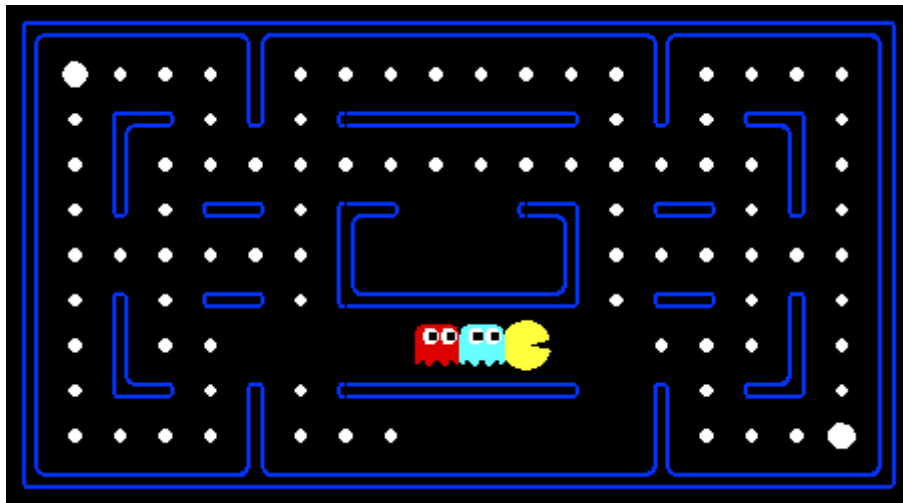


# Spring 2022

# Introduction to Artificial Intelligence

## Homework 3: Multi-Agent Search

Due Date: 2022/4/21 (Friday) 23:59



## Introduction

For those of you not familiar with Pac-Man, it's a game that pacman (the yellow circle with a mouth) moves around in a maze and tries to eat as many food pellets (the small white dots) as possible, while avoiding the ghosts (the other two agents with eyes). If pacman eats all the food in a maze, it wins. The big white dots are capsules, which give pacman power to eat ghosts in a limited time.

In this assignment, you will design agents for the classic version of Pac-Man by implementing three adversarial search algorithms, i.e., minimax search, alpha-beta pruning and expectimax search.

## Welcome to Multi-Agent Pac-Man

The code base of Pac-Man was developed by UC Berkeley.  
(<https://inst.eecs.berkeley.edu/~cs188/sp21/project2/>)

You can only run the code base on a local machine. Google Colab cannot execute it because it has a GUI. Please install python 3 on your own machine and be familiar with the code with CLI.

First, play a game of classic Pac-Man by running the following command:

```
python pacman.py
```

and using the arrow keys to move.

Next, run the given [ReflexAgent](#) in [multiAgents.py](#):

```
python pacman.py -p ReflexAgent
```

Note that the [ReflexAgent](#) performs poorly even on simple layouts:

```
python pacman.py -p ReflexAgent -l testClassic
```

Other Options:

1. Default ghosts are random. You can also play for fun with slightly smarter directional ghosts using [-g DirectionalGhost](#).
2. You can play multiple games in one command with [-n](#).
3. You can turn off graphics with [-q](#) to run games quickly.
4. Use [-h](#) to know more options.

The code base contains the following files:

Files you will edit:	
<a href="#">multiAgents.py</a>	All of your multi-agent search agents will be resided.
Files you might want to look at:	
<a href="#">pacman.py</a>	The main file that runs Pac-Man games. This file also describes a pacman <a href="#">GameState</a> type, which you will use extensively in this assignment.
<a href="#">game.py</a>	The logic behind how the Pac-Man world works. This file describes several supporting types like <a href="#">AgentState</a> , <a href="#">Agent</a> , <a href="#">Direction</a> , and <a href="#">Grid</a> .
<a href="#">util.py</a>	Useful data structures for implementing search algorithms. You don't need to use these for this assignment, but may find other functions defined here to be useful.
Other files you might want to look at, if you are interested in the details of this game.	

## Autograding

In this assignment, TAs will use an autograder to grade your implementation. The autograder has been included in the code base. You can use the following command to test by yourself.

```
python autograder.py
```

The autograder will check your code to determine whether it explores the correct number of game states. This will show what your implementation does on some simulated trees and Pac-Man games. After that, it will show the score you get.

Using the autograder to debug is recommended and will help you to find bugs quickly. To test and debug your code for one particular part, run the following command:

```
python autograder.py -q part1
```

To run it without graphics, use the following command:

```
python autograder.py -q part1 --no-graphics
```

Please do not change the names of any provided functions or classes within the code for technical correctness, or you will wreak havoc on the autograder.

## Requirements

1. Please modify the codes in `multiAgents.py` between `# Begin your code` and `# End your code`. In addition, do not import other packages.
2. All agents you implement should work with **any number of ghosts**. In particular, your search tree will have multiple min/chance layers (one for each ghost) for every max layer.
3. Your code should also expand the game tree to **arbitrary depth** with the supplied `self.depth`. A single level of the search is considered to be one pacman move and all the ghosts' responses, so depth 2 search will involve pacman and each ghost moving twice.
4. Your code should score the leaves of your search tree with the provided `self.evaluationFunction`, which defaults to `scoreEvaluationFunction`.
5. All agents you implement extend `MultiAgentSearchAgent`, which gives access to `self.depth` and `self.evaluationFunction`. Those two variables are populated in response to command line options.

## Part 1: Minimax Search (20%)

- Write an adversarial search agent in the provided [MinimaxAgent](#) class stub in [multiAgents.py](#).
- The actual ghosts operating in the environment may act partially randomly, but the minimax algorithm **assumes the worst**.

