

UNIVERSITAT JAUME I

Development of a distributed system for real time traffic analysis using agents

by

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in the
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Department of computer engineering

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Declaration of Authorship

I, Pablo Jiménez Mateo, declare that this thesis titled, ‘Development of a distributed system for real time traffic analysis using agents’ and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a master degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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UNIVERSITAT JAUME I

Abstract

Escola Superior de Tecnologia i Ciències Experimentals

Department of computer engineering

Master in Intelligent Systems

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The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Acknowledgements

The acknowledgments and the people to thank go here, don't forget to include your project advisor...

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Abbreviations

API	A pplication P rogramming I nterface
GPS	G lobal P osition S ystem
GUI	G raphical U ser I nterface
IoT	I nternet O f T hings
WORA	W rite O nce R un A nywhere

For/Dedicated to/To my...

Chapter 1

Introduction

In this first chapter, the motivation of the project and its main objectives are stated. After that the time planification, employed technologies and the structure of the rest of the thesis are presented.

1.1 Motivation

Nowadays, with the penetration of new technologies such as smartphones and self driving cars, it is possible to share information about the state of the traffic on the transportation networks. This is very useful to have real time path finding algorithms that avoid congestion.

Furthermore, vehicle to vehicle and vehicle to infrastructure communications has been researched for a long time[1] and is still being researched nowadays [2], and this is a direct application of it.

One of the main concerns with this technology is its possible use for surveillance purposes, given the kind of data this system collects and uses privacy should not be overlooked.

The motivation of this project comes from the necessity of developing a tool that allows us to study the behavior of simulated agents in a real scenario. This system is distributed due to its nature, and keeps the privacy of the users at every moment.

The motivation of this project comes from the necessity of studying autonomous vehicles and how they behave depending on traffic. To achieve this goal a multiagent system that supports the usage of distributed agents will be developed. On it, multiple rerouting algorithms will be tested based on [3] and results will be analyzed based on the real time state of the traffic.

1.2 Objectives

The main goals of the final master projects are:

- Analyze multiagent systems for traffic management
- Analyze the existing algorithms for traffic routing
- Propose an algorithm that analyzes the traffic in real time
- Study and analysis of the proposed algorithm

1.3 Planification

Task	Planned hours	Goal
Study and installation of the JADE library	10 hours	Understand how the library JADE works
Development of a graph to represent the urban network	5 hours	Complete the classes and files needed to represent the network
Development of a communication protocol and its ontologies	20 hours	Understand how the inter agent communication will be done
Development of agents	-	-
- Development of the first mobile agents with JADE	15 hours	Implement the vehicles
- Development of the behaviour of the vehicles	15 hours	Implement the logic of the vehicles
- Development of segment agents	15 hours	Implement the segments
- Development of the agent that keeps the time	10 hours	Implement a reliable and deterministic model of time
- Development of the agent that launches the events	10 hours	Implement an agent able to read events from file and launch them to the simulator
Development of the graphical user interface	25 hours	Implement a graphical user interface to view the results in real time
Development of routing algorithms	35 hours	Implement various routing algorithms
Testing and optimizing the application	40 hours	Stress testing the application
Gathering of results	10 hours	Running simulations and creating the graphs
Documentation	10 hours	Documentation of the communication protocols, ontologies and classes
Writing the thesis	80 hours	Writing of the thesis
TOTAL	300 hours	

TABLE 1.1: Time planification

1.4 Employed technologies

The language of choice for this project was Java [4], Java is an all purpose programming language that can be run in pretty much any device following the WORA [5], from desktop operative systems to mobile devices.

This allows us to create a distributed client for this application that will be able to run in an Android or iOs device, making it way easier for all the users to benefit from it without huge limitations.

The GUI is made using the Java swing library [6] to keep dependencies at a minimum, it is a really powerful library that has been used to allow the user to control the desktop application.

The maps image has been taken from a screen capture of Google Maps, the general area of the province of Castelló.

All the communication between nodes (cars and road side units in this scope) are made in a distributed way using the standalone library JADE [7]. JADE is a software framework for the development of applications using the agent paradigm and distributed communication. It complies with the FIPA specification [8] and also comes with a few graphical tools to make the debugging and development of a distributed application easier, since it is a really difficult task due to its nature.

1.5 Structure

Chapter 2

State of the art

This chapter gives an overview of previous work, and how this thesis fits within those studies.

