the the neighboring ones are here)
   *
   * @param board
   *          the board to be evaluated
   * @return the score ( in favor of white)
   */
  private int evalLinesAndDiagonals(IPosition board) {
    int score = 0;
```

```
Set<Integer> squares_rook, squares_bishop;
Piece p;
Side s;

for (Side side : Side.values()) {
  int side_sign = Side.getSideSign(side);
  Side opp_side = Side.getOppositeSide(side);

  squares_rook = board.getOccupiedSquaresByColorAndType(side,
      Piece.ROOK);

  // Open line and halfopen line bonus
  for (int square : squares_rook) {

    boolean half_open = true;
    boolean open = true;
    List<Integer> squares = new ArrayList<Integer>(
        SquareHelper.getAllSquaresInDirection(square,
            Direction.NORTH));
    squares.addAll(SquareHelper.getAllSquaresInDirection(square,
        Direction.SOUTH));

    for (int squ : squares) {
      if (board.getPieceFromBoard(squ) == Piece.PAWN) {
        if (board.getSideFromBoard(squ) == board
            .getActiveColor()) {
          half_open = false;
          open = false;
          break;
        } else
          open = false;
      }
    }
    if (half_open && open)
      score += side_sign * ROOK_OPEN_LINE;
    else if (half_open)
      score += side_sign * ROOK_HALFOPEN_LINE;

    // 7th || 2nd line bonus
    if (SquareHelper.getRow(square) == SquareHelper.getRowForSide(
        side, 7)) {

      boolean rook_7 = true;
      boolean rook_7_abs = true;
      boolean rook_7_cover_r = false;
      boolean rook_7_cover_q = false;
```

```
boolean emty_direction = true;

// Check all squares at the west side of the rook
for (int squ : SquareHelper.getAllSquaresInDirection(
    square, Direction.WEST)) {
  p = board.getPieceFromBoard(squ);
  s = board.getSideFromBoard(squ);
  if (p == Piece.PAWN && s == opp_side) {
    rook_7 = false;
    rook_7_abs = false;
    break;
  } else if (emty_direction && p != null) {
    emty_direction = false;
    rook_7_abs = false;
    if (p == Piece.ROOK && s == side)
      rook_7_cover_r = true;
    else if (p == Piece.QUEEN && s == side)
      rook_7_cover_q = true;
  }

}

// Check all squares at the west side of the rook
emty_direction = true;
for (int squ : SquareHelper.getAllSquaresInDirection(
    square, Direction.EAST)) {
  p = board.getPieceFromBoard(squ);
  s = board.getSideFromBoard(squ);
  if (rook_7 && p == Piece.PAWN && s == opp_side) {
    rook_7 = false;
    rook_7_abs = false;
    break;
  } else if (emty_direction && p != null) {
    rook_7_abs = false;
    emty_direction = false;
    if (p == Piece.ROOK && s == side)
      rook_7_cover_r = true;
    else if (p == Piece.QUEEN && s == side)
      rook_7_cover_q = true;
  }

}

int king_pos = board.getKingPos(opp_side);
if (SquareHelper.getRow(king_pos) == SquareHelper
    .getRowForSide(side, 8))
```

```
          rook_7 = true;

        if (rook_7)
          score += side_sign * ROOK_7TH_2ND;
        if (rook_7_abs)
          score += side_sign * ROOK_7TH_2ND_ABSOLUTE;
        if (rook_7_cover_r)
          score += side_sign * REINFORCED_ROOK_7TH_2ND;
        if (rook_7_cover_q)
          score += side_sign * REINFORCING_QUEEN_7TH_2ND;
      }

    }
    squares_bishop = board.getOccupiedSquaresByColorAndType(side,
        Piece.BISHOP);
    int row_s = SquareHelper.getRowForSide(side, 1);
    boolean bishop_caged = false;
    for (int square : squares_bishop)
      if ((square == SquareHelper.getSquare(row_s, 3) || square ==
          SquareHelper
          .getSquare(row_s, 6))
          && (board.getPieceFromBoard(square
              + Direction.pawnDirection(side).offset) == Piece.PAWN && board
              .getSideFromBoard(square
                  + Direction.pawnDirection(side).offset) == side)) {
        bishop_caged = true;
        for (Direction dir : Direction
            .pawnCapturingDirections(side)) {
          if (board.getPieceFromBoard(square + dir.offset) != Piece.PAWN
              || board.getSideFromBoard(square + dir.offset) != side)
            bishop_caged = false;
        }
      }
    if (bishop_caged == true)
      score += side_sign * BISHOP_BASELINE_CAGED;
  }
  return score;
}

/**
 * evaluates the pawn structure. Checks for covered pawns, passed pawns,
 * isolated pawns, twin pawns... value dependent of the row
 *
 * @param position
 *          the current position
 * @return the value of the pawn structure in favor of white
```

```
 */
private int evalPawns(IPosition position) {

  int score = 0;
  int row, col, col_2, row_side;
  boolean isolated, covered, passed;
  for (Side side : Side.values()) {
    int side_sign = Side.getSideSign(side);
    Side opp_side = Side.getOppositeSide(side);
    Set<Integer> squares_pawn = position
        .getOccupiedSquaresByColorAndType(side, Piece.PAWN);
    Set<Integer> squares_pawn_opp = position
        .getOccupiedSquaresByColorAndType(opp_side, Piece.PAWN);

    if (side == Side.WHITE)
      for (int squ : squares_pawn)
        score += pawn_positions_w[square_to_array_index[squ]];
    else
      for (int squ : squares_pawn)
        score -= pawn_positions_b[square_to_array_index[squ]];

    for (int squ_1 : squares_pawn) {
      row = SquareHelper.getRow(squ_1);
      col = SquareHelper.getColumn(squ_1);

      row_side = SquareHelper.getRowForSide(side, row);

      isolated = true;
      covered = false;

      for (int squ_2 : squares_pawn) {
        // dont check the pawn with himself
        if (squ_2 == squ_1)
          continue;

        col_2 = SquareHelper.getColumn(squ_2);
        if (col == col_2)
          // add malus for multiple pawns in the same line.
          // TODO: maybe dont increase malus for triple,.. pawns
          score += side_sign * MULTI_PAWN;
        else if (col == col_2 + 1 || col == col_2 - 1) {
          isolated = false;

          if (row == SquareHelper.getRow(squ_2))
            // add bonus for twinpawns
            score += side_sign * twin_pawns[row_side];
```

