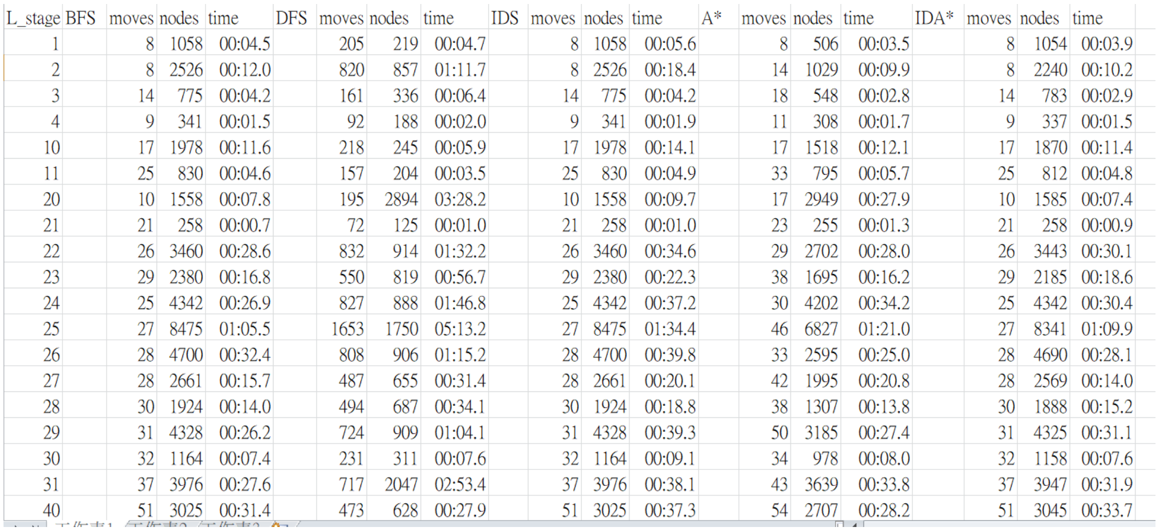
report

這次作業的要求是用五種演算法解rush hour的問題，以下是我針對五種演算法，分別比較其所需移動的步數(深度)及所經過之節點數(空間)。



L_stage	BFS	moves	nodes	time	DFS	moves	nodes	time	IDS	moves	nodes	time	A*	moves	nodes	time	IDA*	moves	nodes	time
1		8	1058	00:04.5		205	219	00:04.7		8	1058	00:05.6		8	506	00:03.5		8	1054	00:03.9
2		8	2526	00:12.0		820	857	01:11.7		8	2526	00:18.4		14	1029	00:09.9		8	2240	00:10.2
3		14	775	00:04.2		161	336	00:06.4		14	775	00:04.2		18	548	00:02.8		14	783	00:02.9
4		9	341	00:01.5		92	188	00:02.0		9	341	00:01.9		11	308	00:01.7		9	337	00:01.5
10		17	1978	00:11.6		218	245	00:05.9		17	1978	00:14.1		17	1518	00:12.1		17	1870	00:11.4
11		25	830	00:04.6		157	204	00:03.5		25	830	00:04.9		33	795	00:05.7		25	812	00:04.8
20		10	1558	00:07.8		195	2894	03:28.2		10	1558	00:09.7		17	2949	00:27.9		10	1585	00:07.4
21		21	258	00:00.7		72	125	00:01.0		21	258	00:01.0		23	255	00:01.3		21	258	00:00.9
22		26	3460	00:28.6		832	914	01:32.2		26	3460	00:34.6		29	2702	00:28.0		26	3443	00:30.1
23		29	2380	00:16.8		550	819	00:56.7		29	2380	00:22.3		38	1695	00:16.2		29	2185	00:18.6
24		25	4342	00:26.9		827	888	01:46.8		25	4342	00:37.2		30	4202	00:34.2		25	4342	00:30.4
25		27	8475	01:05.5		1653	1750	05:13.2		27	8475	01:34.4		46	6827	01:21.0		27	8341	01:09.9
26		28	4700	00:32.4		808	906	01:15.2		28	4700	00:39.8		33	2595	00:25.0		28	4690	00:28.1
27		28	2661	00:15.7		487	655	00:31.4		28	2661	00:20.1		42	1995	00:20.8		28	2569	00:14.0
28		30	1924	00:14.0		494	687	00:34.1		30	1924	00:18.8		38	1307	00:13.8		30	1888	00:15.2
29		31	4328	00:26.2		724	909	01:04.1		31	4328	00:39.3		50	3185	00:27.4		31	4325	00:31.1
30		32	1164	00:07.4		231	311	00:07.6		32	1164	00:09.1		34	978	00:08.0		32	1158	00:07.6
31		37	3976	00:27.6		717	2047	02:53.4		37	3976	00:38.1		43	3639	00:33.8		37	3947	00:31.9
40		51	3025	00:31.4		473	628	00:27.9		51	3025	00:37.3		54	2707	00:28.2		51	3045	00:33.7