### Observations:

- Make sure you understand why pacman rushes to the closest ghost in this case:

```
python pacman.py -p MinimaxAgent -l trappedClassic -a depth=3
```

- The minimax values of the initial state in the [minimaxClassic](#) layout are 9, 8, 7, -492 for depths 1, 2, 3 and 4 respectively. Note that your minimax agent will often win, despite the dire prediction of depth 4 minimax, whose command is shown below. Our agent wins 50-70% of the time: Be sure to test on a large number of games using the [-n](#) and [-q](#) flags.

```
python pacman.py -p MinimaxAgent -l minimaxClassic -a depth=4
```

## Part 2: Alpha-Beta Pruning (25%)

- Implement a new agent that uses alpha-beta pruning to efficiently explore the minimax tree in [AlphaBetaAgent](#) class in [multiAgents.py](#).
- Again, your algorithm will be slightly more general than the pseudo-code discussed in the lecture. This part of the homework is to extend the alpha-beta pruning logic appropriately to multiple MIN agents.
- You must **not prune on equality** in order to match the set of states explored by our autograder. The pseudo-code below represents the algorithm you should implement for this part.

## Alpha-Beta Implementation

---

$\alpha$ : MAX's best option on path to root  
 $\beta$ : MIN's best option on path to root

```
def max-value(state,  $\alpha$ ,  $\beta$ ):  
    initialize  $v = -\infty$   
    for each successor of state:  
         $v = \max(v, \text{value}(\text{successor}, \alpha, \beta))$   
        if  $v > \beta$  return  $v$   
         $\alpha = \max(\alpha, v)$   
    return  $v$ 
```

```
def min-value(state,  $\alpha$ ,  $\beta$ ):  
    initialize  $v = +\infty$   
    for each successor of state:  
         $v = \min(v, \text{value}(\text{successor}, \alpha, \beta))$   
        if  $v < \alpha$  return  $v$   
         $\beta = \min(\beta, v)$   
    return  $v$ 
```

- The autograder will check your code to determine whether it explores the correct number of game states. It is important that you perform alpha-beta pruning without reordering children. In other words, child states should always be processed in the order returned by `GameState.getLegalActions`. Again, do not call `GameState.getNextState` more than necessary.

#### Observations:

- You should see a speed-up: Perhaps depth 3 alpha-beta will run as fast as depth 2 minimax. Ideally, depth 3 on `mediumClassic` should run in just a few seconds per move or faster.

```
python pacman.py -p AlphaBetaAgent -a depth=3 -l smallClassic
```

### Part 3: Expectimax Search (25%)

- Minimax and alpha-beta are great, but they both assume that you are playing against an adversary who makes optimal decisions. As anyone who has ever won tic-tac-toe can tell you, this is not always the case.
- In this part, you will implement the `ExpectimaxAgent` class in `multiAgents.py`, which is useful for modeling probabilistic behavior of agents who may make suboptimal choices.
- Random ghosts are of course not optimal minimax agents, and so modeling them with minimax search may not be appropriate. Rather than taking the MIN over all ghost actions, expectimax agent will take the **expectation** according to your agent's model of how the ghosts act. To simplify your code, please **assume** you will only be running against an adversary that chooses among its legal actions **uniformly at random**.

#### Observations:

- To see how the `ExpectimaxAgent` behaves in Pac-Man, run the following command:

```
python pacman.py -p ExpectimaxAgent -l minimaxClassic -a depth=3
```

You should observe a more cavalier approach in close quarters with ghosts.

- In particular, if pacman perceives that he could be trapped but might escape to grab a few more pieces of food, he'll at least try. Investigate the results of these two cases:

```
python pacman.py -p AlphaBetaAgent -l trappedClassic -a depth=3 -q -n 10
```

```
python pacman.py -p ExpectimaxAgent -l trappedClassic -a depth=3 -q -n 10
```

You should find that your `ExpectimaxAgent` wins about half the time, while your `AlphaBetaAgent` always loses. Make sure you understand why the behavior here differs from the minimax case.

## Part 4: Evaluation Function (20%)

- Write a better evaluation function for pacman in the provided function `betterEvaluationFunction` in `multiAgents.py`. The evaluation function should evaluate only states not including actions.

### Observations:

- With depth 2 search, your evaluation function should clear the `smallClassic` layout with one random ghost more than half the time and still run at a reasonable rate.

### Grading:

- **Test set in autograder.py (10%):**  
The autograder will run your agent on the `smallClassic` layout 10 times. We will assign points to your evaluation function in the following way:
  - If you win at least once without timing out the autograder, you get **1** point. Any agent not satisfying these criteria will receive 0 points.
  - **+1** for winning at least 4 times, **+2** for winning at least 7 times, **+3** for winning all 10 times
  - **+2** for an average score of at least 500, **+4** for an average score of at least 1000 (including scores on lost games)
  - **+1** for no timeout at least 5 times, **+2** for no timeout all 10 times.
- **Hidden test set (10%):**  
For the hidden test set, we will run your agent using 5 random seeds on a specific layout with selected configurations, 10 times for each seed.
  - **+0~10** for pass the above criteria (choose the highest score among the 5 random seeds)
- The autograder will be run on the same machine with `--no-graphics`.

## Report (10%)




- You should write your report following the report template
- The report should be written in **English**.
- Please save the report as a **.pdf** file. (font size: 12)
- For part 1 ~ 4, please take some screenshots of your code and explain how you implement codes **in detail**.

## Submission

**Due Date: 2023/4/21 23:55**

Please compress your [multiAgents.py](#) and report (.pdf) into `STUDENTID_hw3.zip`.

The file structure should look like:

 {student\_id}\_hw3.zip  
├─  multiAgents.py  
└─  report.pdf

**Wrong submission format leads to -10 points.**

## Late Submission Policy

**20% off per late day**