Lab #6: Local search algorithms

The main aim of this lab is to solve the problem of 8 Queen using **Hill climbing with random restart** and **Simulated annealing algorithms.**

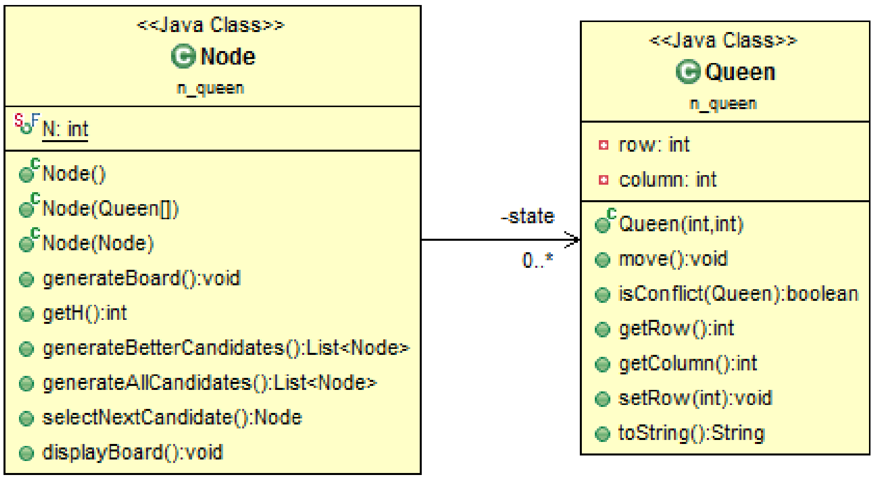
The problem statement is as follows: Consider an N × N chessboard. Place N queens on the board such that no two queens are attacking each other. The queen is the most powerful piece in chess and can attack from any distance horizontally, vertically, or diagonally. Thus, a solution must place the queens such that no two queens are in the same row, the same column, or along the same diagonal.

In this lab, the problem is solved using a **complete-state formulation** (N=8), which means we start with **all 8 queens on the board**. We represent the 8 × 8 chessboard as a matrix. In addition, we assume that each Queen is placed on a different column. Therefore, we try to move the Queen to different row (each by one row) to reach a goal state.

The heuristic is measured by using:

- *h = the number of pairs of attacking queens*

Class diagram is described as follows:



Code:

```
public class Queen {
      private int row;
      private int column;

      public Queen(int row, int column) {
            super();
            this.row = row;
            this.column = column;
      }
```

```
//...
```

Node class: each node includes N Queens and presents a state.

```
public class Node {
	public static final int N = 8;
	private Queen[] state;

	public Node() {
		// generateBoard();
		state = new Queen[N];
	}

	public Node(Queen[] state) {
		this.state = new Queen[N];
		for (int i = 0; i < state.length; i++) {
			this.state[i] = new Queen(state[i].getRow(),
						state[i].getColumn());
		}
	}

	public Node(Node n) {
		this.state = new Queen[N];
		for (int i = 0; i < N; i++) {
			Queen qi = n.state[i];
			this.state[i] = new Queen(qi.getRow(),
						qi.getColumn());
		}
	}

//...
}
```

Task 1: Implement the following methods in **Queen.java** class:

```
//Move the queen by 1 row
public void move() {...}
//Check whether this Queen can attack the given Queen (q)
public boolean isConflict(Queen q) {...}
```

Task 2: Implement the following methods in **Node.java** class:

```
public int getH() {
	int heuristic = 0;
		// Enter your code here
	return heuristic;
}

public List<Node> generateAllCandidates() {
	List<Node> result = new ArrayList<Node>();

	// Enter your code here
	return result;
}
```

Task 3: Implement `execute` for traditional Hill Climbing search and `executeHillClimbingWithRandomRestart` to overcome the local optimum using the given method named `generateAllCandidates` (in **Node.java** class) to generate all candidates.

```
public Node execute(Node initialState) {
// Enter your code here.
return null;
}
public Node executeHillClimbingWithRandomRestart(Node
initialState) {
// Enter your code here.
return null;

}
```

