ASMA Proj 1

Diogo Fernandes up202108752
João Coelho up202004846
Válter Castro up201706546

Problem Description

Design and implement a decentralized waste collection system using a Multi-Agent System.

The system will simulate autonomous garbage trucks (agents) that collaborate to efficiently collect waste from various locations within a city, responding dynamically to changes in waste levels.

Agents

Types of agents:
- Bins;
- Trucks;
- Central (World);

Bins:
- Represent the waste containers distributed across the city.
- Each Bin is an autonomous agent responsible for:
  - Monitoring its own waste level (waste_lvl).
  - Emitting announcements when the waste level reaches threshold.
  - Requesting collection from Truck agents when necessary, initiating the ContractNet Protocol.
  - Participating in a FSM to manage the negotiation and collection process.

Trucks:
- Represent the garbage trucks that carry out the waste collection.
- Each Truck is an autonomous agent with:
  - A waste storage capacity.
  - The ability to decide which Bin to serve, based on distance, current load, and other criteria.
  - The ability to respond to CFPs from bins via ContractNet.
  - The ability to track its position and movement, state(busy or not) and distance traveled.

Central:
- Keeps track of Bins and Trucks.
- Computes real-time statistics such as total waste collected, average bin waste level, and total distance traveled.
- Provides methods to register new agents (add_bin, add_truck).

Interactions

From	To	Type of Interaction	Description
Bin	**Truck**	CFP (Call for Proposal)	When the waste level reaches a threshold, the Bin sends a request to nearby Trucks.
Truck	**Bin**	Proposal	Available Trucks respond with proposals to collect the waste, including availability and distance.
Bin	**Truck**	Accept Proposal / Refusal	The Bin selects one proposal and sends an acceptance message; others may be refused.
Truck	**Bin**	Confirm / Collect	The selected Truck travels to the Bin, collects the waste, and updates its state.

Protocols

A graph was defined following the specification of the locations given in the statement. The weight of the edges is the distance, calculated using the Haversine formula. Bin capacity was set to 20 units, Truck capacity to 80 units and truck velocity to 5 m/s.

ContractNet was implemented in order to manage the decentralized negotiation of waste collection tasks between agents, allowing Bins to broadcast requests and Trucks to evaluate and propose their availability based on current load, location, and task status.

This logic is implemented through a Finite State Machine (FSM) behavior using SPADE’s FSMBehaviour

Protocols

State	Label	Description	Transitions To
State_Zero	INTERVAL	Bin is empty - Interval between bin being empty and full/supplied	STATE_ONE
State_One	CALL_FOR_PROPOSAL	The Bin sends CFP (Call for Proposal) messages to Trucks. Each Truck checks availability and responds if able.	STATE_TWO STATE_THREE
State_Two	FAILURE	No Trucks were available to handle the task. The Bin may retry later.	STATE_ONE
State_Three	PROPOSE	Available Trucks send PROPOSE messages. The Bin evaluates proposals and selects the most suitable Truck.	STATE_FOUR STATE_TWO
State_Four	ACCEPT_PROPOSAL	The Bin sends an ACCEPT_PROPOSAL message to the selected Truck, which begins its trip to the Bin.	STATE_FIVE
State_Five	INFORM:DONE	The Truck completes the collection. Bin is updated. The Truck becomes available again.	STATE_ZERO

Strategies

Dijkstra’s shortest path algorithm was also implemented to calculate the optimal route between a Bin and each available Truck, based on the simulated road network. This allows the system to prioritize proposals from Trucks that are closer to the requesting Bin, improving efficiency and reducing overall travel time in the waste collection process. A set was used for the edgelist, instead of a list, to avoid duplicates and reduce the need for if statements.

Communication uses FIPA-compliant message protocols which define a set of performatives (cfp, propose, accept-proposal, inform, refuse)

Experiments carried out

3 scenarios were carried out, as asked in the statement:

Scenario 1:

- Bin filling rate interval: 300 seconds (fills once)
- Bin filling rate quantity: 100% of capacity
- Trucks: 1
- Simulation duration: 240 seconds

Scenario 2:

- Same as Scenario 1 but with 2 trucks instead of 1

Scenario 3:

- Bin filling rate interval: every 4 seconds
- Bin filling rate quantity: 20% of capacity
- Trucks: 2
- Simulation duration: 120 seconds

Analysis of results - 5m/s

Scenario 1:

- Total Waste Collected: 20
- Total Distance Traveled: 1877.66
- Average Waste Level for each bin:
  - bin0 : 17.50
  - others: 20.00
- Time each bin was full:
  - bin0 : 210s
  - others: 240s

Scenario 2:

- Total Waste Collected: 40
- Total Distance Traveled: 2703.77
- Average Waste Level for each bin:
  - bin0 : 17.50
  - bin1: 13.83
  - others: 20.00
- Time each bin was full:
  - bin0 : 211s
  - bin1: 166s
  - others: 240s

Scenario 3:

- Total Waste Collected: 0
- Total Distance Traveled: 1871.87
- Average Waste Level for each bin: 20.00
- Time each bin was full: 120s

Conclusions

Future Work:

- Implementation of return to depot;
- Implementation of bins overflowing;

Critical analysis:

- Faced some difficulties implementing the ContractNet Protocol
- Project improved skills in asynchronous programming, agent synchronization, and system performance evaluation.