

# **REPORT**

## **Programming Project 2**

Solving N-Queens Problem by Hill-Climbing and its Variants

ITCS 6150 Intelligent Systems  
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## 1. Introduction- N Queens Formulation

N Queens problem consists of N number of queens placed in a NxN board such that the queens are not in conflict with each other (directly or indirectly), i.e. that no other queen is in the same row, column or diagonal as another queen.

## 2. Program Structure

Language Used: Python

Goal State: Heuristic value of board is 0

### **Steepest-Ascent Hill Climbing:**

#### **User Inputs:**

- To solve the N Queens problem, we have taken the N value.
- The number of times the program has to run to get the averages of successes and failures from the user.

#### **Program Flow:**

- A board is generated by placing a queen at random **row-wise**.
- The board's current heuristic is calculated, along with the heuristic value of every movement a queen can make row-wise.
- The lowest value of heuristic is compared to the current board heuristic and a queen is shifted.
- When the heuristic of the next movement is equal to the current board's heuristic, we get a failure message indicating the board's failure in solving the N Queens problem.
- If we get a board whose heuristic value is zero, we know that the goal state has been reached.

### **Hill-Climbing Search with Sideways Moves:**

#### **User Inputs:**

- To solve the N Queens problem, we have taken the N value
- The number of times the program has to be run to get the averages of successes and failures from the user.

#### **Program Flow:**

- A board is generated by placing a queen at random **row-wise**.
- The board's current heuristic is calculated, along with the heuristic value of every movement a queen can make row-wise.
- The lowest value of heuristic is compared to the current board heuristic and a queen is shifted if the heuristic of the current board is greater.
- If the heuristic of the next movement is equal to the current board's heuristic, we move queen to that position and find a better heuristic in the next iteration. This loop end if it has same heuristic for consecutive 100 times.
- If the board's heuristic is equal to zero, then the goal state has been achieved.

## **Random-Restart Hill Climbing Search with/without Sideways**

### **Hill-Climbing Search without Sideways Moves:**

- When the heuristic of the next movement is equal to or greater than the current board's heuristic, we generate a random new board.
- If the board's heuristic is equal to zero, then the goal state has been achieved.

### **Hill-Climbing Search with Sideways Moves:**

- When the heuristic of the next movement is greater than the current board's heuristic, we generate a random new board.
- When the heuristic of the next movement is equal to the current board's heuristic and runs for more than 100 times, we generate a random new board
- If the board's heuristic is equal to zero, then the goal state has been achieved.

## **3. Functions**

Function: **attack\_heuristic()**

- It calculates the heuristic of the board.
- It checks for the queens row-wise and adds to the total heuristic if there is a queen in the same column, right and left diagonal (directly and indirectly).

Function: **h\_board\_creator()**

- It calculated the heuristic value of every movement a queen can make in a board(Successor).

Function: **movement\_queen()**

- It finds the lowest heuristic value in the movement board and moves a queen if the minimum heuristic value is lower than the current board's heuristic value.

Function: **random\_index\_h()**

- Randomly finds the position of lowest heuristic value for queen to move

## **4. Results**

### **a. Steepest-Ascent Hill Climbing**

#### **I. Success and Failure Rates**

Enter size of board: 8

Enter the number of times to calculate average : 500

Rates:

Failure: 84.2 Success: 15.8

#### **II. Average Number of Steps when it Succeeds**

Success: 5

#### **III. Average Number of Steps when it Fails**

Failure: 4

#### **IV. The search sequences from three random initial configurations**

##### **Board No. 1**

Enter size of board: 8

Enter the number of times to calculate average : 1

Initial Board

[[0 0 0 0 0 1 0]

[0 0 0 0 0 0 1]

[0 0 0 0 0 1 0]

[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 1 0 0]]

Move

```
[[0 0 1 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 0 0 0 0 0 1 0]
[1 0 0 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 0 1 0 0]]
```

Reached Goal

---

### Board No. 2

Enter size of board: 8

Enter the number of times to calculate average : 1

Initial Board

```
[[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 0 0 1 0]
[0 0 1 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]]
```

Move

```
[[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 0 0 1 0]
[0 0 1 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 1 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]]
```

Move

```
[[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[1 0 0 0 0 0 0 0]
[0 0 1 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 1 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]]
```