```
      else if (row == SquareHelper.getRow(squ_2
          - Direction.pawnDirection(side).offset)) {
        // add bonus for covered pawns
        // TODO: maybe dont increase bonus for pawns covered
        // by 2 pawns
        covered = true;
        score += side_sign * covered_pawns[row_side];
      }
    }

  }

  if (isolated == true)
    score += side_sign * ISOLATED_PAWN;

  // check if a pawn is passed
  passed = true;
  for (int squ_2 : squares_pawn_opp) {
    col_2 = SquareHelper.getColumn(squ_2);
    if (col == col_2 || col == col_2 + 1 || col == col_2 - 1) {
      passed = false;
      break;
    }

  }
  if (passed == true) {
    // check if a passed pawn is blocked
    for (int squ_2 : squares_pawn_opp) {
      if (squ_1 + Direction.pawnDirection(side).offset == squ_2) {
        score += side_sign * blocked_passed_pawn[row_side];
        break;
      }
    }

    // check if a passed pawn is covered by a king (the king
    // should be in front of the pawn)
    for (Direction dir : Direction
        .pawnCapturingDirections(side))
      if (squ_1 + dir.offset == position.getKingPos(side))
        score += side_sign
            * passed_pawn_with_king[row_side];

    // add the bonus for a passed pawn
    score += side_sign * passed_pawn[row_side];

    // additional bonus for covered passed pawn
```

```
        if (covered == true
            && row == SquareHelper.getRowForSide(side, 7))
          score += side_sign * COVERED_PASSED_7TH_PAWN;

        // if a rook is behind a passed pawn
        // TODO: check if it better do add the bonus is a rook is on
        // the same line (behind the pawn)
        if (position.getPieceFromBoard(squ_1
            - Direction.pawnDirection(side).offset) == Piece.ROOK
            && position.getSideFromBoard(squ_1
                - Direction.pawnDirection(side).offset) == side)
          score += side_sign * PASSED_ROOK_SUPPORT;
      }

    }

  }
  return score;
}

/**
 * draft of king's position evaluation function.
 *
 * @param position
 *          the current position
 * @return the score
 */
private int evalKingPos(IPosition position) {
  int score = 0;
  int count_fig = position.getNumberOfPiecesByColor(Side.WHITE)
      + position.getNumberOfPiecesByColor(Side.BLACK);
  if (count_fig > ENDGAME_THRESHOLD)
    for (Side side : Side.values()) {
      int side_sign = Side.getSideSign(side);
      if (side == Side.WHITE)
        score += side_sign
            * king_positions_w[square_to_array_index[position
                .getKingPos(side)]];
      else
        score += side_sign
            * king_positions_b[square_to_array_index[position
                .getKingPos(side)]];
    }

  return score;
}
```

```
  public void setCastling(IPosition position){
    start_castling[0] = position.canCastle(31) ? 31 : -1;
    start_castling[1] = position.canCastle(71) ? 71 : -1;
    start_castling[2] = position.canCastle(38) ? 38 : -1;
    start_castling[3] = position.canCastle(78) ? 78 : -1;
  }
}
```

1.20 Flag.java

```
package mitzi;

/**
 * The flags for the entries in the Transposition Table (PositionCache).
 *
 */
public enum Flag {
  EXACT, LOWERBOUND, UPPERBOUND
}
```

1.21 GameState.java

```
package mitzi;

import java.util.ArrayList;

public class GameState {

  /**
   * the actual position of the current game state
   */
  private IPosition position;

  /**
   * the history of played moves
   */
  private ArrayList<IMove> history = new ArrayList<IMove>();


  /**
   * The number of the full move. It starts at 1, and is incremented after
```

```
 * Black's move.
 */
private int full_move_clock;

private class GameClock {
  // TODO study UCI time management
}

/**
 * creates a new Game with initial position.
 */
public GameState() {
  position = new Position();
  setToInitial();
}

/**
 * sets the current game to the initial state.
 */
public void setToInitial() {
  position.setToInitial();
  full_move_clock = 1;
}

/**
 * sets the current game to the position of the given fen string
 *
 * @param fen
 *           the position in fen notation
 */
public void setToFEN(String fen) {
  position = new Position();
  position.setToFEN(fen);

  String[] fen_parts = fen.split(" ");
  // set half move clock
  position.setHalfMoveClock(Integer.parseInt(fen_parts[4]));
  // set full move clock
  full_move_clock = Integer.parseInt(fen_parts[5]);
}

/**
 * Do the given move and update half_move_clock, full_move_clock and
 * history. It is checked, if the move is valid or not.
 *
 * @param move
```

```
     *           the given move
     */
    public void doMove(IMove move) {
      if (position.isPossibleMove(move)) {
        position = position.doMove_copy(move);
        /*if (mova.resets_half_move_clock) {
          half_move_clock = 0;
        }*/
        if (position.getActiveColor() == Side.BLACK) {
          full_move_clock++;
        }
        history.add(move);

      } else {
        throw new IllegalArgumentException("INVALID MOVE");
      }
    }

    /**
     * @return the actual position of the game
     */
    public IPosition getPosition() {
      return position;
    }

    /**
     * creates the fen string of the actual board.
     */
    @Override
    public String toString() {
      StringBuilder fen = new StringBuilder();

      fen.append(position.toString());
      fen.append(" ");

