**Worksheet 5 Report Analysis**  
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**Task: Ant colony simulation**

**Objective**

* Simulate ant behavior in order to find food in a grid environment.
* Test how pheromone decay rates affect the efficiency of the ants in food finding.
* Find an optimum decaying rate for obtaining food reliably.

**Code Explanation**

* Grid Configuration
  + Purpose: the grid is a sort of environment to the ants.
  + Hive ('H'): The starting location of all ants at (0, 0).
  + Food ('F'): Located at 5, 5.
  + Obstacles ('X'): Randomly placed barriers to complicate the ants' pathfinding.
  + A\*. Free spaces ('.'): Where ants can move freely.
* Pheromone Matrix
  + Purpose: Keep track of pheromones on each cell.
  + In time, the ants will be led to food.
  + The levels will be capped at 50 to prevent too powerful trails.
  + Pheromones decay at a configurable rate to simulate evaporation.
* Ant Class
  + position: tuple holding the ant's current position, initialized to (0, 0) -- the hive.
  + path: Records the current path of the ant. It would be used to provide a mechanism to lay a pheromone trail as an ant returns to the hive.
  + found\_food: A flag on whether the ant has found the food.
  + move(): Moves the ant to the next position depending on:
  + The pheromone quantity of its immediate neighbors.
  + Random movement if no pheromones are detected.
  + Handles collisions with obstacles. Retries valid neighbors if necessary.
  + Add current position to path (provided food has not been found).
  + Deposits pheromone while on the move on the grid.
* get\_neighbors()
  + It identifies the valid neighboring cells that the ant can move to.
  + It considers the bounds of the grid to avoid out-of-bounds errors:.
  + Avoids cells with obstacles ('X').
  + Return the list of valid neighboring positions.
* Simulation Loop
  + Time Steps: It performs an Ants' movement and pheromone updating for 30 iterations.
* Ant Motion:
  + Either the ants move based on pheromones or explore the grid randomly.
  + When an ant has reached the food:
  + Pheromones are laid down along its return path to guide other ants.
  + Ants return to the hive and prepare for the next iteration.
* Pheromone decay:
  + It simulates the evaporation of pheromones using the pheromone\_decay\_rate.
  + Prevents outdated trails from misleading ants over time.
  + Percept:
  + It displays in every time step the current state of the grid and the current pheromone level to follow up the simulation.

**Future improvements**

* Weighted Random Exploration
* Introduce randomness in movement to explore new paths occasionally, balancing exploitation and exploration.
* Dynamic Pheromone Deposition: Amplify pheromone around food so that effective trails are in contrast.
* Memory for Obstacles: Allowing ants not to revisit dead ends to obtain the optimum movement.
* Improved Visualization: Use a heatmap for pheromone levels and color-coding to differentiate ants.

**Conclusion**

* Optimum decay rate: Between 0.02-0.05, food-finding behavior is turned on all the time.
* High Decay Rate: Causes rapid evaporation, forcing the ants to rely on random movement.
* Low Decay Rate: Trails take too long, leading to outdated paths and inefficiency.