KU LEUVEN

Multi-Agent Systems Based Solution for Pickup-And-Delivery

Thierry Deruyttere (r0660485)
Armin Halilovic (r0679689)
KU Leuven - Multi-Agent Systems

0 Outline

1 Outline

1 Problem definition - Setting

- Pizzeria chain RoboPizza
- Pizza delivery using robots (AGVs)
- RoboPizza receives pizza delivery requests (tasks), robots deliver the pizzas

1 Problem definition - Environment

- Grid city system
- AGVs can go in both directions on streets
- AGVs can pass each other
- Dynamism:
  - Road works cause streets to be closed off
- Efficiency measure:
  - Total waiting time for tasks

1 Problem definition - Robots

- Can move from and to any position in the city
- Have static maps and can compute paths between locations
- Can carry up to 5 pizzas at once
- Can only communicate with entities that are close to them (i.e. city node they are on)
- Run on batteries which need to be recharged
  - Can charge at charging station
  - Station supports limited amount of robots at once
- Potential crash:
  - Can run out of battery $\rightarrow$ reset battery after time delay as simulation of manual replacement

1 Problem definition - Tasks

- Consist of picking up (multiple) pizzas and delivering them to a destination in the city
- If there are more than 5 pizzas in a task, it has to be split up
- Pizzas have no preparation time and can be picked up instantly
- Created each simulation tick with low probability that scales with city size:
  - Amount of pizzas by Gaussian distribution
  - Delivery position uniformly random in city

2 Outline

2 Objectives

- Develop a BDI & Delegate MAS algorithm for the described setting
- Analyze the performance for certain parameter settings

3 Outline

KU LEUVEN

3 Research Questions and Hypotheses I

- What is the relation between the amount of requests that RoboPizza receives and the waiting time for customers?
  - H_1: The waiting time increases with the amount of requests.
  - H_0: The waiting time does **not** increase with the amount of requests.
- Do robots drive more (non-idle time) when there are more requests in the system?
  - H_1: Robots drive more when there are more requests in the system.
  - H_0: Robots do **not** driving more when there are more requests in the system.

3 Research Questions and Hypotheses II

- Does increasing the amount of robots decrease customer waiting time when there are many requests?
  - H_1: Increasing the amount of robots decreases customer waiting time when there are many requests.
  - H_0: Increasing the amount of robots does **not** decrease customer waiting time when there are many requests.
- How do waiting times change as the amount of road works changes (dynamism)?
  - H_1: Waiting times increase as the amount of road works increase.
  - H_0: Waiting times do **not** increase as the amount of road works increase.

4 Outline

4 Independent Variables

- n_{robots} = amount of delivery robots (4)
- p_{task} = probability for a new task $(0.001 * city\_size)$
- p_{road_works} = probability for road works to start $(0.0025 * city\_size)$

4 Dependent Variables

- n_{task} = amount of tasks
- $n_{finished}$ = amount of finished tasks
- t_{wait} = waiting time for customers
- n_{pizzas} = amount of pizzas carried by robots
- $n_{distance}$ = distance all robots have traveled
- $t_{driving}$ = time robots spent driving
- t_{idle} = time robots were idle
- $t_{charging}$ = time robots spent charging
- n_{road_works} = amount of road works
- $n_{dropped}$ = amount of parcels that were dropped

4 Other Variables I

- l_{tick} = length of a single simulator tick (1000)
- $l_{simulation}$ = simulation length in experiments $(10hours)$
- $experiment\_repeats$ = amount of times experiments are ran (100)
- l_{city} = **city grid size** (20)
- l_{robots} = robot length (1)
- d_{node} = distance between two nodes on city grid $(2 * l_{robot})$
- v_{robot} = robot speed (1)
- $distance\_unit$ = distance unit (m)
- $speed\_unit$ = speed unit (m/s)