      // halfmove clock
      fen.append(position.getHalfMoveClock());
      fen.append(" ");

      // fullmove clock
      fen.append(full_move_clock);

      return fen.toString();
    }

    /**
```

```
   * This is the number of halfmoves since the last pawn advance or capture.
   * This is used to determine if a draw can be claimed under the fifty-move
   * rule.
   *
   * @return number of halfmoves since the last pawn advance or capture
   */
  public int getHalfMoveClock() {
    return position.getHalfMoveClock();
  }

  /**
   * The number of the full move. It starts at 1, and is incremented after
   * Black's move.
   *
   * @return number of the full move
   */
  public int getFullMoveClock() {
    return full_move_clock;
  }

  /**
   * return all previous played moves.
   *
   * @return returns a list of all played moves.
   */
  public ArrayList<IMove> getHistory() {
    return history;
  }
}
```

1.22 IrreversibleMoveStack.java

```
package mitzi;

import java.util.LinkedList;

/**
 * This class represents a stack, storing the information, which cannot be
 * reverted only with a given move. It is implemented as a LinkedList
    containing
 * a class which stores the half move clock, the castling, the en passant
    target
 * and the captured piece. (en passant captures does not count as capture).
    The
```

```
 * elements should be accessed via irr_move_info.removeLast();
 */
public class IrreversibleMoveStack {

  static public class MoveInfo {

    int half_move_clock;
    int[] castling = new int[4];
    int en_passant_square;
    Piece capture;
    Boolean is_check;

  }

  /**
   * the stack containing the information
   */
  static public LinkedList<MoveInfo> irr_move_info = new
      LinkedList<MoveInfo>();

  private IrreversibleMoveStack() {
  }

  /**
   * add a new entry.
   *
   * @param half_move_clock
   *           the old half move clock
   * @param castling
   *           the castling array
   * @param en_passant_square
   *           the en passant target square
   * @param capture
   *           the piece, which got captured (null if no capture)
   */
  static public void addInfo(int half_move_clock, int[] castling,
      int en_passant_square, Piece capture, Boolean is_check) {

    MoveInfo inf = new MoveInfo();
    System.arraycopy(castling, 0, inf.castling, 0, 4);
    inf.en_passant_square = en_passant_square;
    inf.half_move_clock = half_move_clock;
    inf.capture = capture;
    inf.is_check = is_check;

    irr_move_info.addLast(inf);
```

```
  }

}
```

1.23 KillerMoves.java

```
package mitzi;

import java.util.HashMap;
import java.util.LinkedList;
import java.util.List;
import java.util.Map;

/**
 * this class saves for each ply a certain number (e.g. 2) of moves
 * (killermoves), which causes an alpha-beta cutoff. If more moves are saved,
 * that allowed, then they get deleted in the order they are saved (like
 * FIFO).This should improve the move ordering.
 *
 */
public class KillerMoves {

  /**
   * a map from a ply to the killermoves.
   */
  private static Map<Integer, LinkedList<IMove>> killer_moves = new
      HashMap<Integer, LinkedList<IMove>>(
      35);

  /**
   * number of killermoves saved
   */
  private static int MAX_SIZE = 2;

  KillerMoves() {
  };

  /**
   * returns for a given ply the killer moves, note that it should be checked
   * if the move is legal.
   *
   * @param ply
   *          the plys from root node
   * @return a list of killer moves.
```

```
 */
static LinkedList<IMove> getKillerMoves(int ply) {
  LinkedList<IMove> k_m = killer_moves.get(ply);
  if (k_m == null)
    k_m = new LinkedList<IMove>();
  return k_m;
}

/**
 * add a new killermove, if more moves are saved than MAX_SIZE, the first
 * killermove got removed.
 *
 * @param ply
 *           depth in the search tree
 * @param move
 *           the move to be added
 */
static void addKillerMove(int ply, IMove move) {
  LinkedList<IMove> k_m = killer_moves.get(ply);
  if (k_m == null)
    k_m = new LinkedList<IMove>();
  if (k_m.size() == MAX_SIZE)
    k_m.iterator().remove();

  k_m.add(move);
}

/**
 * add a new killermove, if more moves are saved than MAX_SIZE, the first
 * killermove got removed.
 *
 * @param ply
 *           depth in the search tree
 * @param move
 *           the move to be added
 * @param entry
 *           if available the old entry can be used for faster update. This
 *           should be a reference to the old element.
 */
static void addKillerMove(int ply, IMove move, List<IMove> entry) {
  if (entry.size() == MAX_SIZE)
    entry.iterator().remove();
  entry.add(move);
}

/**
```

```
   * updates the killermoves after the best move was found, i.e. all moves are
   * shifted from depth -> depth -2
   */
  static void updateKillerMove() {
    for (int i = 2; killer_moves.containsKey(i); i++)
      killer_moves.put(i - 2, killer_moves.get(i));

  }
}
```

1.24 MateScores.java

```
package mitzi;

/**
 * contains the scores for mate positions
 */
public final class MateScores {

  private MateScores() {
  }

  public static final int POS_INF = +30767;
  public static final int NEG_INF = -30767;

}
```

1.25 MitziBrain.java

```
package mitzi;

import java.util.ArrayList;
import java.util.Collections;
import java.util.List;
import java.util.Random;
import java.util.Timer;
import java.util.TimerTask;
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;
import java.util.concurrent.TimeUnit;

import static mitzi.MateScores.*;
```

```
import mitzi.UCIReporter.InfoType;

/**
 * This class implements the AI of Mitzi. The best move is found using the
 * negamax algorithms with Transposition tables. The class regularly sends
 * information about the current search, including nodes per second ("nps"),
    the
 * filling of the Transposition Table ("hashfull") and the current searched
    move
 * on top-level. The board evaluation is moved to a separate class
 * BoardAnalyzer.
 *
 */
public class MitziBrain implements IBrain {