2.1 Smart cities

In the last few years, smart cities have been a hot topic in research [9] given the quantity of available data provided by the internet of things [10] and big data [11] and the newest infrastructures that allow cities to track activities in real time. This leads to the use of this data to improve the quality of life of the citizen, employment[12] and also saving on unused services when they are not necessary.

Smart cities is a general idea of which smart transport is only a small part, but that is the part that this thesis is focusing on.

2.2 Smart transport

Smart transport is a topic that only recently has started to be researched. [13] defines Smart transport as „adequate human–system symbiosis to realize effective, efficient and human-friendly transport of goods and information.“and that is exactly what this thesis is focusing on, a protocol that will make transportation effective and efficient while being human-friendly.

As seen in this review [14] the criteria to find the best alternatives is very varied, it can be based on social, economic, environmental or even land usage. Our protocol is focused

on minimize the network congestion and thus minimizing the total added time of travel times.

Our application helps analysts to test different routing algorithms in a distributed way so, and mix different algorithms within the same simulation. I believe that this tool will be really useful for anyone that wants an initial test since its usage and output are so easily learned.

Chapter 3

Development of the simulator

This chapter gives an overview of how the simulator has been developed, how its internal parts work and which communication schemes it uses.

JADE uses a peculiar system of agents and behaviors, agents represent a static class that keeps all the information stored but doesn't do anything by itself, that's the behaviors job. Behaviors are like scheduled actions for that specific class, such as moving the car this time unit or drawing the new added cars in the GUI.

It is important for behaviors not take a lot of time, since that is the way to sharing computing time between resources, you execute your behavior and *go to sleep* while other behaviors are executed. This makes for a really fast and efficient way of sharing resources if used correctly.

In this simulator, every behavior takes on Tick (that's the unit of time in the simulator) to finish, then depending on its nature it will be repeated until an ending condition is reached.

3.1 Simulation files overview

In this section an overview of what files and classes that are needed for the simulator as well as a brief overview of the classes will be done.

3.1.1 Agents

This subsection details the JADE agents used by the simulator.

3.1.1.1 Car agent

This agent represents a mobile vehicle with a set speed that moves from a starting point to a destination via valid paths. The route that follows is determined by the type of routing algorithm chosen.

3.1.1.2 Event manager agent

This agent reads all the events from a file and executes them at specific points in time, this helps the application to have a deterministic behavior if anyone wants to redo the experiments.

3.1.1.3 Interface agent

This agent keeps all the information about the GUI and is the one that has to keep all its information updated. It also reads the user inputs (such as changing the timescale).

3.1.1.4 Segment agent

This agent represents a road side unit on one segment of the network, that is the connection between two intersections. The road side unit covers the full extent of the segment. All car agents register on it when entering and deregister when leaving, he is in charge of communicating the GUI the position of its car agents, so that the number of messages is reduced (from one message per car to one message per segment).

3.1.1.5 Time keeper agent

This agent keeps the simulation synchronized between all agents, this makes keeping track of time and making scheduled events possible. This is the key to make all the cars move at the same time and, schedule events at a certain moment of the day (such as 12:00).

3.1.2 Behaviors

This subsection details the behaviors used by the simulator.

3.1.2.1 Car behavior

This behavior is used by the Car agent and calculates the next graphical position of the car. It also registers and deregisters the car from the segments. Registering is done when the car enters in a new segment and deregistering is done when the car exits a segment.

In every tick it moves and registers or deregisters of the segment if needed, this is a cyclic behavior that ends when the car reaches its destination.

3.1.2.2 Event manager behavior

This behavior is used by the Event manager agent. It executes the events that has in memory that have previously been read by its agent, if it is the time to execute that event it sends the instructions to the interested party. It also formats the time displayed in the GUI so that it is human readable.

In every tick it sends all the necessary messages if a event is executes, it also sends a message to update the time. This is a cyclic behavior that ends when the simulation ends.

3.1.2.3 Interface add car behavior

This behavior is used by the Interface agent, it receives the instructions to create a new car (from the manager behavior) and creates the graphical representation of it and keeps it updated.

In every tick it checks if a new car has to be added. This is a cyclic behavior that ends when the simulation ends.

3.1.2.4 Interface draw behavior

This behavior is used by the Interface agent (yes, agents can have more than one behavior) and it updates all the parts of the GUI. It updates all the cars position on the GUI, adds new cars to the GUI, deletes cars that have finished from the GUI and updates the time and the number of cars on the GUI.

In every tick it checks whether he has to update the any part of the GUI or not (usually it has to update all the cars position since they move every tick). This is a cyclic behavior that ends when the simulation ends.

