

N Queens Problem Using Hill Climbing

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Introduction

N Queens problem is the problem of placing N queens in NN board in such a way that no two queens will attack each other. This means that two queens should be in the same line or in the same column or diagonal to each other. This means that we move the queens in the NN board so that the goal state is reached. The position where the queen is marked with 'Q' and the blank position is marked with 'x'.

Variants of Hill Climbing:

Steepest Ascent hill climbing: It examines all the neighboring nodes and then selects the node closest to the solution state as the next node.

Hill Climbing with Side way moves: One of the drawbacks of the hill climbing algorithm is that it won't work if there occurs a plateau. So in order to remove this disadvantage we move the queens sideways in order to check whether there exists a solution. An infinite loop occurs whenever the algorithm reaches a flat local maximum that is not a shoulder.

For the limit of 100 consecutive moves in the 8-queens problem the percentage of problem instances raises from 12.5% to 94%. The algorithm averages roughly 19 steps for each successful instance and 59 for each failure instance.

Random Hill Climbing: It conducts series of randomly generated initial states, until a goal state is reached. It might have a probability of 1 as there might be a state where the initial state itself is the goal state. If each hill climbing has a probability of p success, then expected number of restarts is given by $1/p$. For 8 queens as observed in the code we have got the p value as 0.14 approximately with no side way moves. With side way moves allowed we get the value of p as 1.06 approximately.

Program Formulation:

States: Current queens position on the board.

Actions: Move these 'Q' queen to up (or) down in the same column.

Successor function: Generates Successors for the N queens board.

Path Cost: Number of movements for the particular queen, this cost is the heuristic cost.

Input state: N- Number of queens.

Goal state: No two queens should attack each other

Program Structure:

The program has mainly three classes HillClimbing, NQueens and State Classes. The HillClimbing class has all the properties which are related to the variants of Hill Climbing i.e., Steepest Ascent Hill Climbing, Hill Climbing with Side way moves, Random Hill Climbing and Random with side way moves taken. The NQueens class mainly implements on how to get to the goal state by implementing the heuristic values and the best positions of the queens in order to get to the goal state. The State Class implements on storing the values and properties of the state.

Global Variables:

No Global Variables have been used in the program in this assignment.

Functions Used:

```
def GoalState(self, state)
def compareh(self, state1, state2)
def initialstategeneration(self)
def successorgeneration(self, currstate)
def steepestHillClimbing(self, minIters=300, maxIters=1000, Seq=False)
def steepestHCSequences(self)
def Sideways(self, min=300, max= 1000, Seq=False)
def SidewaysHillClimbingSequences(self)
def RRWithOutSideways(self, min, max)
def RRWithSideways(self, min, max)
```

The functions `GoalState` checks whether the solution of the problems has arrived or not.
`compareh` compares the heuristic values and store the value for further usage.
`steepestHillClimbing` and `Sideways` function returns the successes, failures, total successful steps, total fail steps and number of iterations during that run.
`SidewaysHillClimbingSequences` prints the sequences of acquiring the sequences.

```
def InitialStategeneration(self)
def Successorgeneration(self, CurrState)
def compareh(self, stateA, stateB)
```

The function `Successorgeneration` randomly places queens in their column.
`InitialStategeneration` randomly generates initial state with one queen in each column.

```
def generationBoard(self)
def printingstate(self)
def calculateH(self)
```

The function `generationBoard` will generate the board from the queen positions depending on the number of queens that have been given in the input. `printingstate` prints the states and displays the sequence of iterations that will take place to reach the goal state.

Sample Input and Output:

input -

Number of Queens - 8

Ouput -

Steepest-Ascent Hill Climbing -

Rate of Failure is 87.5

Average of Number of Steps for Failures is 5

Rate of Success is 12.5

Average of Number of Steps for Success is 5

RandomState Search Sequence is 1

```
x Q x x Q x Q x
x x x x x x x x
x x Q x x x x Q
x x x x x x x x
Q x x x x x x x
x x x Q x Q x x
x x x x x x x x
x x x x x x x x
```

```
x Q x x Q x Q x
x x x x x x x x
x x x x x x x Q
x x Q x x x x x
Q x x x x x x x
x x x Q x Q x x
x x x x x x x x
x x x x x x x x
```

```
x Q x x x x Q x
x x x x x x x x
x x x x x x x Q
x x Q x x x x x
Q x x x x x x x
x x x Q x Q x x
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```

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x x x x x x Q x
x x x x x x x x
x x x x x x x Q
x x Q x x x x x
Q x x x x x x x
x x x Q x Q x x
x Q x x x x x x
x x x x Q x x x
```