左邊第一行是關卡(題目)編號Lxx.txt，然後後方是各演算法步數、節點數、時間。

根據觀察，DFS雖然所需之步數會較BFS多，但節點數反而會較少，時間方面，DFS 若在錯誤的路徑下不斷搜索，也可能導致浪費較多時間。

而第三種方法，IDS在此種情況下，表現就和BFS一樣，可能是因為其演算法是固定層數的DFS，最後導致和BFS一樣的行為。

第四種A*演算法，由於是採用blocking heuristic的方法，搜索時會以blocking value值較小的情況優先搜索，因此在快接近答案時(blocking value很小)，能較快找到答案，所以所需步數類似於BFS，但經過之節點數明顯優於BFS。

最後一種IDA*的方法，感覺起來表現和BFS差不多，推測是因為每層的深度都固定，所以無法在接近答案時，繼續向下搜索，因此表現會類似於IDS和BFS。

在實作的過程時發現，DFS的答案很容易有步數和節點數很接近之情形，可能是因為在某種情形下，不斷加深的深度都沒有遇到死路，所以一直做多餘的步數，導致深度不斷加深，最後才找到答案。

A*演算法還滿讓我意外的，本來以為要做很久，沒想到加了一些東西就能有不錯的結果了，也因為每次的下一步都是從可能的步數裡挑blocking value最小的，因而

跳過很多會增加blocking value的動作(雖然也可能會跳過答案)，不過這樣的演算法確實有發揮效果。

一開始要做作業時，本來覺得很麻煩，有五種演算法，加上之前學過的BFS、DFS和資料結構都還得差不多了，不過實際做了之後發現好像沒有那麼複雜，也學到了一些python的資料結構用法。另外我有把題目和解法轉換成圖形的形式，以第一題的答案為例，如下所示。

(一開始的puzzle)

```
1 1 _ _ _ 7
4 _ _ 6 _ 7
4 0 0 6 _ 7
4 _ _ 6 _ _
5 _ _ _ 2 2
5 _ 3 3 3 _
```

< 2, 4, 4 > ==> < 2, 4, 1 >(代表該編號的車2，(超過10就用16進位ABC)從左邊的位置移到右邊(4,4→4,1))
然後印出下一個puzzle，之後以此類推

```
1 1 _ _ _ 7
4 _ _ 6 _ 7
4 0 0 6 _ 7
4 _ _ 6 _ _
5 2 2 _ _ _
5 _ 3 3 3 _
```

< 7, 0, 5 > ==> < 7, 3, 5 >

```
1 1 _ _ _ _
4 _ _ 6 _ _
4 0 0 6 _ _
4 _ _ 6 _ 7
5 2 2 _ _ 7
5 _ 3 3 3 7
```

< 1, 0, 0 > ==> < 1, 0, 4 >

```
_ _ _ _ 1 1
4 _ _ 6 _ _
4 0 0 6 _ _
4 _ _ 6 _ 7
5 2 2 _ _ 7
5 _ 3 3 3 7
```

< 4, 1, 0 > ==> < 4, 0, 0 >

```
4 _ _ _ 1 1
4 _ _ 6 _ _
4 0 0 6 _ _
_ _ _ 6 _ 7
5 2 2 _ _ 7
5 _ 3 3 3 7
```

