Sardar Vallabhbhai National Institute of Technology

CS 210 : ARTIFICIAL INTELLIGENCE

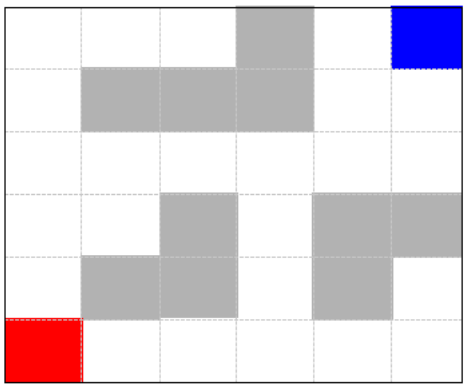
LAB 4-5: Uninformed and Informed Search Techniques

INSTRUCTION:
1. Please save your lab.doc as *LAB_No_Roll_No.doc*.
2. Use/paste the snapshot of the steps followed along with result/s.
3. Mention your observation/comment after results in the doc.
4. Any violation from the Academic honesty /course policies, will results in the strongest consequences available to us.

PART A : Introductory Problem [25 Marks]

Maze Problem [15 Marks]

1. Consider a maze comprising of square blocks in which intelligent agent can move either vertically or horizontally. Diagonal movement is not allowed. Cost of each move is 1.



Red block: initial position, **Blue block:** goal position and **Grey block:** obstacle

Apply following Blind/Uninformed and Informed algorithms :
(a) dfs: Depth first search
(b) bfs: Breadth first search
(c) dls: Depth limited search, use 3 as default depth
(d) ucs: Uniform cost Search
(e) gbfs: Greedy Best First Search
(f) astar: A* Algorithm

Inputs:
Write a python program that takes input number of square blocks as input (i.e. 6 x 6) in first line. Second line contains the initial position of intelligent agent which is (1,1) and the goal square block which is (6,6) in above example. Third line contains the coordinates of the obstacles. Fourth line contains the search strategy.

eg. input file: input.txt
6,6

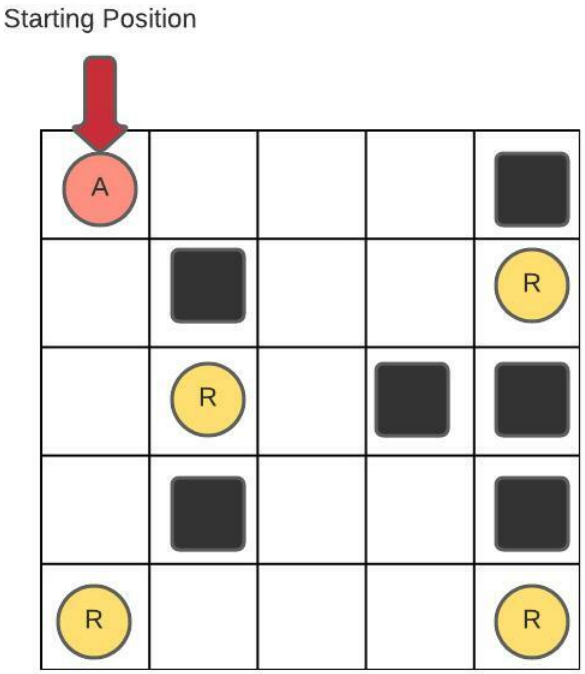
1,1;6,6
2,1;2,5;3,2;3,3;3,5;4,5;4,6;5,2;5,3;6,3
dfs

python TA_4_5_P2_maze_world.py “input$_2$.*txt*]1*output*$_2$.*txt*]

Outputs: Sequence of blocks that are explored (each on separate line) as per search algorithm so as to reach goal position. Last line should contain the total search cost.

2. **Maze problem with multi-goal [10 Marks]**

Consider the maze given in the figure below. The walled tiles are marked in black and your agent A cannot move to or through those positions.



