

**COMP 3211 – Fundamentals of Artificial Intelligence**  
**2025 Spring Semester – Assignment 1**  
**Date Assigned: Feb 14, 2025**  
**Due Time: 23:59 on Feb 25, 2025**

How to submit it:

- Submit your written answers as a pdf file to canvas. If your submission is a scan of a handwritten solution, make sure that it is of high enough resolution to be easily read.
  - Submit your code for the last three programming questions as a zip file named YourStudentID.zip to canvas.
  - Please avoid plagiarism. ***You must acknowledge individuals who assisted you, or sources where you found solutions.*** Failure to do so will be considered plagiarism.
  - No late submission will be accepted.
1. (10 points) Consider again our boundary-following robot, assume now that it's somewhat sensory-impaired: its sensory inputs are only  $(s_2, s_4, s_6, s_8)$ .

- 1.1 Can you design a reactive (stimulus-response) agent for following a boundary based only on these four sensors? If your answer is yes, describe how such an agent can be designed. If your answer is no, give your reason for it.
- 1.2 Now suppose that we have the following features for recording the last performed action and the sensor values in the previous state:
- $pa$  (previous action), with 4 values: N (the last action was heading north), E (the last action was heading east), S (the last action was heading south), and W (the last action was heading west).
  - $ps_i$ : in the previous state, the sensor value of  $s_i$  is 1, where  $i = 2, 4, 6, 8$ .

Given these features, describe how  $s_5$  can be computed. Recall that  $s_5$  is 1 (true) if, relative to the robot's current location, the bottom right corner cell is blocked. In our boundary-following robot, this feature is determined by a sensor. Now, it needs to be computed. You can assume that initially, when the robot is turned on,  $s_5$  is 0. So you only need to describe a way to compute it using the above features after the robot has started moving.

2. (10 points)
- 2.1 Which boolean function does the following TLU implement? The TLU has five inputs. Its weight vector is  $(1.6, 3.3, -1.1, -2.1, 0.5)$ , and the threshold is 2. Give your answer as a boolean expression.

- 2.2 Which boolean function does the following TLU implement? The TLU has five inputs. Its weight vector is  $(1.6, 3.3, -1.1, -2.1, 0.5)$ , and the threshold is 10. Give your answer as a boolean expression.
3. **(Programming)** (30 points) Design and implement a genetic programming system to evolve some perceptrons that match well with a given training set. A training set is a collection of tuples of the form  $(x_1, \dots, x_n, l)$ , where  $x_i$ 's are real numbers and  $l$  is either 1 (positive example) or 0 (negative example). So for your genetic programming system, a “program” is just a tuple  $(w_1, \dots, w_n, \theta)$  of numbers (weights and the threshold). Answer the following questions:
- 3.1 What's your fitness function?
  - 3.2 What's your crossover operator?
  - 3.3 What's your copy operator?
  - 3.4 What's your mutation operator, if you use any?
  - 3.5 What's the size of the initial generation, and how are programs generated?
  - 3.6 When do you stop the evolution? Evolve it up to a fixed iteration, when it satisfies a condition on the fitness function, or a combination of the two?
  - 3.7 What's the output of your system for the provided training set `gp-training-set.csv` in `assign1-data3.zip`?

# The Pacman Game

This is a simple exercise to implement our boundary following production systems in the Pacman game from UC Berkeley. The goal of the Pacman game is simple: control the Pacman (yellow circle) to eat all the foods (white dots) in the map, as shown in Figure 1.

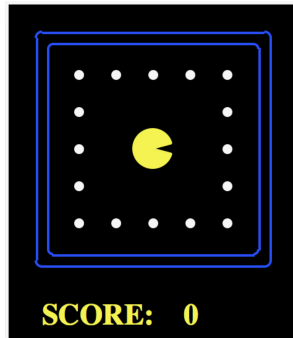


Figure 1: The `smallMap` map

## Environment Setup

Download `assign1-data3.zip` on Canvas and unzip it. Open your terminal, navigate to the `pacman` folder and run `python pacman.py`. You will see the graphical interface of the Pacman game pops out, and you can play the game with your keyboard. If the game works normally, you can proceed to the next step.

## Perception and Movement

Now let's learn how to design a Pacman agent. We have implemented a `NaiveAgent` for your reference, which is an agent that goes west until it can't. Run `python pacman.py --layout testMap --pacman NaiveAgent` to see how the `NaiveAgent` acts. Note that the `--layout` parameter specifies the map, and the `--pacman` parameter specifies the agent. You will see the `NaiveAgent` goes from east to west in the `testMap` map (Figure 2), eats a food, and wins the game.

