Solving N-queens problem using hill-climbing search and its variants

PROJECT DOCUMENTATION REPORT

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Intelligent Systems Project 2

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Problem Formulation

The N-queens problem is a typical programming problem in which we have to find a solution to placing 'n' queens on 'n*n' board such that no two queens can attack each other. Attack means that no 2 queens can be placed in the same row, same column or same diagonal. Though it seems to be a trivial problem, a wide range of programming algorithms can be applied to solve this. Here we have implemented hill climbing search algorithms to solve the n-queens problem. The problem formulation for the n-queens problem can be described as below:

1.) Initial State:

- Incremental Formulation: This method starts with placing the n queens one by one on the board.
- Complete-State Formulation: This method starts with placing all the n queens placed randomly on the board at once.
- We choose the Complete-State formulation and hence the initial state is all the n queens placed randomly.

2.) Goal State: n queens on the board with no two queens in the same row, column or the diagonal.

| **Initial State** | **Goal State** |

3.) States: Any arrangement of 0 to n queens on the board is a state.

4.) Actions: Adding a queen to an empty square of the board.

5.) Transition Model: A board with the chosen queen added to the specified square

Hill Climbing Search: For n-queens, hill climbing search starts with complete state formulation. In this, there is a state with randomly placed n queens on an n * n board. The number successors for any state are given by the

Number of successors = n * (n − 1)

Thus, for 8-queens problem, for every state there will be 8 * 7 = 56 successors, for 4-queens problem, it would be 4 * 3 = 12 successors for each state and so on.

These successors are derived by moving each queen on the board to its either up, left, down or right square. Each new derived configuration of the board is a new state and the best successor is chosen out of all using appropriate heuristic function.

Heuristic Function: The heuristic function used and implemented is the number of conflicts in each state. The best state to be chosen next for evaluation is the state with the lower number of conflicts than the current state. The number of conflicts is the number of queens that a queen can attack. Each attack is counted just once. For example, for the initial state shown above the heuristic value h can be given as
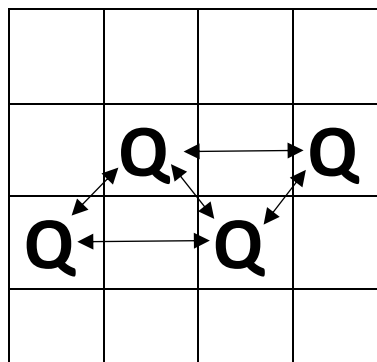
h = 5

The arrows indicate the conflicts and that gives the heuristic value for that state which is 5. The successors of any state are passed to the heuristic evaluation function and the function returns the heuristic value of that successor state. Out of all the successors, the most promising one is selected. Here, the successor state with the lowest heuristic among all is chosen to be the most promising state as the goal of the problem is to minimize the conflicts and bring it to 0. Thus, goal is reached when h=0 for any successor state in any iteration. The heuristic value of the successor state must always be less than the current (its parent) state. In case of the multiple successor states with the same least heuristic value, the first state out of all is selected for expansion. However, the problem of **plateau** can arise in this approach, in which the heuristic value of the current state node is equal to the heuristic value of any of its successor. In this case the algorithm cannot proceed further. We solve this problem with a variant of steepest ascent hill climbing.

Hill Climbing with Sideways Moves: In this approach, the algorithm proceeds further after getting stuck at the plateau. It selects any successor whose heuristic value is equal to the current state node. This may give rise to another problem of infinite iterations. We solve this issue by applying a limit on the number of sideway moves allowed.

Random Restart Hill Climbing Search: Despite of applying the above two variants, the success rate for n-queens problem is still much lesser than its failure rate. **86%** of the times the algorithm gets stuck and returns failure, with only **14%** of success rate. Thus, to improve this success to failure ratio, we use another variant called random restart hill climbing search. In this, the algorithm starts randomly after a certain number of iterations, the algorithm is started again with randomly generated initial state until and unless goal is found. This works same as the basic variant of hill climbing search, only that the algorithm starts again randomly after a specified number of failed iterations.

Random Restart Hill Climbing Search with Sideway Moves: Similar to the above variant with sideway moves, this algorithm allows sideway moves for random restart variant of hill climbing search.

With random restart hill climbing, the probability of getting goal state tends to be equal to 1. Thus, this gives a much higher success rate than the basic version of hill climbing search algorithm

Overall Program Structure

We have implemented the n queens' algorithm to solve this problem using **python**

Global Variables

Variable Name	Description
steps	It is count of no of steps taken for solving the problem
avgSuccessSteps	It's the average number of success steps
avgFailureSteps	Count of average number of steps when the program failed
successCount	Count of times the program was successful to find the solution
failureCount	Count of times the program failed to find the solution
restartCount	Count of times the program restarted from random position when it got stuck.

Functions and Procedures

Function Name	Description
printBoard	Prints the board to the console
generateRandomPosition	Generates a random board configuration by placing the queens at random rows in each column
heuristicFunction	Calculate the number of queens in the same row thus calculating the heuristic value of rows
generateSuccessors	Generate the successors of the current configuration and select the successor with lowest configuration for further evaluation
hillClimb	Solves the problem using normal hill climbing approach
hillClimbRestart	Solves the problem using normal hill climbing approach with random restart
hillClimbSideStepRestart	Solves the problem using normal hill climbing approach with random restart and sideways