Inputs:
Write python/C program that takes the maze as a 5x5 matrix input where 0 denotes an empty tile, 1 denotes an obstruction/wall, 2 denotes the start state and 3 denotes the reward. Assume valid actions as L,R,U,D,S,N where L=move_left, R=move_right, U=move_up, D=move_down.

Use the **A* algorithms as (astar)** on the resultant maze for your agent to reach all the rewards, and keep a record of the tiles visited on the way.

Hints:

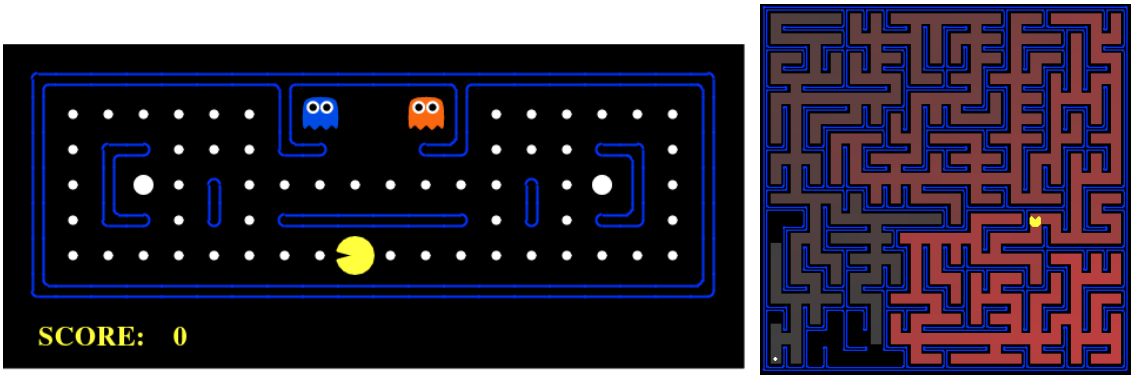
a) Your program should create the appropriate data structure that can capture problem states, as mentioned in the problem.
b) Once the goal is reached (i.e. Reward position), program should terminate.

Outputs: The output should have the sequence of the tiles visited by each algorithm to reach the termination state stored in an output file labeled as "out_astar.txt" and so on. Print the number of steps required to reach the goal.

PART B : Exploratory Problem [25 Marks]

3. **Search in Pac-Man** This problem allow you to visualize the results of the techniques you implement. Pac-Man provides a challenging problem environment that demands creative solutions of a real-world AI problems. The Pacman agent needs to find paths through the maze world, both to reach a location and to collect food efficiently. In this Problem, you are expected to implement and experiment with different AI search techniques that was discussed in the class in a Pacman environment.

   This lab assignment is inspired by Project 1: Search, which is a part of a recent offering of CS188 at UC Berkeley[1]. We thank the authors at Berkeley for making their project available to the public.



Aim: Students implement depth-first, breadth-first, uniform cost, and A* search algorithms. These algorithms are used to solve navigation and traveling salesman problems in the Pacman world.

The code for this assignment is provided to you as LA_4_5_search zip folder. You can download all the code and supporting files as a Folder/ zip archive from the shared link. The code for this project consists of several Python files, some of which you will need to read and understand in order to complete the assignment, and some of which you can ignore.

Assumption : The projects for this class assume you use Python 3.6.

Files you'll edit:

`search.py` : Where all of your search algorithms will reside.

`searchAgents.py` : Where all of your search-based agents will reside.

Files you might want to look at:

`pacman.py` The main file that runs Pacman games. This file describes a Pacman GameState type, which you use in this project.

`game.py` The logic behind how the Pacman world works. This file describes several supporting types like AgentState, Agent, Direction, and Grid.

`util.py` Useful data structures for implementing search algorithms.