  /**
   * maximal number of threads
   */
  private static final int THREAD_POOL_SIZE = 1;

  /**
   * unit for time management
   */
  private static final TimeUnit THREAD_TIMEOUT_UNIT = TimeUnit.MILLISECONDS;

  /**
   * timeout for thread shutdown
   */
  private static final int THREAD_TIMEOUT = 1000;

  /**
   * upper limit for evaluation time
   */
  private int maxEvalTime;

  /**
   * the currently best result
   */
  private AnalysisResult result;

  /**
   * the executor for the tasks
   */
  private ExecutorService exe;

  /**
```

```
 * the current game state
 */
private GameState game_state;

private class PositionEvaluator implements Runnable {

  private final IPosition position;
  private final int searchDepth;

  public PositionEvaluator(final IPosition position, final int depth) {
    this.position = position;
    this.searchDepth = depth;
  }

  @Override
  public void run() {

    try {
      // Parameters for aspiration windows
      int alpha = NEG_INF; // initial value
      int beta = POS_INF; // initial value
      int asp_window = 25; // often 50 or 25 is used
      int factor = 2; // factor for increasing if out of bounds

      // iterative deepening
      for (int current_depth = 1; current_depth <= searchDepth;
          current_depth++) {
        table_counter = 0;
        BoardAnalyzer.table_counter = 0;

        result = negaMax(position, current_depth, current_depth,
            alpha, beta);
        position.updateAnalysisResult(result);

        if (result.score == POS_INF || result.score == NEG_INF) {
          break;
        }

        // If Value is out of bounds, redo search with larger
        // bounds, but with the same variation tree
        if (result.score <= alpha) {
          alpha -= factor * asp_window;
          current_depth--;
          UCIReporter
              .sendInfoString("Boards found: "
                  + (table_counter + BoardAnalyzer.table_counter));
```

```
          continue;
        } else if (result.score >= beta) {
          beta += factor * asp_window;
          current_depth--;
          UCIReporter
              .sendInfoString("Boards found: "
                  + (table_counter + BoardAnalyzer.table_counter));
          continue;
        }

        alpha = result.score - asp_window;
        beta = result.score + asp_window;

        UCIReporter.sendInfoString("Boards found: "
            + (table_counter + BoardAnalyzer.table_counter));
      }
    } catch (InterruptedException e) {
    }

  }

  @Override
  public String toString() {
    return position.toString();
  }

}

/**
 * counts the number of evaluated board
 */
private long eval_counter;

/**
 * counts the number of found boards in the transposition table.
 */
private long table_counter;

/**
 * the board analyzer for board evaluation
 */
private IPositionAnalyzer board_analyzer = new BoardAnalyzer();

/**
 * the current time.
 */
```

```
private long start_mtime = System.currentTimeMillis();

private Timer timer;

@Override
public void set(GameState game_state) {
  this.game_state = game_state;
  this.eval_counter = 0;
  this.table_counter = 0;
}

/**
 * @return the time, which passes since start_mtime
 */
private long runTime() {
  return System.currentTimeMillis() - start_mtime;
}

/**
 * Sends updates about evaluation status to UCI GUI, namely the number of
 * searched board per second and the size of the Transposition Table in
 * permill of the maximal size.
 *
 */
class UCIUpdater extends TimerTask {
  private long old_mtime;
  private long old_eval_counter;
  private long old_eval_counter_seldepth;

  @Override
  public void run() {
    long mtime = System.currentTimeMillis();

    long eval_span_0 = eval_counter - old_eval_counter;
    long eval_span_sel = BoardAnalyzer.eval_counter_seldepth
        - old_eval_counter_seldepth;
    long eval_span = eval_span_0 + eval_span_sel;

    if (old_mtime != 0) {
      long time_span = mtime - old_mtime;
      UCIReporter.sendInfoNum(InfoType.NPS, eval_span * 1000
          / time_span);

      UCIReporter.sendInfoNum(InfoType.HASHFULL,
          ResultCache.getHashfull());
    }
```

```
    old_mtime = mtime;
    old_eval_counter += eval_span_0;
    old_eval_counter_seldepth += eval_span_sel;

  }
}

/**
 * NegaMax with Alpha Beta Pruning and Transposition Tables
 *
 * @see <a
 *
    href="http://en.wikipedia.org/wiki/Negamax#NegaMax_with_Alpha_Beta_Pruning_and_Transp
 *     with Alpha Beta Pruning and Transposition Tables</a>
 * @param position
 *          the position to evaluate
 * @param total_depth
 *          the total depth to search
 * @param depth
 *          the remaining depth to search
 * @param alpha
 *          the alpha value
 * @param beta
 *          the beta value
 * @return returns the result of the evaluation, stored in the class
 *        AnalysisResult
 *
 * @throws InterruptedException
 */
private AnalysisResult negaMax(IPosition position, int total_depth,
    int depth, int alpha, int beta) throws InterruptedException {

  if (Thread.interrupted()) {
    throw new InterruptedException();
  }
  //
     ------------------------------------------------------------------------
  // whose move is it?
  Side side = position.getActiveColor();
  int side_sign = Side.getSideSign(side);

  //
     ------------------------------------------------------------------------
  int alpha_old = alpha;
```

```
// Cache lookup (Transposition Table)
AnalysisResult entry = ResultCache.getResult(position);
if (entry != null && entry.plys_to_eval0 >= depth) {
  table_counter++;
  if (entry.flag == Flag.EXACT)
    return entry.tinyCopy();
  else if (entry.flag == Flag.LOWERBOUND)
    alpha = Math.max(alpha, entry.score * side_sign);
  else if (entry.flag == Flag.UPPERBOUND)
    beta = Math.min(beta, entry.score * side_sign);

  if (alpha >= beta)
    return entry.tinyCopy();
}

//
    ------------------------------------------------------------------------------
// base of complete tree search
if (depth == 0) {
  // position is a leaf node
  return board_analyzer.evalBoard(position, alpha, beta);
}