Source Code for NQueen Hill Climbing

```python
import copy
from random import Random, randint
import numpy as np
steps = 0
avgSuccessSteps = 0
avgFailureSteps = 0
successCount = 0
failureCount = 0

class Node:
    def __init__(self, board, hvalue) -> None:
        self.board = board
        self.hvalue = hvalue

    def printBoard(self):
        print(np.matrix(self.board))

class NQueen:
    def __init__(self, size) -> None:
        self.size = size

    # Generates a random board configuration by placing the queens at random rows in each
column
    def generateRandomPosition(self):
        numOfQueens = self.size
        mat = [['-' for i in range(numOfQueens)] for j in range(numOfQueens)]
        for y in range(numOfQueens):
            queenPositionx = randint(0, self.size - 1)
            for x in range(numOfQueens):
                if (x == queenPositionx):
                    mat[x][y] = 'Q'
                else:
                    mat[x][y] = '-'
        return mat

    def heuristicFunction(self, board):
        heuristicValueRows = 0
        size = len(board)
        # Calculate the number of queens in the same row thus calculating the heuristic value
of rows
        for x in board:
            count = x.count('Q')
            # More than one queen in the row, add to the heuristic value
            if(count > 1):
                heuristicValueRows = heuristicValueRows + (sum(range(x.count('Q'))))
```

```python
        heuristicValueDiagonal = 0

        # Calculate the heuristic of diagonal, from left to right
        for y in range(size-1, -1, -1):
            numQueen = 0
            col = 0
            row = y
            while(col < size and row < size):
                value = board[row][col]
                if(value == 'Q'):
                    numQueen = numQueen + 1
                col = col + 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
        for y in range(size-1, 0, -1):
            numQueen = 0
            col = y
            row = 0
            while(col < size and row < size):
                value = board[row][col]
                if(value == 'Q'):
                    numQueen = numQueen + 1
                col = col + 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))

        #Calculate the heuristic of the diagonal, from right to left
        for y in range(size-1, -1, -1):
            numQueen = 0
            col = y
            row = 0
            while(col >= 0 and row < size):
                value = board[row][col]
                if(value == 'Q'):
                    numQueen = numQueen + 1
                col = col - 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
        for y in range(size-1, 0, -1):
            numQueen = 0
            col = size-1
            row = y
            while(col >= 0 and row < size):
                value = board[row][col]
                if(value == 'Q'):
```

```
                        numQueen = numQueen + 1
                col = col - 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
        # Calculate the total heuristic value as the sum of row and diagonal heuristic
        heuristicValue = heuristicValueRows + heuristicValueDiagonal
        return heuristicValue


    # Generate the successors of the current configuration and select
    # the successor with lowest configuration for further evaluation
    def generateSuccessors(self, Node):
        row = -1
        column = -1
        currentBoard = Node.board
        currentHeuristic = Node.hvalue
        queenPosition = [None] * len(currentBoard)
        boardChange = False
        # Make copy of the current board configuration
        tempBoard = copy.deepcopy(currentBoard)
        # Iteration for column
        for y in range (0,len(currentBoard)):
            # Iteration for row
            for x in range (0,len(currentBoard)):
                # Store the position of queen in current column
                if currentBoard[x][y] == 'Q':
                    queenPosition[y] = x
        for y in range (0,len(currentBoard)):
            if(boardChange == True):
                break
            # Put the current queen position in the temp variable
            currentQueenPosition = queenPosition[y]
            # Remove the queen from the current position to generate successors
            tempBoard[currentQueenPosition][y] = '-'
            for x in range (0,len(currentBoard)):
                # Put the queen on each position in column apart from the current position
                # and calculate the heuristic
                if x != currentQueenPosition:
                    tempBoard[x][y] = 'Q'
                    tempHeuristic = self.heuristicFunction(tempBoard)
                    # If the heuristic of the new configuration is less than current
configuration,
                    # make it the current configuration for further evaluation
                    if currentHeuristic > tempHeuristic:
                        column = y
                        row = x
                        currentHeuristic = tempHeuristic
                        tempBoard[x][y] = '-'
```

```python
                        boardChange = True
                        break
                # Remove the queen from the temp position for next positions
                tempBoard[x][y] = '-'
            # When all rows of the column are evaluated,put the queen at the original
position
            tempBoard[currentQueenPosition][y] = 'Q'

        # Solution was not found
        if column == -1 and row == -1:
            return False
        # Configuration with lower heuristic was found. Replace the current board
configuration
        # with the new configuration
        currentBoard[queenPosition[column]][column] = '-'
        currentBoard[row][column] = 'Q'
        Node.hvalue = currentHeuristic
        print("Current Board:")
        Node.printBoard()
        print("Current Heuristic: ",currentHeuristic)
        return True

    def hillClimb(self):
        # Generate random position of the board
        board = NQueen.generateRandomPosition(self)
        current = Node(board, 0)
        current.printBoard()
        #Calculate no of queens under attack(heuristic)
        current.hvalue = self.heuristicFunction(current.board)

        # Loop until the heuristic function becomes zero or heuristic value of successors is
more than the current node
        while current.hvalue !=0:
            global steps
            steps = steps + 1
            # Call the generate successors functions
            end = self.generateSuccessors(current)
            # Failure
            if end == False:
                break
        # Success! Solution has been found for the problem - Calculate the Success metrics
        if current.hvalue == 0:
            global successCount
            global avgSuccessSteps
            avgSuccessSteps = steps + avgSuccessSteps
            successCount = successCount + 1
            steps = 0
            print("Solution found")
```

```python
            current.printBoard()
        # Calculate the failure metrics
        else:
            global failureCount
            global avgFailureSteps
            avgFailureSteps = steps + avgFailureSteps
            failureCount = failureCount + 1
            steps = 0
            print("Failure")


# Input the no. of Queens to solve the problem
print("Enter number of Queens:")
noOfQueens = int(input())
# N-Queens can only be solved for size greater than 3
if(noOfQueens < 4):
    print("Problem cannot be solved for queens less than 4")
# No of iterations
print("How many times you want to run problem:")
counter = int(input())
iteration = 1
nQueen = NQueen(noOfQueens)
while counter != 0:
    print("Iteration ",iteration)
    nQueen.hillClimb()
    iteration = iteration + 1
    counter = counter - 1

print("Success Count: ",successCount)
