# Introduction

This is a worksheet for the third COMP3071 lab.

In this session, you'll work on two tasks.

The objective of the first task is to update the existing code to enable a systematic comparison of various parameter settings against the average amount of dirt collected by the robot vacuum cleaner system. In the second task, the goal is to integrate a planning algorithm that can efficiently direct the movement of the robot towards the least costly path between two given points.

Today's activities are important for various reasons within the context of the robot vacuum cleaner system. By conducting a systematic comparison of different parameter settings, the system can be optimized to collect the maximum amount of dirt in the least amount of time. This can lead to a more effective cleaning process, ultimately saving time and energy while enhancing the system's overall performance. Moreover, by identifying the most optimal path between two points, the robot can save energy and time during its movement, resulting in faster and more efficient cleaning. This is especially crucial in large areas where the robot needs to cover a significant distance as it can substantially reduce the time and energy required to complete the task.

# Task 1: Getting Started

To start, download the simpleBot2\_withCounting.py file from the module Moodle page. Ensure that you can run the file. It's a solution for the counting task from last week. You can either run the file from the command line or import it into an IDE.

## Task 1

The primary objective of the first task is to improve simpleBot2\_withCounting.py to enable a methodical comparison of various parameter settings concerning the quantity of dirt collected by the robot vacuum cleaner system. Specifically, we want to examine how the number of bots affects the total amount of dirt collected. For each configuration, the experiment needs to be run multiple times.

To achieve this goal, the following modifications can be implemented:

1. Rename the main method as runOneExperiment

* Line 288 and Line 296

1. Update the runOneExperiment method to take a parameter called numberOfBots.

Changes 1

def main(numberOfBots):  
 window = tk.Tk()  
 canvas = initialise(window)  
 registryActives, registryPassives, count = register(canvas, numberOfBots)

1. Modify the register function and its call in the runOneExperiment method to enable the supply of different numberOfBots values.

Changes 1

def register(canvas,noOfBots):  
 registryActives = []  
 registryPassives = []  
 # noOfBots = 1 # Comment out this line

Changes 2

Make sure to comment out the noOfBots on Line 253

1. Instead of just printing the average amount of dirt collected, update the code to extract this information by modifying the moveIt() method.
2. Let's consider how we can achieve this requirement. Previously, the system was set to exit once the following if-statement was fulfilled.

if moves>numberOfMoves:  
 sys.exit()

1. To accomplish this, comment out sys.exit() and replace it with window.destroy() to close the window instead of exiting.
2. After this modification, an element related to the window variable is missing. This element needs to be added to the moveIt() method.

Change 1

def moveIt (canvas,registryActives,

registryPassives,count,moves,window):  
 moves += 1  
 for rr in registryActives:  
 chargerIntensityL, chargerIntensityR = rr.senseCharger(registryPassives)  
 rr.transferFunction(chargerIntensityL, chargerIntensityR)  
 rr.move(canvas,registryPassives,1.0)  
 registryPassives = rr.collectDirt(canvas,registryPassives, count)  
 numberOfMoves = 500  
 if moves>numberOfMoves:  
 print("total dirt collected in",numberOfMoves,"moves is",count.dirtCollected)  
 # sys.exit()  
 window.destroy()  
 canvas.after(50,moveIt,canvas,registryActives,registryPassives,count,moves,window)

1. The runOneExperiment() method also needs to be updated to return the total amount of dirt collected.

Change 1

def runOneExperiment(noOfBots):  
 window = tk.Tk()  
 canvas = initialise(window)  
 registryActives, registryPassives, count = register(canvas,noOfBots)  
 moves = 0  
 moveIt(canvas,registryActives,registryPassives, count, moves,window)  
 window.mainloop()

1. In the updated runOneExperiment() method, add the following argument at the end of the method to return the total amount of dirt collected

return count.dirtCollected

1. Test the code by running the runOneExperiment(numberOfBots) function at the end of the file. Assign any value to numberOfBots. This code should work if all the steps from 1 to 5 are followed.

A. Alternatively, the line can be written as print(runOneExperiment(5)) to print the total amount of dirt collected by 5 bots to the console.

1. Note that the line runOneExperiment() at the end of the file is only for development purposes. It should be commented out when implementing the actual code. Use this line for development from steps 1 to 5 only.

