

```
#####BFS
ALGORITHM#####
```

```
from collections import deque
import sys
import time
```

```
board = []
```

```
def ValidMove(board, x, y):
    """
    :param board: NxN board
    :param x: x position
    :param y: y position
    :return: return 2d board
    """
    return 0 <= x < len(board) and 0 <= y < len(board[0])
```

```
def ShowBoard(board):
    """
    :param board: NxN board
    :return: Print board on console
    """
    for row in board:
        print("".join(row))
    print()
```

```
def Neighbours(board, pos):
    """
    :param board: NxN board
    :param pos: New position of robot
    :return: List of its neighbor
    """
    neighbors = []
    x, y = pos
    for dx, dy in [(1, 0), (-1, 0), (0, 1), (0, -1)]:
        new_x, new_y = x + dx, y + dy
        if ValidMove(board, new_x, new_y) and board[new_x][new_y] != 'O':
            neighbors.append((new_x, new_y))
    return neighbors
```

```
def Initstate():
    """
    :return: Initial state of the board
    """
    print('Initial Board\n')
    file_obj = open(sys.argv[1])
    rows = file_obj.readlines()
    for line in rows:
        if line != "":
            board.append(line.strip())
        else:
            break
    return board
```

```
def Successor(board, robot, boxes, storage):
    """
    :param board: NxN board
    :param robot: Location of robot
    :param boxes: Location of boxes
    :param storage: Location of the storage
    :return: Show next board state
```

```

"""
start_state = (robot, boxes)
visited = set()
queue = deque([(start_state, [])])

while queue:
    (robot, boxes), actions = queue.popleft()

    if sorted(boxes) == sorted(storage):
        return actions

    if (robot, boxes) in visited:
        continue

    visited.add((robot, boxes))

    solution_board = [list(row) for row in board]
    for box in boxes:
        x, y = box
        solution_board[x][y] = 'B'
    solution_board[robot[0]][robot[1]] = 'R'
    ShowBoard(solution_board)

    for neighbor in Neighbours(board, robot):
        new_robot = neighbor
        new_boxes = list(boxes)
        for i, box in enumerate(new_boxes):
            if box == new_robot:
                new_box = (box[0] + (box[0] - robot[0]), box[1] + (box[1] - robot[1]))
                if ValidMove(board, *new_box) and board[new_box[0]][new_box[1]] != 'O':
                    new_boxes[i] = new_box
                    break

        new_state = (new_robot, tuple(new_boxes))
        new_actions = actions + [neighbor]
        queue.append((new_state, new_actions))

return None

```

```

def GetStoragePos(board):
    """
    :param board: NxN board
    :return: Positions of the Storages
    """
    return {(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] == 'S'}

```

```

def GetRobotPos(board):
    """
    :param board: NxN board
    :return: Positions of the Robot
    """
    return [(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] == 'R'][0]

```

```

def GetBoxPos(board):
    """
    :param board: NxN board
    :return: Positions of the boxes
    """
    return tuple((x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] == 'B')