//
    ------------------------------------------------------------------------------
// generate moves
List<IMove> moves = position.getPossibleMoves(true);

//
    ------------------------------------------------------------------------------
// Sort the moves:
ArrayList<IMove> ordered_moves = new ArrayList<IMove>(40);
ArrayList<IMove> remaining_moves = new ArrayList<IMove>(40);
BasicMoveComparator move_comparator = new BasicMoveComparator(position);

// Get Killer Moves:
List<IMove> killer_moves = KillerMoves.getKillerMoves(total_depth
    - depth);

// if possible use the moves from Position cache as the moves with
// highest priority
int number_legal_movs_TT =0;
if (entry != null) {
  ordered_moves.addAll(entry.best_moves);
  number_legal_movs_TT = ordered_moves.size();
```

```
  for (IMove k_move : killer_moves)
    if (moves.contains(k_move)
        && !ordered_moves.contains(k_move))
      ordered_moves.add(k_move);

} else {
  // Killer_moves have highest priority
  for (IMove k_move : killer_moves)
    if (moves.contains(k_move))
      ordered_moves.add(k_move);
}
// add the remaining moves and sort them using a basic heuristic
for (IMove move : moves)
  if (!ordered_moves.contains(move))
    remaining_moves.add(move);

Collections.sort(remaining_moves,
    Collections.reverseOrder(move_comparator));
ordered_moves.addAll(remaining_moves);
//
    ------------------------------------------------------------------------------------

if (entry != null && entry.plys_to_eval0 < depth)
  entry.best_moves.clear();

// create new AnalysisResult and parent
AnalysisResult new_entry = null, parent = null;
if (entry == null)
  new_entry = new AnalysisResult(0, null, false, 0, 0, null);

int best_value = NEG_INF; // this starts always at negative!

int i = 0;
int illegal_move_counter =0;
// alpha beta search
for (IMove move : ordered_moves) {

  if(i>=number_legal_movs_TT && position.isCheckAfterMove(move)){
    illegal_move_counter++;
    continue;
  }

  // output currently searched move to UCI
  if (depth == total_depth && total_depth >= 6)
    UCIReporter.sendInfoCurrMove(move, i + 1);
```

```
position.doMove(move);
AnalysisResult result = negaMax(position, total_depth, depth - 1,
    -beta, -alpha);
position.undoMove(move);

int negaval = result.score * side_sign;

// better variation found
if (negaval > best_value || parent == null) {

  best_value = negaval;

  // update cache entry
  if (entry != null && entry.plys_to_eval0 < depth)
    entry.best_moves.add(move);
  if (entry == null)
    new_entry.best_moves.add(move);

  // update AnalysisResult
  byte old_seldepth = (parent == null ? 0
      : parent.plys_to_seldepth);
  parent = result; // change reference
  parent.best_move = move;
  parent.plys_to_eval0 = (byte) depth;
  if (best_value != POS_INF) {
    parent.plys_to_seldepth = (byte) Math.max(old_seldepth,
        parent.plys_to_seldepth);
  }

  // output to UCI
  if (depth == total_depth) {
    position.updateAnalysisResult(parent);
    game_state.getPosition().updateAnalysisResult(parent);
    UCIReporter.sendInfoPV(game_state.getPosition(), runTime());
  }
}

// alpha beta cutoff
alpha = Math.max(alpha, negaval);
if (alpha >= beta) {
  // set also KillerMove:
  if (!killer_moves.contains(move))
    KillerMoves.addKillerMove(total_depth - depth, move,
        killer_moves);
  break;
}
```

```
      i++;
    }
    // check for mate and stalemate
    if (illegal_move_counter == ordered_moves.size()) {
      eval_counter++;
      if (position.isCheckPosition()) {
        return new AnalysisResult(NEG_INF * side_sign, false, false, 0,
            0, Flag.EXACT);
      } else {
        return new AnalysisResult(0, true, false, 0, 0, Flag.EXACT);
      }
    }

    //
        ----------------------------------------------------------------------------
    // Transposition Table Store;
    if (best_value <= alpha_old)
      parent.flag = Flag.UPPERBOUND;
    else if (best_value >= beta)
      parent.flag = Flag.LOWERBOUND;
    else
      parent.flag = Flag.EXACT;

    if (entry != null && entry.plys_to_eval0 < depth) {
      entry.tinySet(parent);
      Collections.reverse(entry.best_moves);
    }

    if (entry == null) {
      new_entry.tinySet(parent);
      Collections.reverse(new_entry.best_moves);
      ResultCache.setResult(position, new_entry);
    }

    return parent;

  }

  @Override
  public IMove search(int movetime, int maxMoveTime, int searchDepth,
      boolean infinite, List<IMove> searchMoves) {

    // note, the variable seachMoves is currently unused, this feature is
    // not yet implemented!
```

```
    // set up threading
    timer = new Timer();
    exe = Executors.newFixedThreadPool(THREAD_POOL_SIZE);

    // make a copy of the actual position
    IPosition position = game_state.getPosition().returnCopy();

    board_analyzer.setCastling(position);

    int max_depth;

    // set parameters for searchtime and searchdepth
    if (movetime == 0 && maxMoveTime == 0) {
      maxEvalTime = 60 * 60 * 1000; // 1h
      max_depth = searchDepth;
    } else if (movetime == 0 && infinite == false) {
      maxEvalTime = maxMoveTime;
      max_depth = searchDepth;
    } else if (movetime == 0 && infinite == true) {
      maxEvalTime = maxMoveTime;
      max_depth = 200;
    } else if (maxMoveTime == 0) {
      maxEvalTime = movetime;
      max_depth = 200; // this can never be reached :)
    } else if (infinite == true) {
      maxEvalTime = maxMoveTime;
      max_depth = 200; // this can never be reached :)
    } else {
      maxEvalTime = Math.min(movetime, maxMoveTime);
      max_depth = searchDepth;
    }

    timer.scheduleAtFixedRate(new UCIUpdater(), 1000, 5000);
    start_mtime = System.currentTimeMillis();