print("Failure Count: ",failureCount)
print("Success Rate", (successCount/(successCount+failureCount)*100))
print("Failure Rate", (failureCount/(successCount+failureCount)*100))
print("Avg Success Steps", (avgSuccessSteps/(successCount)))
print("Avg Failure Steps", (avgFailureSteps/(failureCount)))
```

```python
import copy
from random import Random, randint
import numpy as np
steps = 0
avgSuccessSteps = 0
iteration = 0
restartCount = 0
class Node:
    def __init__(self, board, hvalue) -> None:
        self.board = board
        self.hvalue = hvalue

    def printBoard(self):
        print(np.matrix(self.board))

class NQueen:
    def __init__(self, size) -> None:
        self.size = size

    # Generates a random board configuration by placing the queens at random rows in each
column
    def generateRandomPosition(self):
        numOfQueens = self.size
        mat = [['-' for i in range(numOfQueens)] for j in range(numOfQueens)]
        for y in range(numOfQueens):
            queenPositionx = randint(0, self.size - 1)
            for x in range(numOfQueens):
                if (x == queenPositionx):
                    mat[x][y] = 'Q'
                else:
                    mat[x][y] = '-'
        return mat

    def heuristicFunction(self, board):
        heuristicValueRows = 0
        size = len(board)
        for x in board:
            # Calculate the number of queens in the same row thus calculating the heuristic
value of rows
            count = x.count('Q')
            # More than one queen in the row, add to the heuristic value
            if(count > 1):
                heuristicValueRows = heuristicValueRows + (sum(range(x.count('Q'))))
        heuristicValueDiagonal = 0
        # Calculate the heuristic of diagonal, from left to right
        for y in range(size-1, -1, -1):
            numQueen = 0
```

```python
            col = 0
            row = y
            while(col < size and row < size):
                value = board[row][col]
                if(value == 'Q'):
                    numQueen = numQueen + 1
                col = col + 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
        for y in range(size-1, 0, -1):
            numQueen = 0
            col = y
            row = 0
            while(col < size and row < size):
                value = board[row][col]
                if(value == 'Q'):
                    numQueen = numQueen + 1
                col = col + 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))

        #Calculate the heuristic of the diagonal, from right to left
        for y in range(size-1, -1, -1):
            numQueen = 0
            col = y
            row = 0
            while(col >= 0 and row < size):
                value = board[row][col]
                if(value == 'Q'):
                    numQueen = numQueen + 1
                col = col - 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
        for y in range(size-1, 0, -1):
            numQueen = 0
            col = size-1
            row = y
            while(col >= 0 and row < size):
                value = board[row][col]
                if(value == 'Q'):
                    numQueen = numQueen + 1
                col = col - 1
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
```

```python
            # Calculate the total heuristic value as the sum of row and diagonal heuristic
            heuristicValue = heuristicValueRows + heuristicValueDiagonal
            return heuristicValue


    # Generate the successors of the current configuration and select
    # the successor with lowest configuration for further evaluation
    def generateSuccessors(self, Node):
        row = -1
        column = -1
        currentBoard = Node.board
        currentHeuristic = Node.hvalue
        queenPosition = [None] * len(currentBoard)
        boardChange = False
        # Make copy of the current board configuration
        tempBoard = copy.deepcopy(currentBoard)
        # Iteration for column
        for y in range (0,len(currentBoard)):
            # Iteration for row
            for x in range (0,len(currentBoard)):
                # Store the position of queen in current column
                if currentBoard[x][y] == 'Q':
                    queenPosition[y] = x
        for y in range (0,len(currentBoard)):
            if(boardChange == True):
                break
            # Put the current queen position in the temp variable
            currentQueenPosition = queenPosition[y]
            # Remove the queen from the current position to generate successors
            tempBoard[currentQueenPosition][y] = '-'
            for x in range (0,len(currentBoard)):
                # Put the queen on each position in column apart from the current position
                # and calculate the heuristic
                if x != currentQueenPosition:
                    tempBoard[x][y] = 'Q'
                    tempHeuristic = self.heuristicFunction(tempBoard)
                    # If the heuristic of the new configuration is less than current
configuration,
                    # make it the current configuration for further evaluation
                    if currentHeuristic > tempHeuristic:
                        column = y
                        row = x
                        currentHeuristic = tempHeuristic
                        tempBoard[x][y] = '-'
                        boardChange = True
                        break
                # Remove the queen from the temp position for next positions
                tempBoard[x][y] = '-'
```

```python
            # When all rows of the column are evaluated,put the queen at the original
position
            tempBoard[currentQueenPosition][y] = 'Q'

        # Solution was not found
        if column == -1 and row == -1:
            return False
        # Configuration with lower heuristic was found. Replace the current board
configuration
        # with the new configuration
        currentBoard[queenPosition[column]][column] = '-'
        currentBoard[row][column] = 'Q'
        Node.hvalue = currentHeuristic
        print("Current Board:")
        Node.printBoard()
        print("Current Heuristic: ",currentHeuristic)
        return True

    def hillClimbRestart(self):
        count = 0
        # Generate random position of the board
        board = NQueen.generateRandomPosition(self)
        current = Node(board, 0)
        current.printBoard()
        # Calculate no of queens under attack(heuristic)
        current.hvalue = self.heuristicFunction(current.board)

        # Loop until solution is found
        while current.hvalue != 0:
            global steps
            steps = steps + 1
            end = self.generateSuccessors(current)

            # Failure --> Restart the algorithm by generating a random position
            if end == False:
                global restartCount
                restartCount = restartCount + 1
                print("Restart called")
                current.board = self.generateRandomPosition()
                current.hvalue = self.heuristicFunction(current.board)

        # Solution found
        if current.hvalue == 0:
            global iteration
            iteration = iteration + 1
            print("Solution found")
            current.printBoard()
        else:
```

```python
            print("Failure")


# Input the no. of Queens to solve the problem
print("Enter number of Queens:")
noOfQueens = int(input())
# N-Queens can only be solved for size greater than 3
if(noOfQueens < 4):
    print("Problem cannot be solved for queens less than 4")
# No of iterations
print("How many times you want to run problem:")
counter = int(input())
nQueen = NQueen(noOfQueens)
while counter != 0:
    nQueen.hillClimbRestart()
    counter = counter - 1

print("Avg Restarts", (restartCount/(iteration)))
print("Avg Steps", (steps/(iteration)))
```