# runOneExperiment()

1. To examine how the number of bots affects the amount of dirt collected and run the experiment multiple times for each configuration, a new function can be introduced in a new .py file. This function can be named runAllExperiments.py and should contain the following methods:
2. Add a new function called runSeveralTimes(numberOfBots, numberOfRuns) that runs the main\_with\_counting function a specific number of times (determined by the "numberOfRuns" parameter) and returns the average amount of dirt collected.
3. Add another function called runSeveralExperiments() that
4. creates a list [1,2,3,…,10] representing the number of bots in each experiment. It loops through this list and calls the runSeveralTimes() function for each number.
5. At the end of this process, a table of the number of bots versus the amount of dirt collected should be displayed. This table can be printed in text on the console, or
6. visualized as a graph such as a bar chart or line chart if you are familiar with a plotting package.
7. Additionally, if you are familiar with statistical analysis, you can calculate whether there is a significant difference between the average dirt gathered for each successive pair of experiments.

## `Task 2: Getting Started

To get started, download the simpleBot3.py and aStar.py files from the module's Moodle page and ensure that you are able to run them either through the command line or by importing them into an IDE.

The simpleBot3.py is similar to the program you have seen in previous weeks, but with the addition of a matrix called "map" which shows the location of dirt on a 10x10 grid. Imagine that there is a camera on the room's ceiling that shows the location of the dirt and relays it to the robot. When you run the program, the map is printed to the console.

The goal of this task is to integrate the A\* search algorithm into simpleBot3.py to guide the robot in cleaning up the room.

Start by familiarizing yourself with both simpleBot3.py and aStar.py. simpleBot3.py contains the code for the robot and the map of the room, while aStar.py contains the A\* search algorithm that finds a path through a network.

A\* is a search algorithm that you may have learned if you've taken a course on AI or algorithms. If not, you can watch this video (https://www.youtube.com/watch?v=6TsL96NAZCo), which provides a clear explanation of it.

The version of A\* implemented in aStar.py conveniently finds a route through a 10 x 10 grid.

When you run aStar.py, it will display three things in the console:

1. the grid to be searched (which represents the dirt on the map),
2. the list of points to be visited in order, and
3. the path taken (indicated by 1 for points visited).

Note that the route starts in the (9,9) corner and progresses by single steps towards (0,0), not taking diagonals to simplify the problem.

Modify "simpleBot3.py" to incorporate the A\* algorithm and conduct experiments to compare the performance of the two methods. You may also consider enhancing the program by visualizing the results or conducting statistical analysis to determine any significant differences between the two methods.

### Task 2

The primary objective of the first task is to improve "simpleBot3.py" with aStar.py so that the robot can move toward the least costly path between two given points.

To achieve this goal, the following modifications can be implemented to the simpleBot3.py:

1. To integrate the aStar.py code into simpleBot3.py, add the following line at the beginning of simpleBot3.py:

from aStar import \*

This imports all the functions from the aStar.py file into simpleBot3.py.

1. Now that the search algorithm is available in simpleBot3.py, you can apply it to the map.
2. In the main method, call the aStarSearch function with the map as the argument, and store the result in a variable called path:

path = aStarSearch(map)

1. You can inspect the contents of the path variable by using the print function or any other suitable method. If you have made the changes correctly, the output should be a list that looks like this:

[(9, 9), (8, 9), (8, 8), (8, 7), (8, 6), (8, 5),

(8, 4), (8, 3), (8, 2), (8, 1), (8, 0), (7, 0),

(6, 0), (5, 0), (4, 0), (3, 0), (2, 0), (1, 0), (0, 0)]

These tuples represent the successive positions of the bot on the 10x10 map.

For instance, the bot starts at position (9, 9) and moves to (8, 9), then to (8, 8), and so on, until it reaches the final position at (0, 0).

The next step is to make the bot traverse through these points.

CHANGE 1:

print(path)

1. To continue, follow these steps to place the bot in the corner of the map:
2. Rather than placing the bot at a random position/angle, specify its position/angle as (950, 950) and -3.0\*math.pi/4.0, respectively.
3. You can either modify the \_\_init\_\_ method of the Bot class to do this, or create a new method called place in the Bot class.