Supporting files you can ignore:

`graphicsDisplay.py`	Graphics for Pacman
`graphicsUtils.py`	Support for Pacman graphics
`textDisplay.py`	ASCII graphics for Pacman

`ghostAgents.py`	Agents to control ghosts
`keyboardAgents.py`	Keyboard interfaces to control Pacman
`layout.py`	Code for reading layout files and storing their contents
`autograder.py`	Project autograder
`testParser.py`	Parses autograder test and solution files
`testClasses.py`	General autograding test classes
`test_cases/`	Directory containing the test cases for each question
`searchTestClasses.py`	Project 1 specific autograding test classes

Files to Edit and Submit: You will fill in portions of `search.py` and `searchAgents.py` during the assignment. Once you have completed the assignment, you will submit a token generated by `submission_autograder.py`. Please *do not* change the other files in this distribution or submit any of our original files other than these files.

Welcome to Pacman

TASK 0: Understanding the Working of Pacman Game (Ungraded)

After downloading the code from the shared link, unzipping it, and changing to the directory, you should be able to :

TASK 0: Play the game of Pacman by typing the following at the command line:

```
python pacman.py
```

Pacman lives in a shiny blue world of twisting corridors and tasty round treats. Navigating this world efficiently will be Pacman's first step in mastering his domain.

The simplest agent in `searchAgents.py` is called the `GoWestAgent`, which always goes West (a trivial reflex agent). This agent can occasionally win:

```
python pacman.py --layout testMaze --pacman GoWestAgent
```

But, things get ugly for this agent when turning is required:

```
python pacman.py --layout tinyMaze --pacman GoWestAgent
```

If Pacman gets stuck, you can exit the game by typing CTRL-c into your terminal.

Soon, your agent will solve not only `tinyMaze`, but any maze you want.

Note that `pacman.py` supports a number of options that can each be expressed in a long way (e.g., `--layout`) or a short way (e.g., `-l`). You can see the list of all options and their default values via:

```
python pacman.py -h
```

Also, all of the commands that appear in this project also appear in `commands.txt`, for easy copying and pasting. In UNIX/Mac OS X, you can even run all these commands in order with `bash commands.txt`.

Question 4.1 (3 points) : Finding a Fixed Food Dot using Depth First Search

In `searchAgents.py`, you'll find a fully implemented `SearchAgent`, which plans out a path through Pacman's world and then executes that path step-by-step. The search algorithms for formulating a plan are not implemented – that's your job.

First, test that the `SearchAgent` is working correctly by running:

```
python pacman.py -l tinyMaze -p SearchAgent -a fn=tinyMazeSearch
```

The command above tells the `SearchAgent` to use `tinyMazeSearch` as its search algorithm, which is implemented in `search.py`. Pacman should navigate the maze successfully.

Now it's time to write full-fledged generic search functions to help Pacman plan routes! Pseudocode for the search algorithms you'll write can be found in the lecture slides. Remember that a search node must contain not only a state but also the information necessary to reconstruct the path (plan) which gets to that state.

Important note: All of your search functions need to return a list of *actions* that will lead the agent from the start to the goal. These actions all have to be legal moves (valid directions, no moving through walls).

Important note: Make sure to **use** the `Stack`, `Queue` and `PriorityQueue` data structures provided to you in `util.py`! These data structure implementations have particular properties which are required for compatibility with the autograder.

Hint: Each algorithm is very similar. Algorithms for DFS, BFS, UCS, and A* differ only in the details of how the fringe is managed. So, concentrate on getting DFS right and the rest should be relatively straightforward. Indeed, one possible implementation requires only a single generic search method which is configured with an algorithm-specific queuing strategy. (Your implementation need *not* be of this form to receive full credit).

Implement the depth-first search (DFS) algorithm in the `depthFirstSearch` function in `search.py`. To make your algorithm *complete*, write the graph search version of DFS, which avoids expanding any already visited states.

Your code should quickly find a solution for:

```
python pacman.py -l tinyMaze -p SearchAgent

python pacman.py -l mediumMaze -p SearchAgent

python pacman.py -l bigMaze -z .5 -p SearchAgent
```

The Pacman board will show an overlay of the states explored, and the order in which they were explored (brighter red means earlier exploration). Is the exploration order what you would have expected? Does Pacman actually go to all the explored squares on his way to the goal?