Source Code for NQueen Hill Climbing with Sideway move

```python
import copy
from random import Random, randint, shuffle, choice
import numpy as np
steps = 0
avgSuccessSteps = 0
avgFailureSteps = 0
successCount = 0
failureCount = 0
noOfSteps = 0

class Node:
    def __init__(self, board, hvalue) -> None:
        self.board = board
        self.hvalue = hvalue

    def printBoard(self):
        print(np.matrix(self.board))

class NQueen:
    def __init__(self, size, steps) -> None:
        self.size = size
        self.steps = steps

    # Generates a random board configuration by placing the queens at random rows in each
column
    def generateRandomPosition(self):
        numOfQueens = self.size
        mat = [['-' for i in range(numOfQueens)] for j in range(numOfQueens)]
        for y in range(numOfQueens):
            queenPositionx = randint(0, self.size - 1)
            for x in range(numOfQueens):
                if (x == queenPositionx):
                    mat[x][y] = 'Q'
                else:
                    mat[x][y] = '-'
        return mat

    def heuristicFunction(self, board):
        heuristicValueRows = 0
        size = len(board)
        # Calculate the number of queens in the same row thus calculating the heuristic value
of rows
        for x in board:
            count = x.count('Q')
            # More than one queen in the row, add to the heuristic value
            if(count > 1):
                heuristicValueRows = heuristicValueRows + (sum(range(x.count('Q'))))
```