3.1.2.5 Segment listen behavior

This behavior is used by the Segment agent and listens to messages from cars to register or deregister, or to update their position. It also listens for messages from the Event manager in case it needs to change its service level.

In every tick it checks for messages from cars or events and updates its lists of registered cars. This is a cyclic behavior that ends when the simulation ends.

3.1.2.6 Segment send to draw behavior

This behavior is used by the Segment agent and sends the information about the cars that are registered on it to the Interface agent so it updates the car positions.

In every tick if there are any cars on it, it sends their information to the interface agent. This is a cyclic behavior that ends when the simulation ends.

3.1.3 Environmental classes

This subsection describes the classes that the simulator uses to model the road network.

3.1.3.1 Intersection

This class represents an intersection, that is a point on the map where one or more segments end or start. It is only possible for a car to change between segments here.

3.1.3.2 Segment

This class represents the connection between two intersections. Each segment has a origin and an end, it also keeps all the important information such as maximum speed, number of tracks and density. This class also has a list of steps that contain the information for its graphical representation.

3.1.3.3 Step

This class is used to represent a line in the canvas where the graphical map is drawn, it contains the x and y coordinates for the initial and ending point of that line, segments are usually made up of more than one step so its graphical representation is real life like.

3.1.3.4 Path

This class is used to keep the segments and steps that a car has to follow to get from its origin to its destination, this path can be dynamically computed depending on the algorithm of choice.

3.1.3.5 Map

This class represents the whole road network, it reads the data from file and instances all the necessary classes to build the directed graph, it also instances the segment agents. It provides many methods to work with the graph.

3.1.4 CanvasWorld

This class contains all the information that is needed to draw the GUI, it also contains an API that allows the Interface agent to modify its contents.

3.1.5 Main

This is the class that is called when the program is started it spawns the required JADE services. It also provides a few configuration options that are worth mentioning:

- **tickLength:** This parameter is used when the application is used in headless mode, that is without spawning the GUI, which is very useful for servers. This overwrites the default tickLength that is usually set by the user via a slider in the GUI. *Default:* 1L
- **startingTick:** This is the tick at which the application starts, because this tick represents one simulation second you can do something like $7 * 3600 + 30 * 60$ to make it start at 7:30 am. *Default:* $7 * 3600 + 59 * 60$
- **finishingTick:** This is the tick at which the simulation will end. *Default:* $24 * 3600$
- **numberOfCars:** This parameter allows the user to put a certain number of smartcars at the beginning of the simulation, this is very useful for stress tests. *Default:* 0
- **drawGUI:** This parameter allows running the application in headless mode. *Default:* true

- **startRMA**: This parameter allows the control of starting the JADE Remote Agent Management, which is an interface to an administration panel for the agents. *Default*: false
- **segmentLogging**: This parameter allows the control of the logging system. *Default*: false
- **loggingDirectory**: This parameter allows us to change where the log files will be stored. *Default*: ""

3.1.6 Search algorithms

At the moment of writing this thesis, there are only three implemented algorithms. The simulator uses the Factory method programming pattern [15] so that if any researcher wants to add a new algorithm he or she can do it easily.

3.1.6.1 Shortest path algorithm

This algorithm is an implementation of the Dijkstra's algorithm [16] that looks for the shortest path on the graph. Cars using this algorithm always take the same path given the same origin and the same destination.

3.1.6.2 Fastest path algorithm

This algorithm is a modification of Dijkstra's that focuses on time rather than on distance, this algorithm searches for the longest time for a given segment knowing the maximum speed of the car and of that segment. This **does not** take into account the state of the traffic.

3.1.6.3 Smartest path algorithm

This algorithm is yet another modification of Dijkstra's algorithm, this algorithm focuses on minimizing the trip time and takes into account the current traffic, so that if there is a congestion on a path and the average speed is slower, it will change to a longer path whose total trip time is lower.

3.1.7 Static files

This subsection will describe the static files that the simulator needs in order to run.

3.1.7.1 Events

A file of events is needed so the simulator can run them, the file should be in *csv* format.

Type	Time	Origin	Ending	Maximum speed	Algorithm
newCar	08:53	I-CV10-08	I-N340-07	86	fastest
newCar	22:27	I-AP7-01	I-CV10-03	114	shortest
newCar	11:07	I-AP7-01	I-CV10-04	86	shortest
newCar	11:46	I-CV10-04	I-CS22-04	105	smartest

TABLE 3.1: A few rows of the events.csv file

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