Hint: If you use a `Stack` as your data structure, the solution found by your DFS algorithm for `mediumMaze` should have a length of 130 (provided you push successors onto the fringe in the order provided by getSuccessors; you might get 246 if you push them in the reverse order). Is this a least cost solution? If not, think about what depth-first search is doing wrong.

Question 4.2 (3 points): Breadth First Search

Implement the breadth-first search (BFS) algorithm in the `breadthFirstSearch` function in `search.py`. Again, write a graph search algorithm that avoids expanding any already visited states. Test your code the same way you did for depth-first search.

```
python pacman.py -l mediumMaze -p SearchAgent -a fn=bfs

python pacman.py -l bigMaze -p SearchAgent -a fn=bfs -z .5
```

Does BFS find a least cost solution? If not, check your implementation.

Hint: If Pacman moves too slowly for you, try the option `--frameTime 0`.

Note: If you've written your search code generically, your code should work equally well for the eight-puzzle search problem without any changes.

```
python eightpuzzle.py
```

Question 4.3 (3 points): Varying the Cost Function

While BFS will find a fewest-actions path to the goal, we might want to find paths that are "best" in other senses. Consider `mediumDottedMaze` and `mediumScaryMaze`.

By changing the cost function, we can encourage Pacman to find different paths. For example, we can charge more for dangerous steps in ghost-ridden areas or less for steps in food-rich areas, and a rational Pacman agent should adjust its behavior in response.

Implement the uniform-cost graph search algorithm in the `uniformCostSearch` function in `search.py`. We encourage you to look through `util.py` for some data structures that may be useful in your implementation. You should now observe successful behavior in all three of the following layouts, where the agents below are all UCS agents that differ only in the cost function they use (the agents and cost functions are written for you):

```
python pacman.py -l mediumMaze -p SearchAgent -a fn=ucs

python pacman.py -l mediumDottedMaze -p StayEastSearchAgent

python pacman.py -l mediumScaryMaze -p StayWestSearchAgent
```

Note: You should get very low and very high path costs for the `StayEastSearchAgent` and `StayWestSearchAgent` respectively, due to their exponential cost functions (see `searchAgents.py` for details).

Question 4.4 (3 points): A* search

Implement A* graph search in the empty function `aStarSearch` in `search.py`. A* takes a heuristic function as an argument. Heuristics take two arguments: a state in the search problem (the main argument), and the problem itself (for reference information). The `nullHeuristic` heuristic function in `search.py` is a trivial example.

You can test your A* implementation on the original problem of finding a path through a maze to a fixed position using the Manhattan distance heuristic (implemented already as `manhattanHeuristic` in `searchAgents.py`).

```
python pacman.py -l bigMaze -z .5 -p SearchAgent -a fn=astar,heuristic=manhattanHeuristic
```

You should see that A* finds the optimal solution slightly faster than uniform cost search (about 549 vs. 620 search nodes expanded in our implementation, but ties in priority may make your numbers differ slightly). What happens on `openMaze` for the various search strategies?

Question 4.5 (3 points): Finding All the Corners

The real power of A* will only be apparent with a more challenging search problem. Now, it's time to formulate a new problem and design a heuristic for it.

In *corner mazes*, there are four dots, one in each corner. Our new search problem is to find the shortest path through the maze that touches all four corners (whether the maze actually has food there or not). Note that for some mazes like `tinyCorners`, the shortest path does not always go to the closest food first! *Hint*: the shortest path through `tinyCorners` takes 28 steps.

Note: Make sure to complete Question 2 before working on Question 5, because Question 5 builds upon your answer for Question 2.