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```python
    heuristicValueDiagonal = 0

    # Calculate the heuristic of diagonal, from left to right
    for y in range(size-1, -1, -1):
        numQueen = 0
        col = 0
        row = y
        while(col < size and row < size):
            value = board[row][col]
            if(value == 'Q'):
                numQueen = numQueen + 1
            col = col + 1
            row = row + 1
        if(numQueen > 1):
            heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
    for y in range(size-1, 0, -1):
        numQueen = 0
        col = y
        row = 0
        while(col < size and row < size):
            value = board[row][col]
            if(value == 'Q'):
                numQueen = numQueen + 1
            col = col + 1
            row = row + 1
        if(numQueen > 1):
            heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))

    #Calculate the heuristic of the diagonal, from right to left
    for y in range(size-1, -1, -1):
        numQueen = 0
        col = y
        row = 0
        while(col >= 0 and row < size):
            value = board[row][col]
            if(value == 'Q'):
                numQueen = numQueen + 1
            col = col - 1
            row = row + 1
        if(numQueen > 1):
            heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
    for y in range(size-1, 0, -1):
        numQueen = 0
        col = size-1
        row = y
        while(col >= 0 and row < size):
            value = board[row][col]
            if(value == 'Q'):
```

```python
                numQueen = numQueen + 1
            col = col - 1
            row = row + 1
        if(numQueen > 1):
            heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
    # Calculate the total heuristic value as the sum of row and diagonal heuristic
    heuristicValue = heuristicValueRows + heuristicValueDiagonal
    return heuristicValue


# Generate the successors of the current configuration and select
# the successor with lowest configuration for further evaluation
def generateSuccessors(self, Node):
    print("Current Board:")
    Node.printBoard()
    global noOfSteps
    row = -1
    column = -1
    currentBoard = Node.board
    currentHeuristic = Node.hvalue
    queenPosition = [None] * len(currentBoard)
    boardChange = False
    # Make copy of the current board configuration
    tempBoard = copy.deepcopy(currentBoard)
    tempStates = list()
    print("Current Heuristic: ", currentHeuristic)
    for y in range (0,len(currentBoard)):
        for x in range (0,len(currentBoard)):
            # Store the position of queen in current column
            if currentBoard[x][y] == 'Q':
                queenPosition[y] = x
    for y in range (0,len(currentBoard)):
        # Put the current queen position in the temp variable
        currentQueenPosition = queenPosition[y]
        # Remove the queen from the current position to generate successors
        tempBoard[currentQueenPosition][y] = '-'
        for x in range (0,len(currentBoard)):
            # Put the queen on each position in column apart from the current position
            # and calculate the heuristic
            if x != currentQueenPosition:
                tempBoard[x][y] = 'Q'
                tempHeuristic = self.heuristicFunction(tempBoard)
                # If the heuristic of the new configuration is less than or equal to
                # current configuration,
                # make it the current configuration for further evaluation
                if currentHeuristic >= tempHeuristic:
                    column = y
                    row = x
                    currentHeuristic = tempHeuristic
```

```python
                    copyState = copy.deepcopy(tempBoard)
                    # Append the state in the temp states array
                    tempStates.append(copyState)
                    tempBoard[x][y] = '-'

            tempBoard[x][y] = '-'
        tempBoard[currentQueenPosition][y] = 'Q'

    # If the current heuristic is equal to the temp heuristic, and no of steps is not
zero
    # we have reached the local minima. Call the side step which will pick the random
state
    # from temp states array with heuristic value same as the current heuristic
    if noOfSteps != 0 and Node.hvalue == currentHeuristic and currentHeuristic != 0:
        print("Stepping to the side as local maxima reached")
        if len(tempStates) > 0:
            selection = randint(0, len(tempStates) - 1)
            currentBoard = tempStates.pop(selection)
            Node.hvalue = currentHeuristic
            Node.board = currentBoard
            # Reduce the no of permitted side steps
            noOfSteps = noOfSteps - 1
            return True
        else:
            return False

    # No solution found and the side step limit is reached
    elif noOfSteps == 0 and currentHeuristic != 0:
        print("No Better state found")
        noOfSteps = self.steps
        return False

    # Better state is found so change the current configuration to the temp board config
    # reset the no of side steap to the initial value and clear the tempStates array
    currentBoard[queenPosition[column]][column] = '-'
    currentBoard[row][column] = 'Q'
    Node.hvalue = currentHeuristic
    Node.board = currentBoard
    noOfSteps = self.steps
    tempStates.clear()
    return True

def hillClimb(self):
    count = 0
    # Generate random position of the board
    board = NQueen.generateRandomPosition(self)
    current = Node(board, 0)
    # Calculate no of queens under attack(heuristic)
```

```python
            current.hvalue = self.heuristicFunction(current.board)
            global steps
            # Loop until the heuristic function becomes zero or heuristic value of successors is
more than the current node
            while current.hvalue != 0:
                steps = steps + 1
                end = self.generateSuccessors(current)
                # Failure
                if end == False:
                    break
            # Success! Solution has been found for the problem - Calculate the Success metrics
            if current.hvalue == 0:
                global successCount
                global avgSuccessSteps
                print("Steps: ", steps)
                avgSuccessSteps = steps + avgSuccessSteps
                successCount = successCount + 1
                steps = 0
                print("Solution found")
                current.printBoard()
            # Calculate the failure metrics
            else:
                global failureCount
                global avgFailureSteps
                print("Steps failure: ", steps)
                avgFailureSteps = steps + avgFailureSteps

                failureCount = failureCount + 1
                steps = 0
                print("Failure")


# Input the no. of Queens to solve the problem
print("Enter number of Queens:")
noOfQueens = int(input())
# N-Queens can only be solved for size greater than 3
if(noOfQueens < 4):
    print("Problem cannot be solved for queens less than 4")
# No of side steps permitted
print("Enter the number of steps for iteration:")
noOfSteps = int(input())
# No of iterations
print("How many times you want to run problem:")
counter = int(input())
nQueen = NQueen(noOfQueens, noOfSteps)
iteration = 1
while counter != 0:
    print("Iteration: ", iteration)
```