< 5, 4, 0 > ==> < 5, 3, 0 >

```
4 _ _ _ 1 1
4 _ _ 6 _ _
4 0 0 6 _ _
5 _ _ 6 _ 7
5 2 2 _ _ 7
_ _ 3 3 3 7

< 3, 5, 2 > ==> < 3, 5, 0 >

4 _ _ _ 1 1
4 _ _ 6 _ _
4 0 0 6 _ _
5 _ _ 6 _ 7
5 2 2 _ _ 7
3 3 3 _ _ 7

< 6, 1, 3 > ==> < 6, 3, 3 >

4 _ _ _ 1 1
4 _ _ _ _ _
4 0 0 _ _ _
5 _ _ 6 _ 7
5 2 2 6 _ 7
3 3 3 6 _ 7

< 0, 2, 1 > ==> < 0, 2, 4 >

4 _ _ _ 1 1
4 _ _ _ _ _
4 _ _ _ 0 0
5 _ _ 6 _ 7
5 2 2 6 _ 7
3 3 3 6 _ 7

Algorithm: A*
Puzzle completed in 8 moves.
Number of nodes visited in search: 506
time: 0:00:03.476703
```

雖然說把 puzzle 的圖形印出來在驗證答案時比較清楚也比較能接受，但也花了不少時間，但總體來說還是滿值得的，畢竟感覺踏實了不少。

說到 remaining questions，應該是 heuristic 的方法應該不止這一種吧，還有老師提到的自己生產題目,目前我只有想法,就是先隨便產生一個小紅在(2, 4)上的 puzzle，把這個狀態當成是最後的答案,然後用上面那五種方法,看看能不能讓小紅走回(2,0)或(2,1)，如果可以，那可能就是一個好題目，不行就再試一組，簡而言之，就是先產生答案，再倒回去變成題目。

附錄

Code

compile 方式：python test.py 1 prog1_puzzle/L01.txt (1-5 代表五種演算法)

程式有放在 github
https://github.com/tim310579/Artificial-Intelligence/tree/main/HW1

test.py(主程式)

```
from Puzzles import *
from Algos import *
from sys import argv
import datetime
import psutil
import os


begin = datetime.datetime.now()

useless, algo, filename = argv
#print(algo, filename)
f = open(filename, 'r')
k = f.readlines()
#for lines in k:
	#print(lines)

tmp = []
for lines in k:
	words = lines.split(' ')
	#print(words[3])
	ori = Orientations.vertical
	length = VehicleTypes.car
	words[4] = words[4][0]
	if words[4] == '1': ori = Orientations.horizontal
	if words[3] == '3': length = VehicleTypes.truck
	tmp.append(Vehicle((int(words[2]), int(words[1])), ori, length, words[0]))
	#print(words[2], words[1], words[4], words[3])


trafficJamtmp = Puzzles(6, 6, 2, tmp)
f.close()

#print(trafficJamtmp)
def printSolution(puzzle, solution):
    for m in solution:
        print(puzzle)
        print(m)
        puzzle.move(m.pos, m.moves)
    print(puzzle)



# Create AI agent and run on specified puzzles
agent = Algos()


solution = ''
if algo == '1':
        solution = agent.bfs(trafficJamtmp)
        #print('BFS')
elif algo == '2':
        solution = agent.dfs(trafficJamtmp)
        #print('DFS')
elif algo == '3':
        solution = agent.ids(trafficJamtmp)
        #print('IDS')
elif algo == '4':
        solution = agent.a_star(trafficJamtmp)
        #print('A*')
elif algo == '5':
        solution = agent.ida_star(trafficJamtmp)
        #print('IDA*')
#solution = agent2.dfs(trafficJamtmp)
printSolution(trafficJamtmp, solution)
print('Algorithm: ', end='')
if algo == '1': print('BFS')
elif algo == '2': print('DFS')
elif algo == '3': print('IDS')
elif algo == '4': print('A*')
elif algo == '5': print('IDA*')

print("Puzzle completed in " + str(len(solution)) + " moves.")
print("Number of nodes visited in search:     " + str(agent.nodesVisited))
#print("Space: " + str(agent.space))
end = datetime.datetime.now()
print('Time: ', end-begin)

#info = psutil.virtual_memory()
```

```
#f = open('result/statistic.txt', 'a')
#f.write(str(len(solution)) + ' ' + str(agent.nodesVisited) + ' ' + str(end-begin) + '\n')
#f.close()
```