The Goal hasn't Reached

RandomState Search Sequence is 2

```
x x x x x x x Q
Q x x x x x x x
x x x x x x x x
x x x x x Q Q x
x x x Q Q x x x
x x Q x x x x x
x x x x x x x x
x Q x x x x x x
```

```
x x x x x x x Q
Q x x x x x x x
x x x Q x x x x
x x x x x Q Q x
x x x x Q x x x
x x Q x x x x x
x x x x x x x x
x Q x x x x x x
```

```
x x x x x x x Q
Q x x x x x x x
x x x Q x x x x
x x x x x Q Q x
x x x x x x x x
x x Q x x x x x
x x x x Q x x x
x Q x x x x x x
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x x x x x x x Q
Q x x x x Q x x
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x x x x x x Q x
x x x x x x x x
x x Q x x x x x
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x x x x Q x x x
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x x x x x x Q x
Q x x x x x x x
x x Q x x x x x
x x x x Q x x x
x Q x x x x x x
```

The Goal hasn't Reached

RandomState Search Sequence is 3

```
x x Q x Q x x x
x x x x x x x x
x x x x x x x x
x x x x x x x x
x Q x x x Q Q x
x x x Q x x x x
Q x x x x x x Q
x x x x x x x x
```

```
x x Q x Q x x x
x x x x x x x x
x x x x x Q x x
x x x x x x x x
x Q x x x x Q x
x x x Q x x x x
Q x x x x x x Q
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x x x x Q x x x
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x x x x x x x x
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```

The Goal hasn't Reached

Sideways move Hill Climbing

.....

Rate of Failure is 5.676855895196507

Average of no. of Steps for Failures is 59

Rate of Success is 94.32314410480349

Average of no. of Steps for Success is 19

RandomState search sequence is

RandomState Search Sequence is 1

```

x x x x x Q Q x
Q x x x x x x x
x x x x Q x x x
x x x x x x x Q
x x Q Q x x x x
x x x x x x x x
x Q x x x x x x
x x x x x x x x

```

```

x x x x x Q x x
Q x x x x x x x
x x x x Q x x x
x x x x x x x Q
x x Q Q x x x x
x x x x x x Q x
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The Goal has been Reached

RandomState Search Sequence is 3

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The Goal has been Reached

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The Goal hasn't Reached

RandomState Search Sequence is 2

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x x Q x x x x x

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The Goal has been Reached

RandomState Search Sequence is 3

```

x x x x Q Q x x
x Q x x x x x x
x x Q x x x x x
x x x x x x x x
x x x x x x x x

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Q x x Q x x x x
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Q x x x x x x x
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x x x x x Q x x
x x Q x x x x x
x x x x Q x x x
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x x x Q x x x x
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The Goal has been Reached

RandomState search sequence is

RandomState Search Sequence is 1

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x x x x x x x x
x x x x x x x x
x Q x x x x x Q
x x x x Q Q x x
x x Q x x x Q x
x x x Q x x x x
Q x x x x x x x
x x x x x x x x
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x x x x x x x x
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The Goal hasn't Reached

RandomState Search Sequence is 3

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The Goal has been Reached

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Random Restarts Hill Climbing

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Average of no. of Random Restarts used With Sideways Move: 1

Average of no. of Steps used With Sideways Move: 25

Average of no. of Random Restarts WithOut Sideways Move: 6

Average of no. of Steps WithOut Sideways Move: 28

.....

.....

FINISHED.

Source Code:

```
from random import randint
from copy import deepcopy as copy
from math import ceil
from math import ceil

class State:
    def __init__(self,n,Qposition):
        self.Qposition = Qposition
        self.n = n
        self.board = self.generationBoard()
        self.h = self.calculateH()

    def printingstate(self):
        if self.board is not None:
            for i in range(self.n):
                for j in range(self.n):
                    if self.board[i][j] == 1:
                        print("Q",end=" ")
                    else:
                        print("x",end=" ")
                print()
            print()

    def generationBoard(self):
        board = []
        for i in range(self.n):
            row = [0] * self.n
            board.append(row)

            for x, y in self.Qposition:
                board[x][y] = 1
        return board

    def calculateH(self):
        costoffline = 0
```



```
costofdiagonal = 0

#Costofline Calculation
for x,y in self.Qposition:
    for index in range(self.n):
        if self.board[x][index] == 1:
            costofline +=1
    if self.board[index][y] == 1:
        costofline +=1
    #eliminate it from counting itself
    costofline -=2