Line 23-27

class Bot:  
  
 def \_\_init\_\_(self,namep,canvasp):  
 # self.x = random.randint(100,900)  
 # self.y = random.randint(100,900)  
 # self.theta = random.uniform(0.0,2.0\*math.pi)  
  
 self.x = 950  
 self.y = 950  
 self.theta = -3.0\*math.pi/4.0

1. Run the code to ensure that the bot starts in the specified position.

Chart, scatter chart

Description automatically generated

Tip: Increase the duration of the after method by changing the value of 200 to a longer time, such as 2000, to obtain a longer static view. However, it is important to note that this change should only be temporary, as it is mainly meant to ensure that the robot's initial starting position is where we intended it to be. After confirming that the robot is starting in the correct position, you can reduce the duration back to the original value of 200 or a suitable time that allows the robot to move smoothly.

Line 242

canvas.after(200,moveIt,canvas,registryActives,registryPassives,count,moves,window,this\_path)

1. In order to enable the transfer function to follow the path generated by the A\* algorithm, add the path variable as a parameter to both the transferFunction and moveIt methods.

Change 1: Line 251

moveIt(canvas, registryActives, registryPassives, count, moves, window, path)

Change 2: Line 232

def moveIt(canvas,registryActives,registryPassives,count,moves,window,this\_path)

Change 3:Line 242

canvas.after(20,moveIt,canvas,registryActives,registryPassives,count,moves,window)

Change 4: Line 235

rr.transferFunction(this\_path)

Change 5: Line 149

def transferFunction(self,jpath):

1. To steer the robot toward the next position in the path, retrieve the element in the path, and call it the target variable.
2. IMPORTANT: Comment out the existing code under the transferFunction.

def transferFunction(self,jpath):  
 # wandering behaviour  
 # if self.currentlyTurning==True:  
 # self.vl = -2.0  
 # self.vr = 2.0  
 # self.turning -= 1  
 # else:  
 # self.vl = 5.0  
 # self.vr = 5.0  
 # self.moving -= 1  
 # if self.moving==0 and not self.currentlyTurning:  
 # self.turning = random.randrange(20,40)  
 # self.currentlyTurning = True  
 # if self.turning==0 and self.currentlyTurning:  
 # self.moving = random.randrange(50,100)  
 # self.currentlyTurning = False

1. Some notes about the target variable
2. The initial coordinates should be (9,9). It's worth noting that a tuple in coordinate form is expressed as (x,y).
3. Keep in mind that the coordinates in the path appear in the format (8,9), while the grid size is 1000 by 1000.
4. To scale up the coordinates, multiply the x and y values of the target by 100, and then add 50 to each result. For instance, the first target's coordinates would be (950, 950).

Change 1: Line 165-167

target=jpath[self.idx\_path]  
constant=100  
target = tuple((constant \* x)+50 for x in target)

Change 2:

class Bot:  
  
 def \_\_init\_\_(self,namep,canvasp)

self.idx\_path=0

1. Use the distanceToLeftSensor and distanceToRightSensor methods to determine the distance from the robot to target.

tr=round(self.distanceToRightSensor(target[0],target[1]))  
tl=round(self.distanceToLeftSensor(target[0],target[1]))

1. To steer the robot towards a pair of coordinates, we can modify code from simpleBot2.py:
2. Look at the code that steers the robot towards the charger when the battery is low, there is simple if-else block as follow

if self.battery<600:

if chargerR>chargerL:

self.vl = 2.0

self.vr = -2.0

elif chargerR<chargerL:

self.vl = -2.0

self.vr = 2.0

if abs(chargerR-chargerL)<chargerL\*0.1:

self.vl = 5.0

self.vr = 5.0

The code adjusts the robot's velocities based on the readings from the left and right sensors.

1. Update the transferFunction method to steer the robot towards the target. Modify the existing code (i.e., the if-else block) that steers the robot towards the charger to steer the robot towards the target instead.

if tr>tl:  
 self.vl = 2.0  
 self.vr = -2.0  
elif tr<tl:  
 self.vl = -2.0  
 self.vr = 2.0  
if abs(tr-tl)<tl\*0.1: #approximately the same  
 self.vl = 5.0  
 self.vr = 5.0

1. Add an if statement to check if the robot is close enough to the target. If the distance from either the left or right sensor is less than a specified threshold, remove the current target from the path list so that the robot can focus on the next one

Change 1:

if (tr<self.thershod\_pt)|(tl<self.thershod\_pt):  
 self.idx\_path += 1

Change 2:

class Bot:  
  
 def \_\_init\_\_(self,namep,canvasp)

self.thershod\_pt=40

1. Optional: You can also add text and a circle to indicate the location of the target. Visualizations can be helpful for development purposes. To do this, use the canvas.create\_text() method and canvas.create\_oval() method under the draw method to draw the text and circle, respectively.