```python
    nQueen.hillClimb()
    counter = counter - 1
    iteration = iteration + 1

print("Success Count : ",successCount)
print("Failure Count: ",failureCount)
print("Success Rate", (successCount/(successCount+failureCount)*100))
print("Failure Rate", (failureCount/(successCount+failureCount)*100))
if failureCount == 0:
    failureCount = 1
if successCount == 0:
    successCount = 1
print("Avg Success Steps", (avgSuccessSteps/(successCount)))
print("Avg Failure Steps", (avgFailureSteps/(failureCount)))
```

```python
import copy
from random import Random, randint
import numpy as np
steps = 0
iteration = 0
restartCount = 0
noOfSteps = 0

class Node:
    def __init__(self, board, hvalue) -> None:
        self.board = board
        self.hvalue = hvalue

    def printBoard(self):
        print(np.matrix(self.board))

class NQueen:
    def __init__(self, size, steps) -> None:
        self.size = size
        self.steps = steps

    # Generates a random board configuration by placing the queens at random rows in each
column
    def generateRandomPosition(self):
        numOfQueens = self.size
        mat = [['-' for i in range(numOfQueens)] for j in range(numOfQueens)]
        for y in range(numOfQueens):
            queenPositionx = randint(0, self.size - 1)
            for x in range(numOfQueens):
                if (x == queenPositionx):
                    mat[x][y] = 'Q'
                else:
                    mat[x][y] = '-'
        return mat

    def heuristicFunction(self, board):
        heuristicValueRows = 0
        size = len(board)
        # Calculate the number of queens in the same row thus calculating the heuristic value
of rows
        for x in board:
            count = x.count('Q')
            # More than one queen in the row, add to the heuristic value
            if(count > 1):
                heuristicValueRows = heuristicValueRows + (sum(range(x.count('Q'))))
        heuristicValueDiagonal = 0
```

```python
    # Calculate the heuristic of diagonal, from left to right
    for y in range(size-1, -1, -1):
        numQueen = 0
        col = 0
        row = y
        while(col < size and row < size):
            value = board[row][col]
            if(value == 'Q'):
                numQueen = numQueen + 1
            col = col + 1
            row = row + 1
        if(numQueen > 1):
            heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
    for y in range(size-1, 0, -1):
        numQueen = 0
        col = y
        row = 0
        while(col < size and row < size):
            value = board[row][col]
            if(value == 'Q'):
                numQueen = numQueen + 1
            col = col + 1
            row = row + 1
        if(numQueen > 1):
            heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))

    #Calculate the heuristic of the diagonal, from right to left
    for y in range(size-1, -1, -1):
        numQueen = 0
        col = y
        row = 0
        while(col >= 0 and row < size):
            value = board[row][col]
            if(value == 'Q'):
                numQueen = numQueen + 1
            col = col - 1
            row = row + 1
        if(numQueen > 1):
            heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
    for y in range(size-1, 0, -1):
        numQueen = 0
        col = size-1
        row = y
        while(col >= 0 and row < size):
            value = board[row][col]
            if(value == 'Q'):
                numQueen = numQueen + 1
            col = col - 1
```

```python
                row = row + 1
            if(numQueen > 1):
                heuristicValueDiagonal = heuristicValueDiagonal + (sum(range(numQueen)))
        # Calculate the total heuristic value as the sum of row and diagonal heuristic
        heuristicValue = heuristicValueRows + heuristicValueDiagonal
        return heuristicValue


    # Generate the successors of the current configuration and select
    # the successor with lowest configuration for further evaluation
    def generateSuccessors(self, Node):
        print("Current Board:")
        Node.printBoard()
        global noOfSteps
        row = -1
        column = -1
        currentBoard = Node.board
        currentHeuristic = Node.hvalue
        queenPosition = [None] * len(currentBoard)
        boardChange = False
        # Make copy of the current board configuration
        tempBoard = copy.deepcopy(currentBoard)
        tempStates = list()
        print("Current Heuristic: ", currentHeuristic)
        for y in range (0,len(currentBoard)):
            for x in range (0,len(currentBoard)):
                # Store the position of queen in current column
                if currentBoard[x][y] == 'Q':
                    queenPosition[y] = x
        for y in range (0,len(currentBoard)):
            # Put the current queen position in the temp variable
            currentQueenPosition = queenPosition[y]
            # Remove the queen from the current position to generate successors
            tempBoard[currentQueenPosition][y] = '-'
            for x in range (0,len(currentBoard)):
                # Put the queen on each position in column apart from the current position
                # and calculate the heuristic
                if x != currentQueenPosition:
                    tempBoard[x][y] = 'Q'
                    tempHeuristic = self.heuristicFunction(tempBoard)
                    # If the heuristic of the new configuration is less than or equal to
current configuration,
                    # make it the current configuration for further evaluation
                    if currentHeuristic >= tempHeuristic:
                        column = y
                        row = x
                        currentHeuristic = tempHeuristic
                        copyState = copy.deepcopy(tempBoard)
                        # Append the state in the temp states array
```

```python
                    tempStates.append(copyState)
                    tempBoard[x][y] = '-'

            tempBoard[x][y] = '-'
        tempBoard[currentQueenPosition][y] = 'Q'

    # If the current heuristic is equal to the temp heuristic, and no of steps is not
zero
    # we have reached the local minima. Call the side step which will pick the random
state
    # from temp states array with heuristic value same as the current heuristic
    if noOfSteps != 0 and Node.hvalue == currentHeuristic and currentHeuristic != 0:
        print("Stepping to the side as local maxima reached")
        if len(tempStates) > 0:
            selection = randint(0, len(tempStates) - 1)
            currentBoard = tempStates.pop(selection)
            Node.hvalue = currentHeuristic
            Node.board = currentBoard
            # Reduce the no of permitted side steps
            noOfSteps = noOfSteps - 1
            return True
        else:
            return False

    # No solution found and the side step limit is reached
    elif noOfSteps == 0 and currentHeuristic != 0:
        print("No Better state found")
        noOfSteps = self.steps
        return False

    # Better state is found so change the current configuration to the temp board config
    # reset the no of side steap to the initial value and clear the tempStates array
    currentBoard[queenPosition[column]][column] = '-'
    currentBoard[row][column] = 'Q'
    Node.hvalue = currentHeuristic
    Node.board = currentBoard
    noOfSteps = self.steps
    tempStates.clear()
    return True

def hillClimbSideStepRestart(self):
    count = 0
    # Generate random position of the board
    board = NQueen.generateRandomPosition(self)
    current = Node(board, 0)
    current.printBoard()
    # Calculate no of queens under attack(heuristic)
    current.hvalue = self.heuristicFunction(current.board)
```