#LEFT UP
indexA, indexB = x - 1, y - 1
while indexA >= 0 and indexB >= 0:
    if self.board[indexA][indexB] == 1:
        costofdiagonal += 1

indexA -= 1
indexB -= 1
#RIGHT DOWN
indexA, indexB = x + 1, y + 1
while indexA < self.n and indexB < self.n:
    if self.board[indexA][indexB] == 1:
        costofdiagonal += 1

indexA += 1
indexB += 1
#LEFT DOWN
indexA, indexB = x + 1, y - 1
while indexA < self.n and indexB >= 0:
    if self.board[indexA][indexB] == 1:
        costofdiagonal += 1

indexA += 1
indexB -= 1
#RIGHT UP
indexA, indexB = x - 1, y + 1
while indexA >= 0 and indexB < self.n:
    if self.board[indexA][indexB] == 1:
        costofdiagonal += 1

indexA -= 1
indexB += 1

return (costofdiagonal+costofline)/2
```

```
class HillClimbing:
```

```
def __init__(self, numberofqueens):
    self.numberofqueens = numberofqueens
    self.initialState = None

def compareh(self, stateA, stateB):
    pass

def InitialStategeneration(self):
    pass

def Successorgeneration(self, CurrState):
    pass

def GoalState(self, state):
    if state.h == 0:
        return True
    return False

def steepestHillClimbing(self, min=300, max=1000, Seq=False):
    if Seq:
        iterations = 3
    else:
        iterations = randint(min, max)
        success = 0
        successsteps = 0
        failure = 0
        total = 0
        failures = 0
        for i in range(iterations):
            iniState = self.InitialStategeneration()
            if(self.GoalState(iniState)):
                continue
        curstate = iniState
        if Seq:
            print("RandomState Search Sequence is ", i + 1)
            curstate.printingstate()
        loop = 0
        while(True):
            isnotCurState = False

        for successor in self.Successorgeneration(curstate):
            if self.compareh(curstate, successor) == 1:
```

```

        #currstate is greater than successor
    curstate = successor
        isnotCurState = True

    loop +=1
    if Seq and isnotCurState:
        curstate.printingstate()

        if self.GoalState(curstate) and isnotCurState:
            successsteps += loop
            success += 1

    total += loop

    if Seq:
        print("The Goal has been Reached")
        break
if isnotCurState == False:
    failure += loop
    failures += 1

    total +=loop

    if Seq:
        print("The Goal hasn't Reached")
        break

return success, successsteps, failures, failure, iterations

```

```

def Sideways(self,min=300,max=1000,Seq=False):
    if Seq:
        iterations = 3
    else:
        iterations = randint(min, max)
        success = 0
        successsteps = 0
        failure = 0
        total = 0
        failures = 0
    for i in range(iterations):
        iniState = self.InitialStategeneration()
        if (self.GoalState(iniState)):
            continue
    curstate = iniState
    if Seq:
        print("RandomState Search Sequence is ", i + 1)
        curstate.printingstate()

```

```

        isnotCurState = False
    loop = 0
    sidewaysiterations = 100
    while (True):
        isnotCurState = False
    equalsucstates = []
        for successor in self.Successorgeneration(curstate):
            compareval = self.compareh(curstate, successor)
            if compareval == 1:
                # currstate is greater than successor
            curstate = successor
                isnotCurState = True
    sidewaysiterations = 100
    elif compareval == 0:
        equalsucstates.append(successor)
        loop += 1
    if Seq and isnotCurState:
        curstate.printingstate()
        if self.GoalState(curstate) and isnotCurState:
            successsteps += loop
            success += 1
    total += loop
        if Seq:
            print("The Goal has been Reached")
            break
    if isnotCurState == False:
        if len(equalsucstates) == 0 or sidewaysiterations == 0:
            failure += loop
            failures += 1
    total += loop
        if Seq:
            print("The Goal hasn't Reached")
            break
    else:
        i = randint(0, len(equalsucstates)-1)
        curstate = equalsucstates[i]
        if Seq:
            curstate.printingstate()
            sidewaysiterations -= 1
    return success, successsteps, failures, failure, iterations

def steepestHCSequences(self):
    self.steepestHillClimbing(Seq=True)

```

```

def sidewaysHillclimbingSequences(self):
    self.Sideways(Seq=True)

def RRWithSideways(self,min,max):
    iterations = randint(min, max)
    noofrestarts = 0
total = 0
for i in range(iterations):
    iniState = self.InitialStategeneration()
    if (self.GoalState(iniState)):
        continue
    curstate = iniState

    while (True):
        sidewayiterations = 100
    loop = 0
    while (True):
        isnotCurState = False
    equalsucstates = []
        for successor in self.Successorgeneration(curstate):
            compareval = self.compareh(curstate, successor)
            if compareval == 1:
                # currstate is greater than successor
            curstate = successor
                isnotCurState = True