Move

```
[[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[1 0 0 0 0 0 0 0]
[0 0 1 0 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 0 1 0 0]
[0 1 0 0 0 0 0 0]
```

[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]

[0 0 0 0 0 0 0 1]

[1 0 0 0 0 0 0 0]

[0 0 1 0 0 0 0 0]

[1 0 0 0 0 0 0 0]

[0 0 0 0 0 1 0 0]

[0 1 0 0 0 0 0 0]

[0 0 0 0 1 0 0 0]]

Fail

---

### Board no. 3

Enter size of board: 8

Enter the number of times to calculate average : 1

Initial Board

[[0 0 0 0 1 0 0 0]

[1 0 0 0 0 0 0 0]

[0 0 0 0 0 1 0 0]

[0 1 0 0 0 0 0 0]

[0 0 0 0 0 0 1 0]

[0 0 0 0 1 0 0 0]

[0 0 0 1 0 0 0 0]

[0 1 0 0 0 0 0 0]]

Move

[[0 0 0 0 1 0 0 0]

[1 0 0 0 0 0 0 0]

[0 0 0 0 0 1 0 0]

[0 1 0 0 0 0 0 0]

[0 0 0 0 0 0 1 0]

[0 0 0 0 0 0 1 0]

[0 0 0 1 0 0 0 0]

[0 1 0 0 0 0 0 0]]

Move

[[0 0 0 0 1 0 0 0]

[1 0 0 0 0 0 0 0]

[0 0 0 0 0 1 0 0]

[0 1 0 0 0 0 0 0]

[0 0 0 0 0 0 1 0]

[0 0 0 0 0 0 1 0]

[0 0 0 1 0 0 0 0]

[0 0 0 0 0 0 0 1]]

Fail

## b. Hill-Climbing Search with Sideways Moves

### I. Success and Failure Rates

Enter size of board: 8

Enter the number of times to calculate average : 500

Rates:

Failure rate: 4.6 Success rate: 95.4

II. Average Number of Steps when it Succeeds

Success average steps: 21

III. Average Number of Steps when it Fails

Failure average steps: 62

IV. Search Sequences for three random initial configurations

**Board No. 1**

Enter size of board: 8

Enter the number of times to calculate average : 1

Initial Board

```
[[0 0 1 0 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[1 0 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]
[1 0 0 0 0 0 0 0]]
```

Move

```
[[0 0 1 0 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[1 0 0 0 0 0 0 0]]
```

Move

```
[[0 0 1 0 0 0 0 0]
[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[1 0 0 0 0 0 0 0]]
```

Move

```
[[0 0 1 0 0 0 0 0]
[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 1]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 1 0 0 0 0 0 0]]
```

Move

```
[[0 0 1 0 0 0 0 0]
[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[0 0 0 0 0 0 1 0]]
```

[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move



[[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]

[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 1 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]

[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Reached Goal

---

## Board No. 2

Initial Board

[[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

[0 0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 1 0 0 0]]

Fail

---

### Board No. 3

Initial Board

[[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]

```

[0 0 0 0 1 0 0 0]]
Move
[[0 0 0 1 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 1 0 0 0 0 0]
[0 0 0 0 0 1 0 0]
[0 0 0 0 0 0 1 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 1 0 0 0]]
Fail

```

**c. Random-Restart Hill Climbing Search**

- i. The average number of random restarts used without sideways moves  
Enter size of board: 8  
Enter the number of times to calculate average : 500  
Average Random Restarts steps 6.08
- ii. The average number of steps required without sideways moves  
Average Steps count:  
Failure average steps: 0  
Success average steps: 29.75  
Board Search Sequence:

**Board No. 1**

Initial Board

```

[[0 0 0 0 0 0 0 1]
[0 0 0 1 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 0 0 0 1 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 1 0]]

```

Move

```

[[0 0 0 0 0 0 0 1]
[0 0 0 1 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 0 0 0 0 0 0 1]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 1 0]]

```

Move

```

[[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 0 0 0 0 0 0 1]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 1 0]]

```

Move

```
[[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 0 0 0 0 0 0 1]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 1 0 0 0 0 0]]
```

Reached Goal

---

## Board No. 2

Initial Board

```
[[1 0 0 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 0 1 0 0 0 0 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 1 0 0]]
```