The Pacman has eight sensors in eight directions: northwest, north, northeast, east, southeast, south, southwest, and west. The sensor will return 1 if there is a wall in its direction, and 0 otherwise. You can use the `getPacmanSensor` function of the `GameState` class to get the list of return values of the sensors in the order described above. For example, if the `getPacmanSensor` function returns  $(s_1, s_2, \dots, s_8) = [0, 0, 1, 1, 1, 0, 0, 0]$ , it means that there are three walls in the northeast, east and southeast of the Pacman.

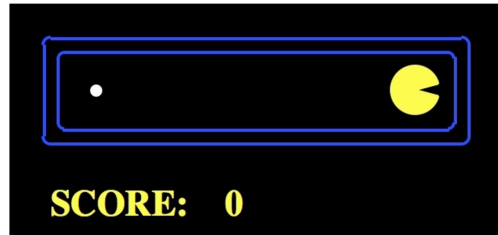


Figure 2: The `testMap` map

The movement of an agent is controlled by the `getAction` function, which is supposed to return one of the five actions at each step: NORTH, SOUTH, EAST, WEST and STOP. Open `reactiveAgents.py` to see the implementation of the `NaiveAgent`: it always returns WEST until it sensed that there is a wall on its west.

Below the `NaiveAgent` class in `reactiveAgents.py`, you will see the `ECAgent` class, which has also been implemented for your reference. The `PSAgent` is an agent that moves according to the production system we discussed in the lecture. You may run the agent in the `smallMap` map for the expected behaviour of the boundary following task.

4. **(Programming)** (25 points) In this problem, you are required to implement `ECAgent`, which is a boundary-following agent that uses the Error-Correction procedure to learn the action functions for the task.

### Task

We have prepared four training sets for learning when to move north, east, south, and west, respectively. Each vector in the training set is in the form of  $(s_1, \dots, s_8, d)$ , where the first 8 elements are the Pacman's sensor readings, and  $d$  is the label of this input, with  $d = 1$  meaning a positive, and 0 a negative example.

You are required to learn a perceptron for each of the actions using the Error-Correction procedure. You can use any programming language for training the perceptrons. You should initialize their weights to all 0 and use learning rate = 1.

- 4.1 (5 points) Give the boolean expression that corresponds to your perceptron for the move north action.
- 4.2 (20 points) Use your learned perceptrons to implement the `ECAgent` in `reactiveAgent.py` in this way: if exactly one of them outputs 1, then do the respective action; if more than one of them output 1, then use the following order: prefer going north, followed by east, south, and west; and finally if none of them outputs 1, then go north.

You can again find the training sets named `north.csv`, `east.csv`, `south.csv`, and `west.csv` in the data files.

## Marking Scheme

We will test your agent with four maps (5 points each). We say that your agent passes a test case if it wins the game, i.e. has eaten all the foods in the map. We will place foods along the boundary of each map, so if your agent is able to follow the boundary, it should also be able to eat all the foods and win the game.

## Notes

- If you have no experience with UNIX or Python before, please go through this tutorial first: <http://ai.berkeley.edu/tutorial.html>, which uses Python 2.7. You should be able to apply it to Python 3 as well.
  - The program may also work in Windows but you will need to handle some dependency issues.
  - There will be no tight spaces (see lecture slides for definition) in the test cases. (note that the `testMap` map is an instance of tight spaces)
  - The order that your agent visits the foods does not matter.
  - If your agent made an invalid move (e.g. move towards the wall), the program will throw an exception and exit. Be careful!
5. **(Programming)** (25 points) This problem also requires you to design a boundary-following agent `SMAgent` with production system. However, `SMAgent` is a state machine with impaired sensors.

## Task

The `SMAgent` is sensory-impaired and can only received only 4 sensor inputs from the 4 directions: north, east, south, west. The agent receives sensor values from the `getPacmanImpairedSensor` function. The sensory input  $(s_2, s_4, s_6, s_8)$  corresponds to the sensor values from the north, east, south, and west respectively.

The `SMAgent` can remember the previous action `prevAction` and the previous sensory input `prevSense`. The initial state of the `SMAgent` has been implemented for you.

To finish this task, you do not need any additional data member other than `prevAction` and `prevSense`. You are required to use `getPacmanImpairedSensor` instead of `getPacmanSensor` and we will disable the `getPacmanSensor` when we test the `SMAgent`.

- 5.1 (20 points) Complete the `getAction` function of the `SMAgent`. We will test your agent with four maps like the Problem 4.
- 5.2 (5 points) Denote  $(\tilde{s}_2, \tilde{s}_4, \tilde{s}_6, \tilde{s}_8)$ , to be the previous sensory input and  $(N, E, S, W)$  to be the one-hot encoding of the the previous action. For example, if the previous action is moving north, then  $(N, E, S, W)=[1, 0, 0, 0]$ . Can we train perceptrons on the feature vector  $(s_2, s_4, s_6, s_8, \tilde{s}_2, \tilde{s}_4, \tilde{s}_6, \tilde{s}_8, N, E, S, W, d)$  with the Error-Correction procedure as in the Problem 4?