```

```
# Driver Code
```

```
board = Initstate()
```

```
storage = GetStoragePos(board)
```

```
robot = GetRobotPos(board)
```

```
boxes = GetBoxPos(board)
```

```
start_time = time.time()
```

```
actions = Successor(board, robot, boxes, storage)
```

```
if actions:
```

```
    print("End solution can be found")
```

```
    solution_board = [list(row) for row in board]
```

```
    for action in actions:
```

```
        x, y = action
```

```
        solution_board[x][y] = 'R'
```

```
    ShowBoard(solution_board)
```

```
else:
```

```
    print("End State cannot be found.")
```

```
print(f'Total execution time is {time.time() - start_time}')
```

```
#####DFS
ALGORITHM#####
import time
import sys

def ValidMove(board, x, y):
    """
    :param board: NxN board
    :param x: x position
    :param y: y position
    :return: return 2d board
    """
    return 0 <= x < len(board) and 0 <= y < len(board[0])

def ShowBoard(board):
    """
    :param board: NxN board
    :return: Print board on console
    """
    for row in board:
        print("".join(row))
    print()

def Neighbors(board, pos):
    """
    :param board: NxN board
    :param pos: New position of robot
    :return: List of its neighbor
    """
    neighbors = []
    x, y = pos
    for dx, dy in [(1, 0), (-1, 0), (0, 1), (0, -1)]:
        new_x, new_y = x + dx, y + dy
        if ValidMove(board, new_x, new_y) and board[new_x][new_y] != 'O':
            neighbors.append((new_x, new_y))
    return neighbors

def Successor(board, robot, boxes, storage, depth, actions=[]):
    """
    :param board: NxN board
    :param robot: Robot position
    :param boxes: Boxes Position
    :param storage: Storage Position
    :param depth: Depth
    :param actions: List of actions performed
    :return: Show next board state
    """
    if sorted(boxes) == sorted(storage):
        return actions

    if depth == 0:
        return None

    for neighbor in Neighbors(board, robot):
        new_robot = neighbor
        new_boxes = list(boxes)
        for i, box in enumerate(new_boxes):
            if box == new_robot:
                new_box = (box[0] + (box[0] - robot[0]), box[1] + (box[1] - robot[1]))
                if ValidMove(board, *new_box) and board[new_box[0]][new_box[1]] != 'O':
                    new_boxes[i] = new_box
                    break

        new_board = [list(row) for row in board]
```

```

        for box in new_boxes:
            x, y = box
            new_board[x][y] = 'B'
        new_board[new_robot[0]][new_robot[1]] = 'R'
        ShowBoard(new_board)

        result = Successor(new_board, new_robot, tuple(new_boxes), storage, depth - 1, actions
+ [new_robot])

        if result:
            return result

    return None

def Initstate():
    """
    :return: Initial state of the board
    """
    print('Initial Board\n')
    file_obj = open(sys.argv[1])
    rows = file_obj.readlines()
    for line in rows:
        if line != "":
            board.append(line.strip())
        else:
            break
    return board

def CallSuccessorWithDepth(board, robot, boxes, storage):
    """
    :param board: NxN board
    :param robot: Position of Robot
    :param boxes: Position of box
    :param storage: Position of storage
    :return: Count of the depths
    """
    depth = 0
    while True:
        print(f"Depth: {depth}")
        result = Successor(board, robot, boxes, storage, depth)
        if result:
            return result
        depth += 1

def GetStoragePos(board):
    """
    :param board: NxN board
    :return: Positions of the Storages
    """
    return {(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] ==
'S'}

def GetRobotPos(board):
    """
    :param board: NxN board
    :return: Positions of the Robot
    """
    return [(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] ==
'R'][0]

def GetBoxPos(board):
    """

```

```

        :param board:NxN board
        :return: Positions of the boxes
        """
        return tuple((x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x]
[y] == 'B')

# Driver Code
board = []
board = Initstate()

storage = GetStoragePos(board)
robot = GetRobotPos(board)
boxes = GetBoxPos(board)

start_time = time.time()

actions = CallSuccessorWithDepth(board, robot, boxes, storage)

if actions:
    print("End state can be found")
    solution_board = [list(row) for row in board]
    for action in actions:
        x, y = action
        solution_board[x][y] = 'R'

    ShowBoard(solution_board)
else:
    print("End state cannot be found")

print(f'Total execution time is {time.time() - start_time}')

```

```

#####GBS
ALGORITHM#####
from heapq import heappop, heappush
import time
import sys
def ValidMove(board, x, y):
    """
    :param board: NxN board
    :param x: x position
    :param y: y position
    :return: return 2d board
    """
    return 0 <= x < len(board) and 0 <= y < len(board[0])

def ManhattanDistance(a, b):
    """
    :param a: Any position
    :param b: Any position
    :return: Absolute distance between 2 co-ordinates
    """
    return abs(a[0] - b[0]) + abs(a[1] - b[1])

def Heuristic(board, robot, boxes, targets):
    """
    :param board: NxN Board
    :param robot: Robot position
    :param boxes: Boxes position
    :param targets: Target locations
    :return: total distance
    """
    total_dist = 0
    for box in boxes:
        min_dist = min(ManhattanDistance(box, target) for target in targets)
        total_dist += min_dist
    return total_dist

def ShowBoard(board):
    """
    :param board: NxN board
    :return: Print board on console
    """
    for row in board:
        print("".join(row))
    print()

def Successor(board, robot, boxes, targets):
    """
    :param board: NxN board
    :param robot: Location of robot
    :param boxes: Location of boxes
    :param targets: Location of the targets
    :return: Show next board state
    """
    directions = [(1, 0), (-1, 0), (0, 1), (0, -1)]

    def is_goal(boxes):
        return sorted(boxes) == sorted(targets)

    def apply_move(entity, direction):
        return (entity[0] + direction[0], entity[1] + direction[1])

    start_state = (robot, tuple(sorted(boxes)))
    visited = set()
    priority_queue = [(Heuristic(board, robot, boxes, targets), start_state)] # (heuristic,
    (robot, boxes))

    while priority_queue:

```

```

_, (robot, boxes) = heappop(priority_queue)

if is_goal(boxes):
    return boxes

if (robot, boxes) in visited:
    continue

visited.add((robot, boxes))

solution_board = [list(row) for row in board]
for box in boxes:
    x, y = box
    solution_board[x][y] = 'B'
solution_board[robot[0]][robot[1]] = 'R'
ShowBoard(solution_board)

for direction in directions:
    new_robot = apply_move(robot, direction)
    if not ValidMove(board, *new_robot) or board[new_robot[0]][new_robot[1]] == 'O':
        continue

    if (new_robot, boxes) not in visited:
        heappush(priority_queue, (Heuristic(board, new_robot, boxes, targets),
(new_robot, boxes)))

return None

def Initstate():
    """
    :return: Initial state of the board
    """
    print('Initial Board\n')
    file_obj = open(sys.argv[1])
    rows = file_obj.readlines()
    for line in rows:
        if line != "":
            board.append(line.strip())
        else:
            break
    return board

def GetStoragePos(board):
    """
    :param board: NxN board
    :return: Positions of the Storages
    """
    return {(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] == 'S'}

def GetRobotPos(board):
    """
    :param board: NxN board
    :return: Positions of the Robot
    """
    return [(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] == 'R'][0]

def GetBoxPos(board):
    """
    :param board: NxN board
    :return: Positions of the boxes
    """
    return tuple((x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x]

```



```
[y] == 'B')
```

```
# Driver Code
```

```
board = []
```

```
board = Initstate()
```

```
storage = GetStoragePos(board)
```

```
robot = GetRobotPos(board)
```

```
boxes = GetBoxPos(board)
```

```
start_time = time.time()
```

```
result = Successor(board, robot, boxes, storage)
```

```
if result:
```

```
    print("End state can be found:")
```

```
    solution_board = [list(row) for row in board]
```

```
    for box in result:
```

```
        x, y = box
```

```
        solution_board[x][y] = 'B'
```

```
    print("\n".join(["".join(row) for row in solution_board]))
```

```
    print()
```

```
else:
```

```
    print("End state cannot be found.")
```

```
print(f'Total execution time is {time.time() - start_time}')
```

```

#####ASTAR
ALGORITHM#####
import heapq
import time
import sys

def ValidMove(board, x, y):
    """
    :param board: NxN board
    :param x: x position
    :param y: y position
    :return: return 2d board
    """
    return 0 <= x < len(board) and 0 <= y < len(board[0])

def ManhattanDistance(pos1, pos2):
    """
    :param a: Any position
    :param b: Any position
    :return: Absolute distance between 2 co-ordinates
    """
    return abs(pos1[0] - pos2[0]) + abs(pos1[1] - pos2[1])

def Heuristic(board, robot, boxes, storagepace):
    """
    :param board: NxN Board
    :param robot: Robot position
    :param boxes: Boxes position
    :param storagepace: storagspace positions
    :return: total distance
    """
    total_dist = 0
    for box in boxes:
        min_dist = min(ManhattanDistance(box, target) for target in storagepace)
        total_dist += min_dist
    return total_dist + ManhattanDistance(robot, boxes[0])

def ShowBoard(board):
    """
    :param board: NxN board
    :return: Print board on console
    """
    for row in board:
        print("".join(row))
    print()

def Successor(board, robot, boxes, storage):
    """
    :param board: NxN board
    :param robot: Location of robot
    :param boxes: Location of boxes
    :param storage: Location of the storage
    :return: Show next board state
    """
    print("Pukoban Using A Star Algorithm")
    directions = [(1, 0), (-1, 0), (0, 1), (0, -1)]

    def is_goal(boxes):
        return sorted(boxes) == sorted(storage)

    def apply_move(entity, direction):
        return (entity[0] + direction[0], entity[1] + direction[1])

