Multi-Agent Systems in Traffic and Transportation

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Abstract

MAS application would be a very helpful tool when applied to traffic and transport management. It could construct a more flexible and autonomous traffic network if modeled as agents, that would be more efficient, time-saving and environmental-friendly that the systems used currently. There are still a lot of challenges to deal with before real-life and real-time applications are possible, but simulation environments are starting to be used for research, and its results are being used in the streets.

1. Introduction

Multi-Agent Systems (MAS) are an extremely helpful tool to implement Traffic Management. These systems are formed by a collection of independent agents (such as cars, traffic lights, etc.), that work and collaborate with each other. Each of these agents is able to provide an abstraction layer, which aids in the simplification of the complexity scale of the overall system.

The main goal of using MAS in Traffic Management is to create a more dynamic, flexible and autonomous system that is capable of reacting to changes even in unpredictable situations, such as accidents, construction sites and traffic jams. This would improve not only efficiency regarding routes, and commute times, but also safety and environmental impact.

2. Applications

MAS technology is successfully used in the case of distributed systems. These systems are those in which their components, agents, can make their own decisions, where each performs a task so that the entire system can achieve its main goal. Their environment is continuously changing, so the communication between agents is a critical task, in order to cope with unexpected situations. Agents have the ability to make their own decisions depending on the conditions of the environment, making the system more autonomous and flexible.

The domain of traffic and transportation is geographically and functionally distributed, its subsystems have a high degree of autonomy, and its environment is highly dynamic, which makes it very adequate for MAS.

The fact that transportation systems are dynamic makes it essential that they are controlled in real-time, which becomes even more important when fast responses helps avoiding life-or-death incidents.

There are three main potential areas of traffic and transport management were MAS are applicable:

2.1. Traffic management

Traffic management is the process of planning, implementing, testing and administrating traffic in order to optimize assignment of traffic supplies to traffic demands under economic and environmental features.

The fact that traffic management is currently highly centralized, and that cars do not give any kind of feedback, makes it very difficult to apply helpful traffic management in real life. That is why it is mostly used in simulation, where we can know the position and intention of every agent in the system. This could change, however, with the addition of smart, self-driving cars (such as Google's Waymo, Tesla's cars, etc.), as they could interact with the whole system much better.

There are some international projects that study interconnection of information systems, real-time Dynamic Message Sign updates, fleet management and emergency systems in traffic management.

2.2. Traffic guidance and control

Agent-oriented approaches may improve existing road, air and rail traffic guidance and control systems by enhancing their interaction capabilities.

On the one hand, in real applications, the predominant type of interaction is between components of a specific infrastructure, such as synchronization of traffic lights, or traffic signs.

However, there is almost no interaction between components of different infrastructures, like between different means of transport, where, if there is any interaction, is just statistics exchange, and no active coordination of activities.

On the other hand, there are many components used in road traffic guidance (speed warnings, changing traffic signs for the surveillance, mobile and stationary meters) that are not as adaptative as they would be if modelled as agents.

We could build a network composed of these components in order to model a MAS where agents communicate and interact to be more efficient when driving or preventing car-jams.

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2.3. Capacity and resource management

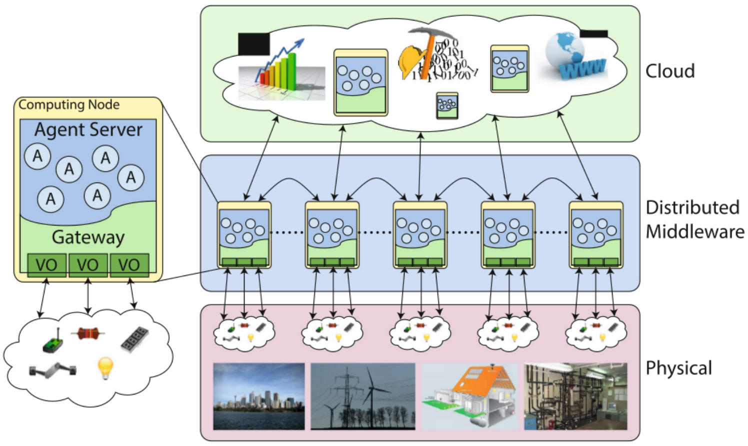
Capacity and resource management is largely to do with provision of transport means based on demands, under the legal, economic, business and technical restrictions and criteria.