Implement the `CornersProblem` search problem in `searchAgents.py`. You will need to choose a state representation that encodes all the information necessary to detect whether all four corners have been reached. Now, your search agent should solve:

```
python pacman.py -l tinyCorners -p SearchAgent -a fn=bfs,prob=CornersProblem
```

```
python pacman.py -l mediumCorners -p SearchAgent -a fn=bfs,prob=CornersProblem
```

To receive full credit, you need to define an abstract state representation that *does not* encode irrelevant information (like the position of ghosts, where extra food is, etc.). In particular, do not use a Pacman `GameState` as a search state. Your code will be very, very slow if you do (and also wrong).

Hint: The only parts of the game state you need to reference in your implementation are the starting Pacman position and the location of the four corners.

Our implementation of `breadthFirstSearch` expands just under 2000 search nodes on `mediumCorners`. However, heuristics (used with A* search) can reduce the amount of searching required.

Question 4.6 (3 points): Corners Problem: Heuristic

Note: Make sure to complete Question 4 before working on Question 6, because Question 6 builds upon your answer for Question 4.

Implement a non-trivial, consistent heuristic for the `CornersProblem` in `cornersHeuristic`.

```
python pacman.py -l mediumCorners -p AStarCornersAgent -z 0.5
```

Note: `AStarCornersAgent` is a shortcut for

```
-p SearchAgent -a fn=aStarSearch,prob=CornersProblem,heuristic=cornersHeuristic
```

Admissibility vs. Consistency: Remember, heuristics are just functions that take search states and return numbers that estimate the cost to a nearest goal. More effective heuristics will return values closer to the actual goal costs. To be *admissible*, the heuristic values must be lower bounds on the actual shortest path cost to the nearest goal (and non-negative). To be *consistent*, it must additionally hold that if an action has cost c, then taking that action can only cause a drop in heuristic of at most c.

Remember that admissibility isn't enough to guarantee correctness in graph search – you need the stronger condition of consistency. However, admissible heuristics are usually also consistent, especially if they are derived from problem relaxations. Therefore it is usually easiest to start out by brainstorming admissible heuristics. Once you have an admissible heuristic that works well, you can check whether it is indeed consistent, too. The only way to guarantee consistency is with a proof. However, inconsistency can often be detected by verifying that for each node you expand, its successor nodes are equal or higher in in f-value. Moreover, if UCS and A* ever return paths of different lengths, your heuristic is inconsistent. This stuff is tricky!

Non-Trivial Heuristics: The trivial heuristics are the ones that return zero everywhere (UCS) and the heuristic which computes the true completion cost. The former won't save you any time, while the latter will timeout the autograder. You want a heuristic which reduces total compute time, though for this assignment the autograder will only check node counts (aside from enforcing a reasonable time limit).

Grading: Your heuristic must be a non-trivial non-negative consistent heuristic to receive any points. Make sure that your heuristic returns 0 at every goal state and never returns a negative value. Depending on how few nodes your heuristic expands, you'll be graded:

Number of nodes expanded	Grade
More than 2000	0/3
At most 2000	1/3
At most 1600	2/3
At most 1200	3/3

Remember: If your heuristic is inconsistent, you will receive *no* credit, so be careful!

Question 4.7 (4 points): Eating All The Dots

Now we'll solve a hard search problem: eating all the Pacman food in as few steps as possible. For this, we'll need a new search problem definition which formalizes the food-clearing problem: `FoodSearchProblem` in `searchAgents.py` (implemented for you). A solution is defined to be a path that collects all of the food in the Pacman world. For the present project, solutions do not take into account any ghosts or power pellets; solutions only depend on the placement of walls, regular food and Pacman. (Of course ghosts can ruin the execution of a solution! We'll get to that in the next project.) If you have written your general search methods correctly, `A*` with a null heuristic (equivalent to uniform-cost search) should quickly find an optimal solution to `testSearch` with no code change on your part (total cost of 7).

```
python pacman.py -l testSearch -p AStarFoodSearchAgent
```

Note: `AStarFoodSearchAgent` is a shortcut for

```
-p SearchAgent -a fn=astar,prob=FoodSearchProblem,heuristic=foodHeuristic
```

You should find that UCS starts to slow down even for the seemingly simple `tinySearch`. As a reference, our implementation takes 2.5 seconds to find a path of length 27 after expanding 5057 search nodes.