Algos.py(演算法部分)

```
from Puzzles import *
from collections import deque
import copy
from queue import PriorityQueue
class Algos:

    def __init__(self):
        self.nodesVisited = 0
        self.space = 0

    def bfs(self, puzzle):

        bfsQueue = deque([])
        self.nodesVisited = 0
        self.space = 0
        # The current node/state
        current = BfsNode(puzzle, [])

        seenPuzzleStates = {}
        seenPuzzleStates[str(current.puzzle.getGrid())] = True;

        while not current.puzzle.won():
            self.nodesVisited += 1

            for m in current.getPossibleMoves():

                # Duplicate puzzle state and perform a move
                newState = copy.deepcopy(current)
                newState.puzzle.move(m.pos, m.moves)
                self.space += 1
                # If new state is unseen, add to queue and seen states list
                if ((not str(newState.puzzle) in seenPuzzleStates) or
seenPuzzleStates[str(newState.puzzle)] > len(newState.movesSoFar)):
                    bfsQueue.append(BfsNode(newState.puzzle,
current.movesSoFar + [m]))
                    seenPuzzleStates[str(newState.puzzle)] = True;
            current = bfsQueue.popleft()

        return current.movesSoFar
    def dfs(self, puzzle):

        # □Queue to hold untraversed nodes
        dfsQueue = deque([])
        self.nodesVisited = 0

        # The current node/state
        current = DfsNode(puzzle, [])

        seenPuzzleStates = {}
        seenPuzzleStates[str(current.puzzle.getGrid())] = True;

        while not current.puzzle.won():
            self.nodesVisited += 1

            for m in current.getPossibleMoves():

                # Duplicate puzzle state and perform a move
                newState = copy.deepcopy(current)
                newState.puzzle.move(m.pos, m.moves)

                # If new state is unseen, add to queue and seen states list
                if ((not str(newState.puzzle) in seenPuzzleStates) or
seenPuzzleStates[str(newState.puzzle)] > len(newState.movesSoFar)):
                    dfsQueue.append(DfsNode(newState.puzzle,
current.movesSoFar + [m]))
                    seenPuzzleStates[str(newState.puzzle)] = True;
            current = dfsQueue.pop()

        return current.movesSoFar
    def ids(self, puzzle):

        cnt = 0
        idsQueue = PriorityQueue()
        self.nodesVisited = 0
        self.space = 0
        # The current node/state
        current = IdsNode(puzzle, [], 0)
        seenPuzzleStates = {}
        seenPuzzleStates[str(current.puzzle.getGrid())] = True
        #print(type(current))
        while not (current.puzzle.won()):
                        if 1 == 1:
                                self.nodesVisited += 1

                                for m in current.getPossibleMoves():
                                        cnt += 1
                                        #print('iiii')
                                        # Duplicate puzzle state and perform a
move
                                        newState = copy.deepcopy(current)
                                        newState.puzzle.move(m.pos,
m.moves)
                                        self.space += 1
                                        # If new state is unseen, add to queue
and seen states list
                                        if ((not str(newState.puzzle) in
seenPuzzleStates) or seenPuzzleStates[str(newState.puzzle)] >
len(newState.movesSoFar)):

#idsQueue.append(IdsNode(current.thedeep+1, newState.puzzle, current.movesSoFar +
[m]))

idsQueue.put((current.thedeep+1, cnt, IdsNode(newState.puzzle, current.movesSoFar +
[m], current.thedeep+1)))

seenPuzzleStates[str(newState.puzzle)] = True;
                                                #deep += 1
                                #current = idsQueue.popleft()
                                tmp = idsQueue.get()
                                current = tmp[2]
                                #print(tmp[0])
        return current.movesSoFar

    def a_star(self, puzzle):

        # □Queue to hold untraversed nodes
        a_starQueue = PriorityQueue()
        self.nodesVisited = 0
        self.space = 0
        # The current node/state
        current = A_starNode(puzzle, [], 0)

        seenPuzzleStates = {}
        seenPuzzleStates[str(current.puzzle.getGrid())] = True;
        cnt = 0
        while not(current.puzzle.won()):
            #print(current.blocking)
            self.nodesVisited += 1