4 Other Variables II

- cap_{robot} = amount of pizzas a robot can carry $_{(5)}$
- $cap_{charging\_station}$ = amount of robots that can charge simultaneously $_{(2)}$
- $cap_{battery}$ = robot battery capacity $_{(l_{city} * l_{city} * d_{node})}$
- $cap_{recharge}$ = battery capacity recharged per tick $_{(0.01 * cap_{battery})}$
- $paths\_to\_explore$ = **amount of paths to explore towards destinations** $_{(3)}$
- t_{road_works} = **time duration of road works** $_{(l_{city} * l_{city} * d_{node} * 1000)}$

4 Other Variables III

- $t_{battery\_rescue}$ = time delay for replacement of empty batteries
  $(5 * (cap_{battery}/cap_{recharge}) * l_{tick})$
- $t_{intention\_reservation}$ = **time duration of intention reservations**
  $(4 * l_{city} * d_{node}/v_{robot}) * 1000)$
- $t_{refresh\_intention}$ = the amount of time it takes before a robot resends intention ants $(0.5 * t_{intention\_reservation})$
- $t_{refresh\_exploration}$ = the amount of time it takes before a robot resends intention ants $(0.4 * t_{intention\_reservation})$
- $\mu_{pizza}, \sigma_{pizza}$ = **pizza amount parameters** (4, 0.75)
- t_{pizza} = preparation and pickup time of a pizza (0)

5 Outline

5 Multi-Agent System Design: Overview

- Agents
  - Robot Agent for each robot
  - Resource Agent for each node on world graph
- Ant-based Delegate MAS
  - Desire Ants
    - Find delivery tasks
  - Exploration Ants
    - Find paths towards destinations
  - Intention Ants
    - Choose path and create reservation
- Buildings
  - 1 Pizzeria
  - 1 Charging Station
  - Random Road Works

5 Multi-Agent System Design: Robot Strategy

- strategy

6 Outline

6 Experiments

- Different parameter settings for each hypothesis
- Each experiment is run 50 times
- Experiment end statistics are written to files
- Test method: two-sample t-test
- Significance level: 0.05
- Hypotheses entail one-tailed tests. Null hypothesis will be rejected if the mean difference between sample means is too small.

- Could not experiment with varying dynamism because of an error with RinSim Experiment repeats we couldn't fix

6 Experiments: Question 1 (1)

- What is the relation between the amount of requests that RoboPizza receives and the waiting time for customers?
  - H_1: The waiting time increases with the amount of requests.
  - H_0: The waiting time does **not** increase with the amount of requests.

- TODO: Hypotheses in termen van $H_0 : \mu_1 \geq \mu_2$ en $H_1 : \mu_1 < \mu_2$
- http://stattrek.com/hypothesis-test/difference-in-means.aspx

6 Experiments: Question 1 (2)

- grafieken ofzo

6 Experiments: Question 2 (1)

- Do robots drive more (non-idle time) when there are more requests in the system?
  - H_1: Robots drive more when there are more requests in the system.
  - H_0: Robots do **not** driving more when there are more requests in the system.

- TODO: Hypotheses in termen van $H_0 : \mu_1 \geq \mu_2$ en $H_1 : \mu_1 < \mu_2$
- http://stattrek.com/hypothesis-test/difference-in-means.aspx

6 Experiments: Question 2 (2)

- grafieken ofzo

6 Experiments: Question 3 (1)

- Does increasing the amount of robots decrease customer waiting time when there are many requests?
  - H_1: Increasing the amount of robots decreases customer waiting time when there are many requests.
  - H_0: Increasing the amount of robots does **not** decrease customer waiting time when there are many requests.

- TODO: Hypotheses in termen van $H_0 : \mu_1 \geq \mu_2$ en $H_1 : \mu_1 < \mu_2$
- http://stattrek.com/hypothesis-test/difference-in-means.aspx

6 Experiments: Question 3 (2)

- grafieken ofzo

7 Outline

KU LEUVEN

7 Conclusions

- conclude our Conclusions

Questions?