Move

```
[[1 0 0 0 0 0 0 0]
[0 0 0 1 0 0 0 0]
[0 0 1 0 0 0 0 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]]
```

Move

```
[[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 0 1 0 0 0 0 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 0 1 0 0]
[0 0 0 1 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]]
```

Restart Board

```
[[0 0 0 0 1 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 1 0 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 1 0]
[0 0 1 0 0 0 0 0]
[0 1 0 0 0 0 0 0]]
```

Move

```
[[0 0 0 0 1 0 0 0]
```

[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 1 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 1 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 1 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

Reached Goal

---

### Board No. 3

Initial Board

[[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]

[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]]

Restart Board

[[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]

Move

[[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]]



Restart Board

[[0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0]  
[0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1]  
[0 0 0 0 1 0 0]  
[0 0 0 0 1 0 0]]

Move

[[0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0]  
[0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1]  
[0 0 0 0 1 0 0]  
[0 0 0 0 1 0 0]]

Move

[[0 0 0 0 0 1 0]  
[0 1 0 0 0 0 0]  
[0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1]  
[0 0 0 1 0 0 0]  
[0 0 0 0 0 0 1]  
[0 0 1 0 0 0 0]  
[0 0 0 0 1 0 0]]

Restart Board

[[0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0]  
[1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0]  
[0 0 1 0 0 0 0]  
[0 0 0 0 1 0 0]]

Move

[[0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0]  
[1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0]  
[0 0 1 0 0 0 0]  
[0 0 0 0 1 0 0]]

Move

[[0 0 0 1 0 0 0]  
[0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0]]

[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 1 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Restart Board

[[0 1 0 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 1 0 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

```

[[0 0 0 1 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 1 0 0 0]
[0 0 0 0 0 0 1 0]
[1 0 0 0 0 0 0 0]
[0 0 1 0 0 0 0 0]
[1 0 0 0 0 0 0 0]]

```

Move

```

[[0 0 0 1 0 0 0 0]
[0 1 0 0 0 0 0 0]
[0 0 0 0 0 0 0 1]
[0 0 0 0 1 0 0 0]
[0 0 0 0 0 0 1 0]
[1 0 0 0 0 0 0 0]
[0 0 1 0 0 0 0 0]
[0 0 0 0 0 1 0 0]]

```

Reached Goal

- iii. The average number of random restarts used with sideways moves

Enter size of board: 8

Enter the number of times to calculate average : 500

Restart average steps: 0.07

- iv. The average number of steps required with sideways moves

Failure average steps: 0

Success average steps: 21.93

Search Sequences of Boards:

### Board No. 1

Initial Board

```

[[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 1 0 0]
[0 1 0 0 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 1 0 0 0 0 0 0]
[0 1 0 0 0 0 0 0]]

```

Move

```

[[0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 1 0]
[0 0 0 0 0 1 0 0]
[0 1 0 0 0 0 0 0]
[1 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0]
[0 0 0 0 0 0 0 1]
[0 1 0 0 0 0 0 0]]

```

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 1 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 1 0 0 0 0 0 0]]

Restart Board

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]

[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]

[0 0 0 0 0 1 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 1 0 0 0]]

Reached Goal

---

## Board No. 2

Initial Board

[[0 0 1 0 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 1 0 0 0 0 0]  
[0 0 1 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]  
[1 0 0 0 0 0 0 0]]

[0 0 0 0 0 0 0 1]  
[0 0 0 0 1 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 1 0]]

Reached Goal

---

### Board No. 3

Initial Board

[[0 0 0 1 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 1 0 0 0]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 1 0 0 0 0 0]]

[0 0 0 0 1 0 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]]

Restart Board

[[0 0 0 0 0 0 0 1]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 0 1]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]]

Move

[[0 0 0 0 0 0 0 1]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]]

Move

[[0 0 0 0 0 0 0 1]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]]

Move

[[0 0 0 0 0 0 0 1]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 0 1 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 0 0 0 0 1]  
[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]

Move

[[0 0 0 1 0 0 0 0]



[0 1 0 0 0 0 0 0]  
[0 0 0 0 0 0 1 0]  
[0 0 1 0 0 0 0 0]  
[0 0 0 0 0 1 0 0]  
[0 0 0 0 0 0 0 1]  
[1 0 0 0 0 0 0 0]  
[0 0 0 0 1 0 0 0]]  
Reached Goal