CHANGE 1:

class Bot:  
  
 def \_\_init\_\_(self,namep,canvasp):

self.loc\_target\_x=0  
self.loc\_target\_y=0

CHANGE 2:

def transferFunction(self,jpath):

## Used for drawing on the board !  
self.loc\_target\_x=target[0]-10  
self.loc\_target\_y=target[1]-10  
print(f'Current Distance: {tr} and {tl}, and the targe loc {jpath[self.idx\_path]}')

CHANGE 3:

def draw(self,canvas):

canvas.create\_oval(self.loc\_target\_x-target\_size,self.loc\_target\_y-target\_size, \  
 self.loc\_target\_x+target\_size,self.loc\_target\_y+target\_size, \  
 fill="red",tags=self.name)

CHANGE 4

def draw(self,canvas):

canvas.create\_text(self.loc\_target\_x-5,self.loc\_target\_y-25,  
 text=f"x: {self.loc\_target\_x-40}\_ y:{self.loc\_target\_y-40}",tags=self.name)

1. Check whether all coordinate pairs have been completely traversed. There are several ways to do this.

* One way is to check if the path list is empty at the end of each call to the transferFunction. If the path list is empty, return the string 'finished'. Additionally, if the path list is empty or if the number of moves exceeds a specified threshold, end the simulation, OR
* Check if the number of moves doesn't exceed the threshold and if the current path index equals the path size. If both conditions are met, print the total amount of dirt collected and indices in the path, then destroy the window.

def moveIt(canvas,registryActives,registryPassives,

count,moves,window,this\_path):  
 moves += 1  
 for rr in registryActives:  
 rr.transferFunction(this\_path)  
 rr.move(canvas,registryPassives,1.0)  
 registryPassives = rr.collectDirt(canvas,registryPassives, count)  
 numberOfMoves = 2000  
 if (moves>numberOfMoves)| (rr.idx\_path==len(this\_path)):  
 print("total dirt collected in",numberOfMoves,"moves is",count.dirtCollected)  
 print(f'Total idx {rr.idx\_path}')  
 window.destroy()  
 canvas.after(200,moveIt,canvas,registryActives,registryPassives,count,moves,window,this\_path)

# Experiments

The next task is to conduct experiments to determine whether the two behaviors differ, as we did in Task 1.

1. Using the same framework as Task 1, create a similar setup that compares:

* The code you just wrote
* The original 'wandering' code from the transfer function that you commented out earlier."

1. Replace 'main' with a function that takes a parameter (e.g., 'wandering' or 'planned') and returns the amount of dirt gathered.
2. Run the code 100 times in each of the 'wandering' or 'planned' states, and record the amount of dirt collected each time.
3. Visualize the results, calculate some descriptive statistics, and consider performing a t-test to determine whether there is a significant difference."

If you want to achieve exceptional results, consider introducing some randomness to the setup. For instance, you could use a generator that creates various distributions of dirt, and then test whether the A\* planning algorithm can still find a solution.

# Extensions

Here are some extensions to the tasks above. While I do not expect you to attempt these during class, they can provide ideas that may serve as the basis for your coursework.

1. Instead of using the planning algorithm, consider using genetic algorithms. Genetic algorithms find a good route by first taking a 'population' of initially random solutions (i.e. paths), ranking them based on solution quality (i.e. amount of dirt collected), and then creating a new population by making small changes ('mutations') to successful paths or by crossing-over two successful paths. Implement this method and compare the wandering, planned, and genetic solutions based on the amount of dirt collected and computation time. To do this effectively, you will need to carefully consider the number of allowed moves. If you analyze this project clearly, it could make for a decent coursework project.
2. Re-introduce the 'battery' from last week and make sure that the battery charge runs out before the path is complete; otherwise, this task is meaningless! Modify the transfer function so that it prioritizes going back to the battery when the charge is low. Then, re-plan the best route from the charger to the corner.