            for m in current.getPossibleMoves():
                cnt += 1
                # Duplicate puzzle state and perform a move
                newState = copy.deepcopy(current)
                newState.puzzle.move(m.pos, m.moves)
                self.space += 1
                # If new state is unseen, add to queue and seen states list
                if ((not str(newState.puzzle) in seenPuzzleStates) or
seenPuzzleStates[str(newState.puzzle)] > len(newState.movesSoFar)):
                    #a_starQueue.append(A_starNode(newState.puzzle,
current.movesSoFar + [m], 0))
                    a_starQueue.put((current.blocking, cnt,
A_starNode(newState.puzzle, current.movesSoFar + [m], current.getblocking())))
                    seenPuzzleStates[str(newState.puzzle)] = True;
            #current = a_starQueue.popleft()
            tmp = a_starQueue.get()
            current = tmp[2]
        return current.movesSoFar
    def ida_star(self, puzzle):

        ida_starQueue = PriorityQueue()
        self.nodesVisited = 0
        self.space = 0
        # The current node/state
        current = IDA_starNode(puzzle, [], 0, 0)

        seenPuzzleStates = {}
        seenPuzzleStates[str(current.puzzle.getGrid())] = True;
        cnt = 0
        while not(current.puzzle.won()):
            #print(current.blocking)
            self.nodesVisited += 1

            for m in current.getPossibleMoves():
                cnt += 1
                # Duplicate puzzle state and perform a move
                newState = copy.deepcopy(current)
                newState.puzzle.move(m.pos, m.moves)
                self.space += 1
                # If new state is unseen, add to queue and seen states list
                if ((not str(newState.puzzle) in seenPuzzleStates) or
seenPuzzleStates[str(newState.puzzle)] > len(newState.movesSoFar)):
                    #a_starQueue.append(A_starNode(newState.puzzle,
current.movesSoFar + [m], 0))
                    ida_starQueue.put((current.thedeep, current.blocking, cnt,
IDA_starNode(newState.puzzle, current.movesSoFar + [m], current.getblocking(),
current.thedeep+1)))
                    seenPuzzleStates[str(newState.puzzle)] = True;
            #current = a_starQueue.popleft()
            tmp = ida_starQueue.get()
            current = tmp[3]
        return current.movesSoFar

class BfsNode:
    def __init__(self, puzzle, movesSoFar):
        self.puzzle = puzzle
        self.movesSoFar = movesSoFar

    def getPossibleMoves(self):
        results = []
        current = self.puzzle
        for v in current.vehicles:
            for i in current.moveRange(v):
                #print('v:',v,'v')
                # Don't move if move length is 0
                if not i == 0:
                        results += [Move(v.pos, i, v.orientation, v.number)]
        #print(results)
        return results

class DfsNode:
    def __init__(self, puzzle, movesSoFar):
        self.puzzle = puzzle
        self.movesSoFar = movesSoFar

    def getPossibleMoves(self):
        results = []
        current = self.puzzle
        for v in current.vehicles:
            for i in current.moveRange(v):
                #print('v:',v,'v')
                # Don't move if move length is 0
                if not i == 0:
                        results += [Move(v.pos, i, v.orientation, v.number)]
        #print(results)
        return results

class IdsNode:
    def __init__(self, puzzle, movesSoFar, thedeep):
        self.puzzle = puzzle
        self.movesSoFar = movesSoFar
        self.thedeep = thedeep

    def getPossibleMoves(self):
        results = []
        current = self.puzzle
        for v in current.vehicles:
            for i in current.moveRange(v):
                #print('v:',v,'v')
                # Don't move if move length is 0
                if not i == 0:
                        results += [Move(v.pos, i, v.orientation, v.number)]
        #print(results)
        return results

class A_starNode:
    def __init__(self, puzzle, movesSoFar, blocking):
        self.puzzle = puzzle
        self.movesSoFar = movesSoFar
        self.blocking = blocking

    def getPossibleMoves(self):
        results = []
        current = self.puzzle
        for v in current.vehicles:
            for i in current.moveRange(v):
                #print('v:',v,'v')
                # Don't move if move length is 0
                if not i == 0:
                        results += [Move(v.pos, i, v.orientation, v.number)]