    // reset the result
    result = null;

    // create a new task
    PositionEvaluator evaluator = new PositionEvaluator(position, max_depth);

    // execute the task
    exe.execute(evaluator);

    return wait_until();
  }
```

```
/**
 * stops all active threads if mitzi is running out of time
 *
 * @return the best move
 */
public IMove wait_until() {

  exe.shutdown();

  // wait for termination of execution
  try {
    if (exe.awaitTermination(maxEvalTime, THREAD_TIMEOUT_UNIT)) {
      UCIReporter.sendInfoString("task completed");
    } else {
      UCIReporter.sendInfoString("forcing task shutdown");
      exe.shutdownNow();
      exe.awaitTermination(THREAD_TIMEOUT, TimeUnit.SECONDS);
    }
  } catch (InterruptedException e) {
    // TODO Auto-generated catch block
    e.printStackTrace();
  }

  // shut down timers and update killer moves
  timer.cancel();
  UCIReporter.sendInfoPV(game_state.getPosition(), runTime());
  KillerMoves.updateKillerMove();

  // if no best_move has been found yet, choose any
  if (result == null) {
    List<IMove> possibleMoves = game_state.getPosition()
        .getPossibleMoves();
    int randy = new Random().nextInt(possibleMoves.size());
    return possibleMoves.get(randy);
  }

  // return the best move of the last completely searched tree
  return result.best_move;
}

@Override
public IMove stop() {
  // shut down immediately
  exe.shutdownNow();
```

```
    // shut down timers and update killer moves
    timer.cancel();
    UCIReporter.sendInfoPV(game_state.getPosition(), runTime());
    KillerMoves.updateKillerMove();

    // return the best move of the last completely searched tree
    if (result == null)
      return null; // this should never happen

    return result.best_move;
  }
}
```

1.26 ResultCache.java

```
package mitzi;

import java.util.LinkedHashMap;
import java.util.Map;

/**
 * After creating a new <code>AnalysisResult</code> instance, use this class
    to
 * cache it for later lookup of moves, score, etc. The AnalysisResults are
 * indexed by the HashCode of the corresponding position, therefore it can
 * happen, that different AnalysisResults have the same HashCode. In such a
 * case, the old values get overridden. The AnalysisResults store a different
 * hashvalue to reduce the probability of using a wrong AnalysisResult, if two
 * positions have the same HashCode.
 *
 */
public class ResultCache {

  private static final int MAX_ENTRIES = 600000;

  /**
   * A map from the Position's <code>hashCode</code> to the AnalysisResult.
   * The size of the table is limited with <code>MAX_ENTRIES</code>
   */
  private static LinkedHashMap<Integer, AnalysisResult> position_cache = new
      LinkedHashMap<Integer, AnalysisResult>(
      MAX_ENTRIES + 1, 1) {

    private static final long serialVersionUID = 4582735742585308092L;
```

```
  protected boolean removeEldestEntry(
      Map.Entry<Integer, AnalysisResult> eldest) {
    return size() > MAX_ENTRIES;
  }
};

/**
 * Cannot be instantiated. For access to the static cache use
 * <code>ResultCache.getPosition(p)</code>.
 */
private ResultCache() {
}

/**
 * Looks up a <code>Position</code> in the cache and returns the saved value
 * if found and with coinciding second hashvalue. otherwise null.
 *
 * @param lookup
 *          the <code>Position</code> to look up in the cache
 * @return a previously cached <code>AnalysisResult</code> if available,
 *        null otherwise.
 */
public static AnalysisResult getResult(IPosition lookup) {
  int hash = lookup.hashCode();
  AnalysisResult ce = position_cache.get(hash);
  if (ce == null || lookup.hashCode2() != ce.hashvalue)
    return null;
  else
    return ce;
}

/**
 * stores a AnalysisResult corresponding to a Position. The second
    hashvalue is automatically set here.
 * @param pos the position corresponding to the AnalysisResult
 * @param ce the AnalysisResult
 */
public static void setResult(IPosition pos, AnalysisResult ce) {
  ce.hashvalue = pos.hashCode2();
  int hash = pos.hashCode();
  position_cache.put(hash, ce);

}

/**
```

```
   *
   * @return the number of stored results in this cache
   */
  public static int size() {
    return position_cache.size();
  }

  /**
   * @return the hash is x permill full
   */
  public static int getHashfull() {
    return (int) ((double) position_cache.size() / MAX_ENTRIES * 1000);
  }
}
```

1.27 UCIReporter.java

```
package mitzi;

import static mitzi.MateScores.*;

public final class UCIReporter {

  /**
   * the engine should send these infos regularly
   *
   * DEPTH: search depth in plies
   *
   * NODES: number of nodes searched
   *
   * NPS: number of nodes per second searched
   *
   * HASHFULL: the hash is x permill full
   */
  public static enum InfoType {
    DEPTH("depth"), NODES("nodes"), NPS("nps"), HASHFULL("hashfull");

    public String string;

    InfoType(String string) {
      this.string = string;
    }
  }
```

```
private static String last_pv = "";

private UCIReporter() {
};

/**
 * Send debugging messages to the GUI.
 *
 * @param string
 *           the message to be displayed
 */
public static void sendInfoString(String string) {
  System.out.println("info string " + string);
}

/**
 * Send information about search depth, number of nodes searched and number
 * of nodes searched per second to the GUI.
 *
 * @param type
 *           one of UCIReporter.InfoType
 * @param eval_counter
 *           the integer value to be sent
 */
public static void sendInfoNum(InfoType type, long eval_counter) {
  System.out.println("info " + type.string + " " + eval_counter);
}