Such tasks can be seen in various organizations such as shippings and freight logistics, taxi firms, public transportations and airlines.

A good example is freight transport, where some vehicle might be overloaded, whereas in their returning trip may be almost empty. MAS could be used to plan a demand-oriented schedule, where the vehicle react dynamically to the transport requirements.

3. Current projects

The SmartCity Cosenza project [5], by Res-Novae is a smart street environment using MAS that implemented in the city of Cosenza, Italy. It is located in the center of the city, using an architecture called Rainbow platform. This architecture implies that sensors are spread around the city, and gather raw data which is sent to the nodes (modeled as agents) that process the data (calculate the mean, overall info, etc.) summarizing it and sending it to the central server that is in charge of the tasks that need the information of all the nodes, while each node is able to respond to the needs of its designated area.

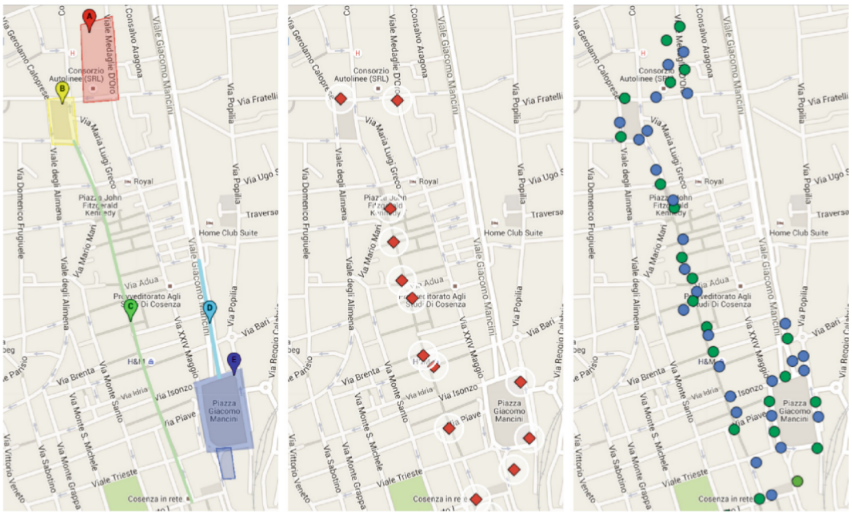


Rainbow Architecture

There are two types of sensors: type A, which host noise, temperature, humidity and luminosity sensors and type B, which host air quality sensors.

All this information is shown in an real-time mobile application that can be used by users or research purposes.

Kimley Horn enterprise is in charge of a lot of projects that try to use different technologies in order to improve different areas. We will talk particularly about KITS Advanced Traffic Management System, [6] that is locally applied in the city of Austin, Texas. Cyclists can download a phone app, that takes into account their location, so that the city's traffic management system prioritizes their ride in real-time. It has been proven that the cyclists' routes flow is improved.



(a) (b) (c)

Smart Street Cosenza. (a) Target areas; (b) Computational Nodes; (c) Sensors nodes. Green locations host one type A node and one type B node, blue locations hosts only a type A node.

4. An ideal future

In an ideal future, thanks to MAS, we could achieve deep vehicle-to-vehicle cooperation. Such cooperation could help in many areas.

One example could be parking search, where there have been several studies, and some [4] achieve up to 25

A feature that is related to this one, is social memory, which enables agents to remember not only who they interacted with, but also who helped us, so that the next time we could help them back. That way, we could build a trust network of vehicles and things, so that future interactions would yield greater efficiency in expressing intent.

Another example would be Smart Cities. These cities are composed of several agents, such as environmental sensors, traffic lights, and other technologies to manage a city's assets. These could also interact with smart vehicles, so that vehicles can improve decision-making, safety and mobility (by warning about road status).