```python
        # Loop until solution is found
        while current.hvalue != 0:
            global steps
            steps = steps + 1
            end = self.generateSuccessors(current)

            # Failure --> Restart the algorithm by generating a random position
            if end == False:
                global restartCount
                restartCount = restartCount + 1
                print("Restart called")
                current.board = self.generateRandomPosition()
                current.hvalue = self.heuristicFunction(current.board)

        # Solution found
        if current.hvalue == 0:
            print("Solution found")
            global iteration
            iteration = iteration + 1
            current.printBoard()
        else:
            print("Failure")


# Input the no. of Queens to solve the problem
print("Enter number of Queens:")
noOfQueens = int(input())
# N-Queens can only be solved for size greater than 3
if(noOfQueens < 4):
    print("Problem cannot be solved for queens less than 4")
# No of side steps
print("Enter the number of steps for iteration:")
noOfSteps = int(input())
# No of iterations
print("How many times you want to run problem:")
counter = int(input())

nQueen = NQueen(noOfQueens, noOfSteps)
while counter != 0:
    nQueen.hillClimbSideStepRestart()
    counter = counter - 1

print("Avg Restarts", (restartCount/(iteration)))
print("Avg Steps", steps/iteration)
```

Outputs

Hill climbing search statistics

Number of runs(n)	avg no of steps when succeeded	avg no of steps when failed	success Count	failure Count	Success Rate	Failure Rate
100	7	6	8	92	8%	92%
200	6	6	39	161	19.5%	80.5%
300	6	6	50	250	16.6%	83.33%
400	6	6	70	330	17.5%	82.5%
500	6	6	80	420	16 %	84 %
600	6	6	94	506	15.6%	84.4%
700	6	6	106	594	15.14%	84.85%
800	7	6	129	671	16.125%	83.875%
900	6	6	146	754	16.2%	83.7%
1000	6	6	154	846	15.4%	84.6%

Search Sequences for 4 runs:

Enter number of Queens:

8

How many times you want to run problem:

4

Iteration 1

[['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' 'Q' '-' '-' '-' 'Q' '-']]

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-' '-']

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Current Heuristic: 5

Current Board:

[[' -' '-' '-' '-' '-' 'Q' '-' '-']

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 ['Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 4

Current Board:

[[' -' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 3

Current Board:

[[' -' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 2

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Failure

Iteration 2

[['-' 'Q' '-' '-' '-' '-' '-' '-' '-']

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Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

[['-' '-' 'Q' '-' 'Q' '-' '-' '-']

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

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Current Heuristic: 1

Current Board:

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Current Heuristic: 0

Solution found

[['-' '-' 'Q' '-' '-' '-' '-' '-']

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Iteration 3

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Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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32

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

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Current Heuristic: 1

Current Board:

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Current Heuristic: 0

Solution found

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Iteration 4

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Current Heuristic: 7

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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35

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Current Heuristic: 3

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

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Current Heuristic: 2

Failure

Success Count: 2

Failure Count: 2

Success Rate 50.0

Failure Rate 50.0

Avg Success Steps 6.0

Avg Failure Steps 6.

Hill Climbing search with sideway statistics

Number of runs(n)	avg no of steps when succeeded	avg no of steps when failed	success Count	failure Count	Success Rate	Failure Rate
100	17	6	91	9	91%	9%
200	19	51	185	15	92.5%	7.5%
300	20	81	276	24	92%	8%
400	20	37	378	22	94.5%	5.5%
500	19	61	473	27	94.6%	5.4 %
600	19	53	569	31	94.83%	5.15%
700	19	58	650	50	92.85 %	7.14%
800	19	62	748	52	93.5%	6.5%
900	19	55	848	52	94.22%	5.7%
1000	21	59	944	56	94.39%	5.60%

Search Sequences for 4 runs

Enter number of Queens:

8

Enter the number of steps for iteration:

100

How many times you want to run problem:

4

Iteration: 1

Current Board:

[['Q' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' 'Q' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-']]

Current Heuristic: 4

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' 'Q' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']]

Current Heuristic: 2

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' 'Q' '-' 'Q' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']]

Current Heuristic: 1

Steps: 5

Solution found

[['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']]

Iteration: 2

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' 'Q' 'Q' 'Q' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 9

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' 'Q' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 4

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' 'Q' '-' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 3

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' 'Q' '-' '-']

['-' 'Q' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 2

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' 'Q' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' 'Q' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

41

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' 'Q' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' '-' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' 'Q' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' 'Q' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' '-' '-' '-']

 ['-' 'Q' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-' '-']

['-' 'Q' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['-' 'Q' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

45

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['Q' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Steps: 20

Solution found

[['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-' '-']]

Iteration: 3

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

46

['-' '-' '-' '-' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' 'Q']

['-' '-' '-' 'Q' 'Q' '-' '-' '-']]

Current Heuristic: 8

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' 'Q']

['-' '-' '-' 'Q' '-' '-' '-' '-']]

Current Heuristic: 5

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 3

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 2

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' 'Q' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' 'Q' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Steps: 8

Solution found

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']]

Iteration: 4

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

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['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' 'Q' '-' 'Q' '-' 'Q' '-']]

Current Heuristic: 10

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' 'Q' '-' 'Q' '-' '-' '-']]

Current Heuristic: 6

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' 'Q']

['-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 3

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

[-' '-' '-' 'Q' '-' '-' '-' '-']

[-' '-' '-' '-' '-' '-' '-' '-']

[-' '-' '-' '-' '-' '-' 'Q' '-']

[-' 'Q' '-' '-' '-' '-' '-' '-']

[-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Steps: 4

Solution found

[-' '-' '-' '-' '-' '-' '-' 'Q']

[-' '-' '-' 'Q' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

[-' '-' '-' '-' '-' '-' 'Q' '-']

[-' 'Q' '-' '-' '-' '-' '-' '-']

PS C:\Users\aksha\Desktop\IS\Project 2\Final Code> python .\NQueen_Hill_Climb_Sideway.py

Enter number of Queens:

8

Enter the number of steps for iteration:

100

How many times you want to run problem:

4

Iteration: 1

Current Board:

[['-' '-' '-' 'Q' '-' '-' 'Q' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 5

Current Board:

[['-' '-' '-' 'Q' '-' '-' 'Q' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 3

Current Board:

[['-' '-' '-' 'Q' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 2

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 1

Steps: 5

Solution found

[['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' '-' 'Q' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']]

Iteration: 2

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

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 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' 'Q' 'Q' '-' 'Q' 'Q' '-' '-']]

Current Heuristic: 9

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' 'Q' 'Q' '-' 'Q' '-' '-' '-']]

Current Heuristic: 5

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' 'Q' '-' '-' 'Q' '-' '-' '-']]

Current Heuristic: 2

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 2

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

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 ['-' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 2

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

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 ['Q' '-' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Steps failure: 6

Failure

Iteration: 3

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['Q' '-' '-' '-' 'Q' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

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['-' '-' '-' '-' '-' '-' 'Q' 'Q' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 3

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 2

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-' 'Q']

['Q' '-' '-' '-' '-' '-' '-' '-' '-']

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['-' '-' '-' 'Q' '-' '-' '-' '-']]

Current Heuristic: 1

Steps: 4

Solution found

[['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' 'Q' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' 'Q' '-']

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Iteration: 4

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 8

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 4

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 3

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 2

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 2

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' 'Q' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

60

['-' '-' '-' '-' '-' '-' 'Q' '-']

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['-' 'Q' '-' '-' '-' '-' '-' '-']

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['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' 'Q' '-']

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 ['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' 'Q' '-']

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 ['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

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 ['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' 'Q' '-']

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['-' '-' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

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 ['-' '-' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

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 ['Q' 'Q' '-' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

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['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' 'Q' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Steps: 22

Solution found

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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['-' '-' '-' '-' 'Q' '-' '-' '-']

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['-' '-' '-' '-' '-' 'Q' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' 'Q' '-' '-' '-' '-' '-' '-']]

Success Count: 3

Failure Count: 1

Success Rate 75.0

Failure Rate 25.0

Avg Success Steps 10.333333333333334

Avg Failure Steps 6.0

Random Restart Hill climbing search with and without sideways statistics

Number of runs(n)	Avg restarts without sideways	Avg steps without sideways	Avg restarts with sideways	Avg steps with sideways
100	6	28	0.04	24
200	5	27	0.04	21
300	7	31	0.04	21
400	5	26	0.06	22
500	6	27	0.05	21
600	6	28	0.07	23
700	5	27	0.05	24
800	6	29	0.07	23
900	5	26	0.06	23
1000	5	27	0.06	22

Search Sequences for 4 runs of Avg restart without sideways move

Enter number of Queens:

8

How many times you want to run problem:

4

[['-' '-' '-' '-' 'Q' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['Q' 'Q' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']

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[' - ' 'Q' ' - ' ' - ' ' - ' 'Q' ' - ' ' - ']

  [' - ' ' - ' 'Q' ' - ' ' - ' ' - ' ' - ' ' - ']]

Current Heuristic: 10

Current Board:

[[' - ' 'Q' ' - ' ' - ' 'Q' ' - ' ' - ' 'Q']

 [' - ' ' - ' ' - ' ' - ' ' - ' ' - ' 'Q' ' - ']

 ['Q' ' - ' ' - ' ' - ' ' - ' ' - ' ' - ' ' - ']

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 [' - ' ' - ' 'Q' ' - ' ' - ' ' - ' ' - ' ' - ']]

Current Heuristic: 7

Current Board:

[[' - ' ' - ' ' - ' ' - ' 'Q' ' - ' ' - ' 'Q']

 [' - ' ' - ' ' - ' ' - ' ' - ' ' - ' 'Q' ' - ']

 ['Q' ' - ' ' - ' ' - ' ' - ' ' - ' ' - ' ' - ']

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Current Heuristic: 6

Current Board:

[[' - ' ' - ' ' - ' ' - ' 'Q' ' - ' ' - ' 'Q']

 [' - ' ' - ' ' - ' ' - ' ' - ' ' - ' 'Q' ' - ']

 ['Q' ' - ' ' - ' ' - ' ' - ' ' - ' ' - ' ' - ']

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['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 5

Current Board:

[['-' '-' '-' 'Q' 'Q' '-' '-' 'Q']

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Current Heuristic: 4

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' 'Q']

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Current Heuristic: 3

Current Board:

[['-' '-' '-' '-' 'Q' '-' '-' 'Q']

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 11

Current Board:

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Current Heuristic: 10

Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 9

Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

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Current Heuristic: 3

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Current Heuristic: 2

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 5

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Current Heuristic: 3

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 7

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 9

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Current Heuristic: 8

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Current Heuristic: 7

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 1

Current Board:

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Current Heuristic: 0

Solution found

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Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 2

Restart called

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Current Board:

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Current Heuristic: 0

Solution found

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Current Board:

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Current Heuristic: 9

Current Board:

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Current Heuristic: 7

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 3

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Current Heuristic: 2

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Current Heuristic: 1

Restart called

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Current Heuristic: 8

Current Board:

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Current Heuristic: 7

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 7

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Current Heuristic: 6

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Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Restart called

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

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Current Heuristic: 3

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Current Heuristic: 2

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Current Heuristic: 1

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Current Heuristic: 0

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Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 7

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 7

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Current Heuristic: 6

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Current Heuristic: 5

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Current Heuristic: 4

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Current Heuristic: 2

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 8

Current Board:

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Current Heuristic: 7

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Current Heuristic: 6

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Current Heuristic: 5

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Current Heuristic: 4

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Restart called

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Current Heuristic: 5

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Current Heuristic: 4

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Current Heuristic: 2

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 4

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Restart called

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Current Heuristic: 9

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Current Heuristic: 7

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 3

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Current Heuristic: 2

Restart called

Current Board:

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Current Heuristic: 7

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 5

Current Board:

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Restart called

Current Board:

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Current Heuristic: 3

Current Board:

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Current Board:

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Current Heuristic: 0

Solution found

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Avg Restarts 5.75

Avg Steps 43.25

Enter number of Queens:

8

Enter the number of steps for iteration:

100

How many times you want to run problem:

4

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Current Board:

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Current Heuristic: 11

Current Board:

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Current Heuristic: 6

Current Board:

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Current Heuristic: 4

Current Board:

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Current Heuristic: 2

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

128

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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 ['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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147

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

152

['-' '-' '-' 'Q' '-' 'Q' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

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['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' 'Q' '-' '-' '-' '-' '-' '-']

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['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' '-' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

['-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-']

154

[-' '-' '-' '-' 'Q' '-' '-' '-']

[-' 'Q' '-' '-' '-' '-' '-' '-']

[-' '-' '-' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

[-' '-' '-' 'Q' '-' 'Q' '-' '-']

[-' '-' '-' '-' '-' '-' '-' 'Q']

[-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[[-' '-' '-' '-' '-' '-' 'Q' '-']

[-' '-' '-' '-' '-' 'Q' '-' '-' '-']

[-' 'Q' '-' '-' '-' '-' '-' '-']

[-' '-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

[-' '-' '-' 'Q' '-' '-' '-' '-']

[-' '-' '-' '-' '-' '-' '-' '-' 'Q']

[-' '-' 'Q' '-' '-' '-' '-' '-']]

Current Heuristic: 1

No Better state found

Restart called

Current Board:

[[-' '-' '-' '-' '-' '-' '-' 'Q']

[-' '-' '-' '-' 'Q' '-' 'Q' '-']

[-' '-' '-' '-' '-' '-' '-' '-']

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[-' 'Q' '-' '-' '-' '-' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

[-' '-' '-' 'Q' '-' 'Q' '-' '-']

[-' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 11

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 7

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

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Current Heuristic: 4

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

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Current Heuristic: 3

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 2

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

157

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['-' '-' '-' '-' 'Q' '-' '-' '-']

 ['-' '-' 'Q' '-' '-' '-' '-' '-']

 ['Q' '-' '-' '-' '-' '-' '-' 'Q']

 ['-' '-' '-' '-' '-' 'Q' '-' '-']

 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

 ['Q' '-' '-' '-' 'Q' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

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 ['Q' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-' 'Q']

165

['Q' '-' '-' '-' '-' '-' '-' '-']

['-' '-' 'Q' 'Q' '-' '-' '-' '-']

['-' '-' '-' '-' '-' 'Q' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['Q' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

167

['-' '-' '-' '-' '-' '-' 'Q' '-']

['-' '-' '-' '-' 'Q' '-' '-' '-']

['-' '-' '-' '-' '-' '-' '-' 'Q']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' '-' 'Q' 'Q']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

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 ['-' '-' '-' 'Q' '-' '-' '-' '-']

 ['-' 'Q' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 1

Solution found

[['-' '-' '-' '-' 'Q' '-' '-' '-']

 ['-' '-' '-' '-' '-' '-' 'Q' '-']

 ['Q' '-' '-' '-' '-' '-' '-' '-']

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['Q' 'Q' '-' '-' '-' '-' '-' '-' '-']]

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

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['Q' 'Q' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 7

Current Board:

[['-' '-' '-' '-' '-' '-' 'Q' '-' '-']

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['Q' 'Q' '-' '-' '-' '-' '-' '-' '-']]

Current Heuristic: 4

172

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 2

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

['Q' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

173

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' 'Q' '-' '-']

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Current Heuristic: 1

Solution found

[[-' '-' '-' 'Q' '-' '-' '-' '-']

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 [-' '-' '-' '-' '-' '-' '-' 'Q' '-']]

Current Board:

[[-' '-' 'Q' '-' 'Q' '-' '-' '-']

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['Q' '-' '-' 'Q' '-' 'Q' '-' 'Q']

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 ['-' '-' '-' '-' '-' '-' 'Q' '-']]

Current Heuristic: 9

Current Board:

[['-' '-' 'Q' '-' 'Q' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' 'Q' '-']]

Current Heuristic: 5

Current Board:

[['-' '-' 'Q' '-' 'Q' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' 'Q' '-']]

Current Heuristic: 3

Current Board:

[['-' '-' 'Q' '-' 'Q' '-' '-' '-']

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 ['-' '-' '-' '-' '-' '-' '-' 'Q']

 ['Q' '-' '-' '-' '-' 'Q' '-' '-']

179

[‐' '‐' '‐' 'Q' '‐' '‐' '‐' '‐']

 [‐' '‐' '‐' '‐' '‐' '‐' '‐' '‐']]

Current Heuristic: 2

Current Board:

[['‐' '‐' 'Q' '‐' 'Q' '‐' '‐' '‐']

 ['‐' '‐' '‐' '‐' '‐' '‐' 'Q' '‐']

 ['‐' 'Q' '‐' '‐' '‐' '‐' '‐' '‐']

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 ['Q' '‐' '‐' '‐' '‐' '‐' '‐' '‐']

 ['‐' '‐' '‐' 'Q' '‐' '‐' '‐' '‐']

 ['‐' '‐' '‐' '‐' '‐' 'Q' '‐' '‐']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['‐' '‐' 'Q' '‐' '‐' '‐' '‐' '‐']

 ['‐' '‐' '‐' '‐' '‐' '‐' 'Q' '‐']

 ['‐' 'Q' '‐' '‐' '‐' '‐' '‐' '‐']

 ['‐' '‐' '‐' '‐' 'Q' '‐' '‐' '‐']

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 ['Q' '‐' '‐' '‐' '‐' '‐' '‐' '‐']

 ['‐' '‐' '‐' 'Q' '‐' '‐' '‐' '‐']

 ['‐' '‐' '‐' '‐' '‐' 'Q' '‐' '‐']]

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['‐' '‐' 'Q' '‐' '‐' '‐' '‐' '‐']

 ['‐' '‐' '‐' '‐' '‐' '‐' 'Q' '‐']

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 ['‐' '‐' '‐' '‐' 'Q' '‐' '‐' 'Q']

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Current Heuristic: 1

Solution found

[['-' '-' 'Q' '-' '-' '-' '-' '-']

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Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

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Current Heuristic: 8

181

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

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Current Heuristic: 5

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q']

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Current Heuristic: 2

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 2

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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184

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' 'Q' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['Q' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' 'Q' '-']

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194

Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' '-' '-' '-' '-' 'Q' 'Q' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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196

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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197

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

198

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

Current Board:

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Stepping to the side as local maxima reached

[['-' 'Q' '-' '-' '-' '-' '-' '-']

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Current Heuristic: 1

Solution found

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Avg Restarts 0.25

Avg Steps 60.75

Conclusion

Based on the above observations, we can conclude that by using Hill climbing with Sideway moves and random restart, we can solve the problem in minimum steps and successfully.