/**
 * Send information about the currently searched move to the GUI.
 *
 * @param move
 *           currently searching this IMove
 * @param move_number
 *           currently searching move number n, for the first move n should
 *           be 1 not 0.
 */
public static void sendInfoCurrMove(IMove move, int move_number) {
  System.out.println("info currmove " + move + " currmovenumber "
      + move_number);
}



/**
 * The Principal variation (PV) is a sequence of moves that programs
```

```
 * consider best and therefore expect to be played. Also all infos belonging
 * to the PV should be sent together.
 *
 * @param position
 *           a Position with an AnalysisResult
 * @param time
 *           the time searched in ms
 */
public static void sendInfoPV(IPosition position, long time) {
  AnalysisResult result = position.getAnalysisResult();
  if (result == null)
    return;

  StringBuilder pv = new StringBuilder();

  if (result.score == NEG_INF && position.getActiveColor() == Side.WHITE
      || result.score == POS_INF
      && position.getActiveColor() == Side.BLACK) {
    pv.append("info score mate -"
        + ((result.plys_to_eval0 + result.plys_to_seldepth + 1) / 2)
        + " depth " + result.plys_to_eval0 + " seldepth "
        + (result.plys_to_seldepth + result.plys_to_eval0) + " pv");
  } else if (result.score == NEG_INF
      && position.getActiveColor() == Side.BLACK
      || result.score == POS_INF
      && position.getActiveColor() == Side.WHITE) {
    pv.append("info score mate "
        + ((result.plys_to_eval0 + result.plys_to_seldepth + 1) / 2)
        + " depth " + result.plys_to_eval0 + " seldepth "
        + (result.plys_to_seldepth + result.plys_to_eval0) + " pv");
  } else {
    pv.append("info score cp " + result.score + " depth "
        + result.plys_to_eval0 + " seldepth "
        + (result.plys_to_seldepth + result.plys_to_eval0) + " pv");
  }

  for (IMove move : result.getPV(position, result.plys_to_eval0)) {
    pv.append(" " + move);
  }

  String new_pv = pv.toString();
  if (!last_pv.equals(new_pv)) {
    System.out.print(new_pv);
    System.out.println(" time " + time);
    last_pv = new_pv;
  }
```

```
  }
}
```

1.28 MitziGUI.java

```
package mitzi;

import javax.swing.JFrame;

import java.awt.*;
import java.awt.event.*;

import javax.swing.*;


public class MitziGUI extends JFrame implements MouseListener,
    MouseMotionListener {

  private static final long serialVersionUID = -4180006263951182 46L;

  JLayeredPane layeredPane;
  JPanel chessBoard;
  JLabel chessPiece;
  int xAdjustment;
  int yAdjustment;

  int start_square;
  int end_square;

  private static GameState state = new GameState();

  private static boolean mitzis_turn;

  private static Side mitzis_side =null;

  Dimension boardSize = new Dimension(800, 800);

  public Object[] options = { "ok" };

  public MitziGUI() {
    redraw();
  }

  private void redraw() {
```

```
    // Use a Layered Pane for this this application
    layeredPane = new JLayeredPane();

    layeredPane.setPreferredSize(boardSize);
    layeredPane.addMouseListener(this);
    layeredPane.addMouseMotionListener(this);

    // Add a chess board to the Layered Pane
    chessBoard = new JPanel();
    layeredPane.add(chessBoard, JLayeredPane.DEFAULT_LAYER);
    chessBoard.setLayout(new GridLayout(8, 8));
    chessBoard.setPreferredSize(boardSize);
    chessBoard.setBounds(0, 0, boardSize.width, boardSize.height);

    // Color it b/w
    Color black = Color.getHSBColor((float) 0.10, (float) 0.40,
        (float) 0.80);
    Color white = Color.getHSBColor((float) 0.15, (float) 0.13,
        (float) 0.98);
    for (int i = 0; i < 64; i++) {
      JPanel square = new JPanel(new BorderLayout());
      chessBoard.add(square);
      square.setBackground((i + i / 8) % 2 == 0 ? white : black);
    }

    getContentPane().removeAll();
    getContentPane().add(layeredPane);
  }

  private int getSquare(int x, int y) {
    x = x / 100 + 1;
    y = (800 - y) / 100 + 1;
    return x * 10 + y;
  }

  private Component squareToComponent(int squ) {

    int row = 8 - squ % 10;
    int col = ((int) squ / 10) - 1;

    Component c = chessBoard.getComponent(row * 8 + col);
    return c;
  }

  public void setToFEN(String fen) {
```

```
redraw();

JPanel panel;

String[] fen_parts = fen.split(" ");

// populate the squares
String[] fen_rows = fen_parts[0].split("/");
char[] pieces;
for (int row = 0; row < 8; row++) {
  int offset = 0;
  for (int column = 0; column + offset < 8; column++) {
    pieces = fen_rows[row].toCharArray();
    int square = row * 8 + column + offset;
    JLabel piece;
    switch (pieces[column]) {
    case 'P':
      piece = new JLabel("");
      break;
    case 'R':
      piece = new JLabel("");
      break;
    case 'N':
      piece = new JLabel("");
      break;
    case 'B':
      piece = new JLabel("");
      break;
    case 'Q':
      piece = new JLabel("");
      break;
    case 'K':
      piece = new JLabel("");
      break;
    case 'p':
      piece = new JLabel("");
      break;
    case 'r':
      piece = new JLabel("");
      break;
    case 'n':
      piece = new JLabel("");
      break;
    case 'b':
      piece = new JLabel("");
```