5. Agent-oriented traffic simulation

Traffic simulation models can be classified into two types of models: macroscopic and microscopic.

Macroscopics ones take into account the global qualities of traffic flow.

Microscopic, on the other hand, observes the behaviour of an individual vehicle. It also takes into consideration the capabilities of the driver of the vehicle (perception, intention, driving attitudes...).

We are going to center on MATSim software for traffic simulation, in this case, MATSim is a mixture of both, is simulates the behaviour of each vehicle individually, much like in particle physics simulations, but also is capable of showing the traffic flow in general, giving an important insight into the traffic issues. It even offers the previously mentioned demand-scheduled public transport, which should improve the usage of the city-resources.

MATSim provides a framework to implement large-scale (up to around 10 million) agent-based transport simulations. The framework consists of several modules which can be combined or used stand-alone. Modules can be replaced by own implementations to test single aspects of your own work. Currently, MATSim offers a framework for demand-modeling, agent-based mobility-simulation (traffic flow simulation), re-planning, a controller to iteratively run simulations as well as methods to analyze the output generated by the modules. Moreover, it allows some Smart City-like simulations too, like pollution simulation[1], traffic light management, and even evacuation simulation, in case of an imminent catastrophe[2].

[1] http://matsim.org/gallery/quito
[2] http://matsim.org/gallery/padang

6. Challenges

In order to achieve a complete system of autonomous traffic, we still have to deal with a large number of challenges.

The first challenge could be how the vehicles would communicate with each other. Ideally, all vehicles would be programmed equally, but since that will not be possible, a standardized message format will have to be developed, that is usable in any situation.

Another challenge could be related to local traffic laws, where each country or area could have different rules such as speed limits, or preference, the vehicles must adapt to.

It is also difficult to decide which vehicles to cooperate with. It has been shown unnecessary to cooperate with all vehicle in the same city, and that it is enough with those close-by. However, deciding which are the cars with which we have to interact, is not an easy task.

A major challenge would be to know when the autonomous vehicle has to let some decisions to the passengers. For example, if the vehicle has to drop them in some place, and it is jammed, the passenger might prefer to be dropped further away, and walk, rather than waiting in the jam. That is why the smart vehicle has to decide when to ask the passengers.

Apart of these, there are still a large number of ethical issues, but these have been heavily discussed in other documents, and therefore we are not going to address them in detail.

7. Conclusion

Agent-oriented techniques provide an improved approach to software development. They provide a set of tools that can be applied to domains that are functionally or geographically distributed into autonomous subsystems, where the subsystems exist in a dynamic environment, and they have to interact. The range of application of MAS make traffic and transportation areas adequate models as they fulfill the characteristics to use agent-oriented techniques.

In the report we have explained many applications that could be improved using MAS, but nowadays there are only conceptual applications as they are not applied in real life yet. Their implementation could bring a lot of benefits as a more efficient air, rail and road network, making it more ecological and even economical as they would become more autonomous and dynamical.

The MAS applications are now mainly used for simulation purposes only as it can be seen in the MATSim software.

References

[1] Birgit Burmeister, Afsaneh Haddadi, Guido Matylis, *Application of multi-agent systems in traffic and transportation*, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.195.6148&rep=rep1&type=pdf

[2] I.Cobeanu, V.Comnac, *Multi-agent systems: traffic control applications*, http://webbut.unitbv.ro/BU2011/Series%20I/BULETIN%20I/Cobeanu_I.pdf

[3] *MATSim traffic simulation software*, http://www.matsim.org/

[4] Seng W. Loke, *Creating a Social Brain for Cooperative Connected Autonomous Vehicles: Issues and Challenges*, https://arxiv.org/abs/1710.00461

[5] Andrea Giordano, Giandomenico Spezzano, Andrea Vinci *Smart Agents and Fog Computing for Smart City Applications*, https://link.springer.com/chapter/10.1007%2F978-3-319-39595-1_14

[6] Kimley Horn, *KITS Advanced Traffic Management System*, https://www.kimley-horn.com/service/kits-advanced-traffic-management/