        sidewayiterations = 100
    elif compareval == 0:
        equalsucstates.append(successor)
        loop += 1
    if self.GoalState(curstate) and isnotCurState:
        total += loop
        break
    if isnotCurState == False:
        if len(equalsucstates) == 0 or sidewayiterations == 0:
            total += loop
            break
    else:
        i = randint(0, len(equalsucstates) - 1)
        curstate = equalsucstates[i]
        sidewayiterations -= 1

    if not self.GoalState(curstate):

```

```

        curstate = self.InitialStategeneration()
        noofrestarts += 1
    else:
        break
return ceil(noofrestarts / iterations), ceil(total / iterations)
def RRWithoutSideways(self,min,max):
    iterations = randint(min, max)
    noofrestarts = 0
total = 0
for i in range(iterations):
    iniState = self.InitialStategeneration()
    if (self.GoalState(iniState)):
        continue
    curstate = iniState

    while(True):
        loop = 0
    while (True):
        isnotCurState = False
for successor in self.Successorgeneration(curstate):
    if self.compareh(curstate, successor) == 1:
        #currstate is greater than successor

    curstate = successor

        isnotCurState = True

    loop += 1
    if self.GoalState(curstate) and isnotCurState:
        total += loop
        break
if isnotCurState == False:
    total += loop
    break
if not self.GoalState(curstate):
    curstate = self.InitialStategeneration()
    noofrestarts += 1
else:
    break
return ceil(noofrestarts/iterations), ceil(total/iterations)
class NQueens(HillClimbing):
    def __init__(self, n):
        HillClimbing.__init__(self,n)

    def InitialStategeneration(self):
        Qposition = []

```

```

        for y in range(self.numberofqueens):
            x = randint(0,self.numberofqueens-1)
            queen = [x,y]
            Qposition.append(queen)
        #print(*Qposition, sep=", ")
    initialState = State(self.numberofqueens,Qposition)
    self.initialState = initialState
    return initialState

    def Successorgeneration(self,CurrState):
        for index,[x,y] in enumerate(CurrState.Qposition):
            for xcord in range(self.numberofqueens):
                if CurrState.board[xcord][y] != 1:
                    successor = copy(CurrState.Qposition)
                    successor[index] = [xcord,y]
                    successorState = State(self.numberofqueens,successor)
                    yield successorState

    def compareh(self,stateA,stateB):
        if stateA.h < stateB.h:
            return -1
        elif stateA.h > stateB.h:
            return 1
        else:
            return 0

if __name__ == '__main__':
    print("Number of Queens -",end=" ")
    numberofqueens = int(input())
    min = 100
    max = 500
    nQueensHillClmbing = NQueens(numberofqueens)
    print("Steepest-Ascent Hill Climbing -")
    print("")
    success, successSteps, failures, failure, noOfTimes = nQueensHillClmbing.s
    try:
        print("Rate of Failure is",(failures/noOfTimes)*100)
        print("Average of Number of Steps for Failures is", ceil(failure / fai
        print("Rate of Success is", (success / noOfTimes) * 100)
        print("Average of Number of Steps for Success is",ceil(successSteps/su

    except ZeroDivisionError:

```

```

        pass
print()
    nQueensHillClimbing.steepestHCSequences()

print('')
print("Sideways move Hill Climbing")
print("."*70)
success, successSteps, failures, failure, noOfTimes = nQueensHillClimbing.s
try:
    print("Rate of Failure is",(failures/noOfTimes)*100)
    print("Average of no. of Steps for Failures is", ceil(failure / failur
    print("Rate of Success is", (success / noOfTimes) * 100)
    print("Average of no. of Steps for Success is",ceil(successSteps/succe

except ZeroDivisionError:
    pass
print()
    for i in range(3):
        print("RandomState search sequence is ")
        nQueensHillClimbing.sidewaysHillclimbingSequences()

print("."*70)
print("."*70)

print("Random Restarts Hill Climbing")
print("."*70)
AvgRandomRestarts, avgSteps = nQueensHillClimbing.RRWithSideways(min,max)
print("Average of no. of Random Restarts used With Sideways Move:",AvgRanc
print("Average of no. of Steps used With Sideways Move:",avgSteps)

AvgRandomRestarts, avgSteps = nQueensHillClimbing.RRWithOutSideways(min, ma
print("Average of no. of Random Restarts WithOut Sideways Move:", AvgRandc
print("Average of no. of Steps WithOut Sideways Move:", avgSteps)
print("." * 70)
print("." * 70)
print("FINISHED")

```