```

```

def valid_move(entity, direction):
    new_entity = apply_move(entity, direction)
    if not ValidMove(board, *new_entity) or board[new_entity[0]][new_entity[1]] == 'O':
        return False
    return True

start_state = (robot, tuple(sorted(boxes)))
visited = set()
priority_queue = [(0, start_state)]

while priority_queue:
    f_cost, (robot, boxes) = heapq.heappop(priority_queue)

    if is_goal(boxes):
        return boxes

    if (robot, boxes) in visited:
        continue

    visited.add((robot, boxes))

    solution_board = [list(row) for row in board]
    for box in boxes:
        x, y = box
        solution_board[x][y] = 'B'
    solution_board[robot[0]][robot[1]] = 'R'
    ShowBoard(solution_board)

    for direction in directions:
        new_robot = apply_move(robot, direction)
        if not ValidMove(board, *new_robot) or board[new_robot[0]][new_robot[1]] == 'O':
            continue

        if (new_robot, boxes) not in visited:
            heapq.heappush(priority_queue, (f_cost + 1 + Heuristic(board, new_robot,
boxes, storage),
                                         (new_robot, boxes)))

        for box_index, box in enumerate(boxes):
            if box == new_robot:
                new_box = apply_move(box, direction)
                if valid_move(box, direction) and (
                    new_box, boxes[:box_index] + (new_box,) + boxes[box_index + 1:]) not in
visited:
                    heapq.heappush(priority_queue, (f_cost + 1 + Heuristic(board,
new_robot, boxes, storage),
                                                    (new_robot,
boxes[:box_index] + (new_box,) +
boxes[box_index + 1:])))
            return None

def Initstate():
    """
    :return: Initial state of the board
    """
    print('Initial Board\n')
    file_obj = open(sys.argv[1])
    rows = file_obj.readlines()
    for line in rows:
        if line != "":
            board.append(line.strip())
    else:
        break
    return board

```

```

def GetStoragePos(board):
    """
    :param board: NxN board
    :return: Positions of the Storages
    """
    return {(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] ==
'S'}

def GetRobotPos(board):
    """
    :param board: NxN board
    :return: Positions of the Robot
    """
    return [(x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x][y] ==
'R'][0]

def GetBoxPos(board):
    """
    :param board: NxN board
    :return: Positions of the boxes
    """
    return tuple((x, y) for x in range(len(board)) for y in range(len(board[0])) if board[x]
[y] == 'B')

# Driver Code
board = []
board = Initstate()

storage = GetStoragePos(board)
robot = GetRobotPos(board)
boxes = GetBoxPos(board)

start_time = time.time()

result = Successor(board, robot, boxes, storage)

if result:
    print("End state can be found:")
    solution_board = [list(row) for row in board]
    for box in result:
        x, y = box
        solution_board[x][y] = 'B'
    print("\n".join(["".join(row) for row in solution_board]))

else:
    print("End state cannot be found:")

print(f'Total execution time is {time.time() - start_time}')

```

## BFS States

### Initial Board

```
000000
0 BR 0
0 BO 0
00 0 0
00SS 0
000000
```

```
000000
0 BRRO
0 BO 0
00 0 0
00SS 0
000000
```

```
000000
0BRR 0
0 BO 0
00 0 0
00SS 0
000000
```

```
000000
0 BR 0
0 BORO
00 0 0
00SS 0
000000
```

```
000000
0BBR 0
0 RO 0
0OBO 0
00SS 0
000000
```

```
000000
0BBR 0
0 BO 0
00 0 0
00SS 0
000000
```

```
000000
0RBR 0
0 BO 0
00 0 0
00SS 0
000000
```

```
000000
0 BR 0
0 BO 0
00 ORO
00SS 0
000000
```

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0BBR 0  
0 BO 0  
0ORO 0  
0OBS 0  
000000

000000  
0BRR 0  
0 BO 0  
0OBO 0  
0OSS 0  
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0BBR 0  
0RBO 0  
0OBO 0  
0OSS 0  
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0 BO 0  
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0OSS 0  
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0O 0 0  
0OSS 0  
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0 BO 0  
0O 0 0  
0ORS 0  
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End State cannot be found.  
Total execution time is 0.0020017623901367188 secs

GBS States  
Initial Board

000000  
O BR O  
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ORBR O  
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End state cannot be found.  
Total execution time is 0.0 secs.

## AStar States

### Initial Board

#### Pukoban Using A Star Algorithm

```
000000
0 BR 0
0 BO 0
00 0 0
00SS 0
000000
```

```
000000
0BRR 0
0 BO 0
00 0 0
00SS 0
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```
000000
0 RR 0
0 BO 0
00 0 0
00SS 0
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```
000000
0 BRRO
0 BO 0
00 0 0
00SS 0
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```
000000
0RBR 0
0 BO 0
00 0 0
00SS 0
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0RBR 0
0 BO 0
00 0 0
00SS 0
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000000
0 BR 0
0 RO 0
00 0 0
00SS 0
000000
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000000
0 BR 0
0 RO 0
00BO 0
00SS 0
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000000  
0BBR 0  
0 BO 0  
00 0 0  
0OSS 0  
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0BBR 0  
0 RO 0  
00 0 0  
0OSS 0  
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0OBO 0  
0OSS 0  
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O BRBO  
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End state cannot be found:  
Total execution time is 0.003007173538208008 secs