        #print(results)
        return results
    def getblocking(self):
                current = self.puzzle
                blockingcars = 0
                red_car_pos = 0
                for v in current.vehicles:          #find red car
```

```
                        if v.number == '0':
                                if v.pos[0] == 4:
                                        return 0
                                else:
                                        red_car_pos = v.pos[0]
                                break
                blockingcars = 1
                for v in current.vehicles:
                        if v.orientation == Orientations.vertical and v.pos[0] >
red_car_pos:    #may block
                                if v.vType == VehicleTypes.car and (v.pos[1] == 1
or v.pos[1] == 2):      #is block
                                        blockingcars +=1
                                elif v.vType == VehicleTypes.truck and (v.pos[1]
>= 0 and v.pos[1] <=2):      #is block
                                        blockingcars +=1
                return blockingcars

class IDA_starNode:
    """Represents a single state of the BFS
    Attributes:
        puzzle (JamPuzzle):   the puzzle state this node represents
        movesSoFar (Move[]):   array of moves taken to get to the current
                state.   Holds the solution at the end, since BFs itself
                doesn't track moves so far for each state.
    getPossibleMoves(self): retrieves list of all valid moves from this
            node's state
    """

    def __init__(self, puzzle, movesSoFar, blocking, thedeep):
        """Constructor takes a puzzle state and list of moves taken
        so far to get there.
        """
        self.puzzle = puzzle
        self.movesSoFar = movesSoFar
        self.blocking = blocking
        self.thedeep = thedeep

    def getPossibleMoves(self):
        """Find the □moveRange() of each vehicle in puzzle state and
        adds every □move (except 0 moves) in the range for each vehicle
        to a result list of Move objects
        Return:
            Move[]: □the array of all valid moves for this node's state
        """
        results = []
        current = self.puzzle
        for v in current.vehicles:
            for i in current.moveRange(v):
                #print('v:',v,'v')
                # Don't move if move length is 0
                if not i == 0:
                        results += [Move(v.pos, i, v.orientation, v.number)]
        #print(results)
        return results
    def getblocking(self):
                current = self.puzzle
                blockingcars = 0
                red_car_pos = 0
                for v in current.vehicles:          #find red car
                        if v.number == '0':
                                if v.pos[0] == 4:
                                        return 0
                                else:
                                        red_car_pos = v.pos[0]
                                break
                blockingcars = 1
                for v in current.vehicles:
                        if v.orientation == Orientations.vertical and v.pos[0] >
red_car_pos:     #may block
                                if v.vType == VehicleTypes.car and (v.pos[1] == 1
or v.pos[1] == 2):       #is block
                                        blockingcars +=1
                                elif v.vType == VehicleTypes.truck and (v.pos[1]
>= 0 and v.pos[1] <=2):       #is block
                                        blockingcars +=1
                return blockingcars
class Move:
    def __init__(self, pos, moves, orientation, number):
        self.pos = pos;
        self.moves = moves;
        self.orientation = orientation;
        self.number = number;

    def __str__(self):
        #print(self.orientation, self.number)
        #return "Move car at ("+str(self.pos[1])+','+str(self.pos[0])+") by
"+str(self.moves)+" to ("+str(self.pos[1])+','+str(self.pos[0])+")"
```

```
                action = "< " + self.number + ", " + str(self.pos[1]) + ", " +
str(self.pos[0]) + " >"
                if self.orientation == Orientations.horizontal:
                        return action + " ==> < " + self.number + ", " +
str(self.pos[1]) + ", " + str(self.pos[0]+self.moves) + " >"
                else:
                        return action + " ==> < " + self.number + ", " +
str(self.pos[1]+self.moves) + ", " + str(self.pos[0]) + " >"
```

