KU LEUVEN

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

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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

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)
- $p_{request}$ = probability for a new request (0.001*city size)
- $\mu_{pizza}, \sigma_{pizza}$ = Gaussian distribution parameters for amount of pizzas (4, 0.75)
- $p_{road\_works\_start}$ = probability for road works to start (0)
- city size = the size of the city (20)
- timeRoadWorks = the time a roadwork takes ((city size * city size * node distance) * 1000)
- chargingStationCapacity = the amount of robots that can charge at the same time (2)

4 Dependent Variables

- t_{wait} = total waiting time for customers
- $t_{robots\_driving}$ = total time robots spent driving
- t_{robots_idle} = total time robots were idle
- $t_{robots\_charging}$ = total time robots were charging
- $n_{robots\_distance}$ = the cumulative distance all robots have traveled
- $n_{requests}$ = amount of requests in the system
- n_{road_works} = amount of road works
- $n_{deliveries}$ = amount of finished deliveries
- avg_{pizzas} = average amount of pizzas carried by robots

4 Other Variables

- v_{robots} = moving speed of the robots (1)
- c_{robots} = the amount of pizzas a robot can carry (5)
- t_{pizza} = the baking time of a pizza (0)
- $t_{simulation}$ = the total length of the simulation (10 hours)
- $robot\_charge$ = amount by which a battery will be recharged in one tick (0.01 * battery capacity)
- $battery\_capacity$ = the pizzas of a robot's battery (city size * city size * node distance)
- node distance = the length between two nodes (2 * robot length)
- robot length = the length of the robot (1)
- paths to explore = amount of paths explored by A* (3)

4 Other Variables

- battery rescue delay = The time it takes before a robot without battery is saved (5 * (battery capacity / $robot\_charge$) * tick length)
- tick length = the length of one tick (1000L)
- $t_{intentionRefresh}$ = the amount of time it takes before a robot resends intention ants (0.5 * intention reservation lifetime)
- $t_{intentionReservation}$ = the amount of time an intention reservation lasts (4 * city size * node distance / robot speed) * 1000)
- $t_{explorationRefresh}$ = the amount of time it takes before a robot resends intention ants (0.4 * intention reservation lifetime)

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 $H_1 : \mu_1 < \mu_2$
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6 Experiments: Question 3 (2)

- grafieken ofzo

7 Outline

7 Conclusions

- conclude our Conclusions

Questions?