Note: Make sure to complete Question 4 before working on Question 7, because Question 7 builds upon your answer for Question 4.

Fill in `foodHeuristic` in `searchAgents.py` with a *consistent* heuristic for the `FoodSearchProblem`. Try your agent on the `trickySearch` board:

```
python pacman.py -l trickySearch -p AStarFoodSearchAgent
```

Our UCS agent finds the optimal solution in about 13 seconds, exploring over 16,000 nodes.

Any non-trivial non-negative consistent heuristic will receive 1 point. Make sure that your heuristic returns 0 at every goal state and never returns a negative value. Depending on how few nodes your heuristic expands, you'll get additional points:

Number of nodes expanded	**Grade**
More than 15000	1/4
At most 15000	2/4
At most 12000	3/4
At most 9000	4/4 (full credit; medium)
At most 7000	5/4 (optional extra credit; hard)

Remember: If your heuristic is inconsistent, you will receive *no* credit, so be careful! Can you solve `mediumSearch` in a short time? If so, we're either very, very impressed, or your heuristic is inconsistent.

Question 4.8 (3 points): Suboptimal Search

Sometimes, even with A* and a good heuristic, finding the optimal path through all the dots is hard. In these cases, we'd still like to find a reasonably good path, quickly. In this section, you'll write an agent that always greedily eats the closest dot. `ClosestDotSearchAgent` is implemented for you in `searchAgents.py`, but it's missing a key function that finds a path to the closest dot.

Implement the function `findPathToClosestDot` in `searchAgents.py`. Our agent solves this maze (suboptimally!) in under a second with a path cost of 350:

```
python pacman.py -l bigSearch -p ClosestDotSearchAgent -z .5
```

Hint: The quickest way to complete `findPathToClosestDot` is to fill in the `AnyFoodSearchProblem`, which is missing its goal test. Then, solve that problem with an appropriate search function. The solution should be very short!

Your `ClosestDotSearchAgent` won't always find the shortest possible path through the maze. Make sure you understand why and try to come up with a small example where repeatedly going to the closest dot does not result in finding the shortest path for eating all the dots.

Submission and Evaluation:

This assignment includes an autograder for you to grade your answers on your machine. This can be run with the command:

```
python autograder.py
```

You need to run it and submit the generated output as snapshot in your final doc/PDF before observation/comment section on MS Team.

Include a neatly formatted pdf document (format already shared) that describes your heuristics, and other observations/explanations while implementing the lab in the document.

It is expected that you complete this assignment by yourself. You may not consult with your classmates or anybody else about their solutions. You are also not to look at solutions to this assignment or related ones on the Internet. You are allowed to use resources on the Internet for programming (say to understand a particular command or a data structure), and also to understand concepts. However, you must list every resource you have consulted or used at the end of document under references section, explaining exactly how the resource was used. Failure to list all your sources will be considered an academic violation.

Place all files in which you have written code in or modified in a directory named TA_4_5-rollno, where rollno is your roll number. Tar and Gzip the directory to produce a single compressed file (say TA_4_5_-rollno.tar.gz). Submit this compressed file on MS Team, under Lab Assignment 4-5.

Evaluation: Your code will be autograded for technical correctness. Please do not change the names of any provided functions or classes within the code, or you will wreak havoc on the autograder. However, the correctness of your implementation – not the autograder's judgements – will be the final judge of your score. If necessary, we will review and grade assignments individually to ensure that you receive due credit for your work.

Academic Dishonesty: We will be checking your code against other submissions in the class for logical redundancy. If you copy someone else's code and submit it with minor changes, we will know. These cheat detectors are quite hard to fool, so please don't try. We trust you all to submit your own work only; please don't let us down. If you do, we will pursue the strongest consequences available to us.

Reference [1] http://ai.berkeley.edu/project_overview.html