```
        break;
      case 'q':
        piece = new JLabel("");
        break;
      case 'k':
        piece = new JLabel("");
        break;
      default:
        piece = new JLabel("");
        offset += Character.getNumericValue(pieces[column]) - 1;
        break;
      }
      panel = (JPanel) chessBoard.getComponent(square);
      piece.setFont(new Font("Serif", Font.PLAIN, 100));
      panel.add(piece);
    }
  }
  chessBoard.updateUI();
}

public void mousePressed(MouseEvent e) {
  chessPiece = null;
  Component c = chessBoard.findComponentAt(e.getX(), e.getY());

  if (c instanceof JPanel)
    return;
  Point parentLocation = c.getParent().getLocation();
  xAdjustment = parentLocation.x - e.getX();
  yAdjustment = parentLocation.y - e.getY();
  start_square = getSquare(e.getX(), e.getY());
  chessPiece = (JLabel) c;
  chessPiece.setLocation(e.getX() + xAdjustment, e.getY() + yAdjustment);
  chessPiece.setSize(chessPiece.getWidth(), chessPiece.getHeight());
  layeredPane.add(chessPiece, JLayeredPane.DRAG_LAYER);
}

// Move the chess piece around
public void mouseDragged(MouseEvent me) {
  if (chessPiece == null)
    return;
  chessPiece
      .setLocation(me.getX() + xAdjustment, me.getY() + yAdjustment);
}

// Drop the chess piece back onto the chess board
public void mouseReleased(MouseEvent e) {
```

```
if (chessPiece == null)
  return;
chessPiece.setVisible(false);
end_square = getSquare(e.getX(), e.getY());

// check for promotion
IMove move;
if (state.getPosition().getPieceFromBoard(start_square) == Piece.PAWN
    && (SquareHelper.getRow(end_square) == 8 || SquareHelper
        .getRow(end_square) == 1)) {
  move = new Move(start_square, end_square, askPromotion());
} else {
  move = new Move(start_square, end_square);
}

//if its not your turn, you are not allowed to do anything.
if(mitzis_side == state.getPosition().getActiveColor())
{
  Container parent = (Container) squareToComponent(start_square);
  parent.add(chessPiece);
  chessPiece.setVisible(true);
  return;
}

//try to do move
try {
  state.doMove(move);
} catch (IllegalArgumentException ex) {
  Container parent = (Container) squareToComponent(start_square);
  parent.add(chessPiece);
  chessPiece.setVisible(true);
  return;
}


IPosition position = state.getPosition();
setToFEN(position.toFEN());
if (state.getPosition().isMatePosition()) {
  JOptionPane.showOptionDialog(this,
      "You Won!","Information",
      JOptionPane.DEFAULT_OPTION, JOptionPane.QUESTION_MESSAGE, null,
      options, options[0]);
  return;
}
if (state.getPosition().isStaleMatePosition()) {
  JOptionPane.showOptionDialog(this,
```

```
        "Draw","Information",
        JOptionPane.DEFAULT_OPTION, JOptionPane.QUESTION_MESSAGE, null,
        options, options[0]);
    return;
  }

  mitzis_turn = true;
}

public void mouseClicked(MouseEvent e) {
}

public void mouseMoved(MouseEvent e) {
}

public void mouseEntered(MouseEvent e) {
}

public void mouseExited(MouseEvent e) {
}

private Piece askPromotion() {
  Object[] options = { "Queen", "Rook", "Bishop", "Knight" };
  int n = JOptionPane.showOptionDialog(this,
      "Which piece do you want to promote to?", "Pawn Promotion",
      JOptionPane.DEFAULT_OPTION, JOptionPane.QUESTION_MESSAGE, null,
      options, options[0]);
  if (n == 0) {
    return Piece.QUEEN;
  } else if (n == 1) {
    return Piece.ROOK;
  } else if (n == 2) {
    return Piece.BISHOP;
  } else {
    return Piece.KNIGHT;
  }
}

public static void main(String[] args) {
  JFrame frame = new MitziGUI();
  frame.setDefaultCloseOperation(DISPOSE_ON_CLOSE);
  frame.pack();
  frame.setResizable(false);
  frame.setLocationRelativeTo(null);
  frame.setVisible(true);
  frame.setTitle("Mitzi GUI");
```

```
MitziGUI gui = (MitziGUI) frame;
Object[] choice = { "You", "Mitzi" };

String initialFEN = "rnbqkbnr/pppppppp/8/8/8/8/PPPPPPPP/RNBQKBNR w KQkq -
    0 1";
state.setToFEN(initialFEN);
gui.setToFEN(initialFEN);
int n = JOptionPane.showOptionDialog(frame,
    "Who should start","Question",
    JOptionPane.DEFAULT_OPTION, JOptionPane.QUESTION_MESSAGE, null,
    choice, choice[0]);

if(n==0)
{
  mitzis_turn = false;
  mitzis_side = Side.BLACK;
}
else
{
  mitzis_turn = true;
  mitzis_side = Side.WHITE;
}
IBrain mitzi = new MitziBrain();
IMove move;
while (true) {
  System.out.print("");
  if(mitzis_turn) {
    // Mitzis turn

    mitzi.set(state);
    move = mitzi.search(5000, 5000, 6, true, null);
    state.doMove(move);

    gui.setToFEN(state.getPosition().toFEN());
    if (state.getPosition().isMatePosition()) {
      JOptionPane.showOptionDialog(frame,
          "Mitzi Won!","Information",
          JOptionPane.DEFAULT_OPTION, JOptionPane.QUESTION_MESSAGE, null,
          gui.options, gui.options[0]);
      return;
    }
    if (state.getPosition().isStaleMatePosition()) {
      JOptionPane.showOptionDialog(frame,
          "Draw!","Information",
          JOptionPane.DEFAULT_OPTION, JOptionPane.QUESTION_MESSAGE, null,
```

```
            gui.options, gui.options[0]);
          return;
        }
        mitzis_turn=false;
      }
    }
  }
}
```