Puzzles.py(圖形部分)

```
from enum import Enum, IntEnum

class VehicleTypes(IntEnum):
    car = 2
    truck = 3
class Orientations(IntEnum):
    horizontal = 0
    vertical = 1
#class Number(IntEnum):


class Puzzles:
    def __init__(self, gridSizeX, gridSizeY, doorPos, vehicles):
        self.gridSizeY = gridSizeY
        self.gridSizeX = gridSizeX
        self.doorPos = doorPos
        self.vehicles = vehicles

    def getSizeTuple(self):
        """Returns grid sizes as an (x, y) tuple
        Return:
            (int, int):    tuple representing (width, height) of □puzzle grid
        """
        return (self.gridSizeX, self.gridSizeY)

    def getGrid(self):

        #symbol = ord('A')
        symbol = ord('1')
        grid = [["_" for y in range(self.gridSizeY)] for x in range(self.gridSizeX)]
        for v in self.vehicles:
            # iterate through each vehicle, assigning it a □symbol and replacing its
            # covered locations with that symbol in the grid
            tempSymbol = chr(symbol)

            if v.pos[1] == self.doorPos and v.orientation == Orientations.horizontal:
                #print(v.pos[1])
                tempSymbol = '0'
            else:
                symbol += 1
            if symbol == 58: symbol += 7
            locs = v.coveredUnits()
            #print(locs)
            for l in locs:
                #print(l,"lll")
                grid[l[0]][l[1]] = tempSymbol
        return grid


    def move(self, pos, moves):
        """Wrapper for moveVehicle()
        Args:
            pos ((int, int)):    position of vehicle to move (x, y)
            moves (int):    number of moves to move vehicle
        """
        v = self.getVehicleAt(pos)
        if v == None:
            raise Exception("Can't move vehicle; not found", pos)
        self.moveVehicle(v, moves)


    def moveVehicle(self, veh, moves):
        orient = veh.orientation
        newPosList = list(veh.pos)
        newPosList[orient] += moves
        veh.pos = tuple(newPosList)


    def moveRange(self, veh):
        minMove = 0
        # □iterate over spaces behind to □check
        for i in range(-1, -veh.pos[veh.orientation]-1, -1):

            # Only way to change a value in a tuple by index :/
            newPosList = list(veh.pos)
            newPosList[veh.orientation] += i
```

```
            newPosTuple = tuple(newPosList)

            blocked = False
            for v in self.vehicles:
                if newPosTuple in v.coveredUnits():
                    blocked = True
                    break
            if blocked:
                break
            else:
                minMove = i

        maxMove = 0
        # iterate over spaces ahead to check, not □pos of vehicle.    □Accounts for
length of vehicle
        for j in range(veh.vType,
self.getSizeTuple()[veh.orientation]-veh.pos[veh.orientation]):
            # j is # of spaces ahead of vehicle position to check!
            # not position to check, or # of moves
            newPosList = list(veh.pos)
            newPosList[veh.orientation]+=j
            newPosTuple = tuple(newPosList)

            blocked = False
            for v in self.vehicles:
                if newPosTuple in v.coveredUnits():
                    blocked = True
                    break
            if blocked:
                break
            else:
                maxMove = j - veh.vType + 1

        return range(minMove, maxMove+1)


    def getVehicleAt(self, pos):
        for v in self.vehicles:
            if v.pos == pos:
                return v
        return None

    def won(self):
        v = self.getVehicleAt((4, self.doorPos))
        #print('haha:', v,'over')
        if v != None and v.orientation == Orientations.horizontal:
            return True
        return False

    def __str__(self):
        result = "    " * self.doorPos + " " + "    " * (self.gridSizeX - self.doorPos - 1) +
"\n"
        grid = self.getGrid()
        result += "\n".join([" ".join([grid[x][y] for x in range(self.gridSizeX)]) for y in
range(self.gridSizeY)]) + "\n"
        return result

    def __eq__(self, b):
        return self.getGrid() == b.getGrid()


class Vehicle:

    def __init__(self, pos, orientation, vType, number):
        self.pos = pos
        self.orientation = orientation
        self.vType = vType
        self.number = number

    def coveredUnits(self):

        if self.orientation == Orientations.vertical:
            result = [(self.pos[0], self.pos[1] + i) for i in range(int(self.vType))]
        if self.orientation == Orientations.horizontal:
            result = [(self.pos[0] + i, self.pos[1]) for i in range(int(self.vType))]
        return result

    def __str__(self):
        orientTxt = "Horizontal" if self.orientation == Orientations.horizontal else
"Vertical"
        vehTxt = "Car" if self.vType == VehicleTypes.car else "Truck"
        positions = str(self.coveredUnits())
        return orientTxt + " " + vehTxt + " at (" + str(self.pos[0]) + "," + str(self.pos[1]) +
") covering " + positions
```