The pseudocode of Hill Climbing Search:

```
function HILL-CLIMBING(problem) returns a state that is a local maximum
    inputs: problem, a problem
    local variables: current, a node
                     neighbor, a node

    current ← MAKE-NODE(INITIAL-STATE[problem])
    loop do
        neighbor ← a highest-valued successor of current
        if VALUE[neighbor] ≤ VALUE[current] then return STATE[current]
        current ← neighbor
    end
```

Notice that, VALUE[neighbor] <= VALUE[current] means the current state is the best state. Hill climbing algorithm reaches a peak.

The pseudocode of Hill Climbing Search with Random Restart:

```
function(initialState) {//Node initialState
    state <- execute HillClimbingSearh(initialState);
    //computeH(state)=0 means that the solution is found
    while (computeH(state)!=0){
        // Random Restart If not a Solution.
       //generate new configuration of N Queens
        state <- state.generateBoard();
        state <- execute HillClimbingSearh(state);
    }
    return state;
};
```

Additional task. Using the following defined variable to track the information of the implemented algorithms (defined in `HillClimbingSearchNQueen` class).

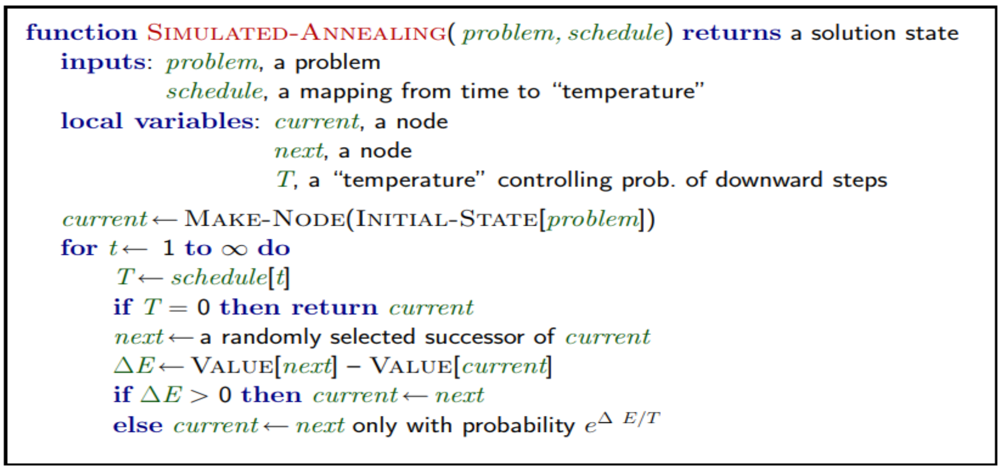
```
int stepClimbed = 0;
int stepClimbedAfterRandomRestart = 0;
int randomRestarts = 0;
```

Task 4: Apply SA alogrithm for NQueen problem, pseudocode is described as follows:

First, implement the following method to select a random successor of the current state.

```
public Node selectNextRandomCandidate() {
     // Enter your code here.
     return null;
}
```

Then, implement the SA algorithm w.r.t the following pseudo code as follows:



```
function SIMULATED-ANNEALING( problem, schedule) returns a solution state
   inputs: problem, a problem
           schedule, a mapping from time to "temperature"
   local variables: current, a node
                    next, a node
                    T, a "temperature" controlling prob. of downward steps

   current ← MAKE-NODE(INITIAL-STATE[problem])
   for t ← 1 to ∞ do
       T ← schedule[t]
       if T = 0 then return current
       next ← a randomly selected successor of current
       $\Delta E$ ← VALUE[next] – VALUE[current]
       if $\Delta E > 0$ then current ← next
       else current ← next only with probability $e^{\Delta E/T}$
```

Hint: We can use the **h** measure as aforementioned as the value of **VALUE[next], VALUE[current]**, cooling rate is used as a coefficient to decrease the temperature for each iteration (see attached project applying SA algorithm to solve TSP problem).