A Multi-Agent Based Framework for Controlling Self Managing Fleets of Autonomous Vehicles with a Transparent Reasoning Process

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Abstract

This dissertation aims to research on multi agent systems to develop a base system to control a fleet of self-driving and self-organizing vehicles with a transparent reasoning process. The main focus for the application area is on the use in mobility as a service/ride hailing scenarios. Every vehicle will be controlled by a belief-desire-intention agent and will use utility functions to make its decisions. The agents will delegate unfavorable jobs to each other by using the contract net protocol for a decentralized decision making.

Keywords

BDI Agent, Multi-agent system, Mobility as a Service, Simulation, XAI

1. Introduction

Due to climate change growing scarcity of resources we have to reconsider parts of our way to live. One of these is the mobility sector which offers great potential for optimization. A new and much more efficient way to move could be mobility as a service (MaaS) which means to buy "mobility services as packages based on consumers' needs instead of buying the means of transport" [1]. A specialization of MaaS where every passenger is served by a single autonomous vehicle is called ride-hailing [2].

MaaS solutions based on a free floating model that are designed to cover the last few meters, such as the bike and scooter sharing services that are widely used today, have some problems. They tend an accumulation of vehicles in remote, inconvenient or dangerous places. To cover this, additional employees are needed to permanently pick up the vehicles and place them at locations with higher customer traffic.

This dissertation is part of a project that uses a multi agent system (MAS) to develop a self driving and self-organizing fleet of E-trikes which are intended to be used in a free float model. This system is designed to be an improvement of the above described already available sharing services. The vehicles will drive autonomously to the position of a calling customer, search proactive for useful parking positions when not in use, drive to a charging station when needed

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and communicate with each other to find the most suitable E-trike for every incoming job. Every vehicle will be controlled by an BDI agent. Customer orders are first delegated to the nearest vehicle. This vehicle will use a utility function to decide if the customer job can be handled by itself. If not it will use the contract net protocol (CNP) to delegate it to a more suitable E-trike. For this decision, the utility function will take into account, among other things, the already accepted customer trips, the current battery level and expected arrival times. By using the BDI architecture, each agent can think about the order and the way in which it performs its tasks, which include customer, loading and parking trips.

As trust is an important factor between interactions of humans and AI systems [3] we want to achieve this for the framework. The reasoning process should be transparent and decisions should be explainable to the user (e.g. why there is currently a waiting time). Also further predictive explanations should be provided (e.g. user wants to know how much longer he has to wait).

In a first step the advantages of such a system will be examined in a simulation, later it is planed to build two prototypes which will be tested in real life on the university campus. This dissertation focuses on the development of the MAS and the evaluation by using a simulation. The development of the hardware or software components, that does not belong the decision making (like the obstacle detection as part of the autonomous driving), is not part of this thesis. The MAS developed in this dissertation will be designed in such a way that it is suitable as a basic framework for use in other scenarios with autonomous self-managing vehicles.

2. Motivation

The individual technologies and methods in this dissertation are all well studied in their own right. Their combined use for the upper described use case, especially in the context of XAI, seems new and not much researched. An evaluation of the possibilities of such a combination seems to be an interesting research gap.

Multi-agent approaches in context of traffic scenarios are discussed in [4]. BDI agents are well known and have already been used for vehicles in projects that are to some kind comparable to this [5] but mostly focused on the design of the agents and without an performance evaluation. There are projects which researches similar problems but differ in the detail. So [6] uses neither BDI agents nor the CNP. There are research projects in ride-hailing, but without the use of BDI agents for the vehicles [7]. There are also highly scalable decentral approaches for decision making but without the communication aspect of this project [8]. Projects that use both, BDI agents and a utility function, are not in the context of ride hailing [9]. The decentralized decision-making approach is also not widespread. In projects with an similar application scenario centralized approaches seem to dominate. [10]

3. Research Question

The goal of this dissertation is to develop a MAS framework with a transparent reasoning process that can be used to control a fleet of cooperating autonomous self-organizing vehicles usable for various application scenarios. Although this MAS framework is intended to be usable for a variety of application scenarios, the focus is on ride-hailing with e-trikes as described above.
The aim is to find a reasonable balance between the achievability of the goals (in the case of the ride-hailing scenario the waiting/driving times or customer losses) and the energy consumption of the overall system.

Research Question: How can a MAS framework for self-driving autonomous vehicles be developed, to provide a transparent reasoning process for users across different application domains?

To date, the following sub questions have been found that should be answered:

- How does such a MAS compete with traditional/already existing solutions in terms of the achievability of its goals?
- How does such a MAS compete with traditional/already existing solutions in terms of the resources required?
- How does the different features of the MAS influence the results mentioned above?
- Can the user understand the decisions made by the agents' reasoning process at any point in time?

4. Approach and first Results

With the BDI architecture, a suitable agent architecture has already been identified for the project. The list of tasks that an agent has to fulfil changes regularly. Therefore, it is necessary for the agent to keep thinking about the best possible plans to fulfil them. For the communication between the agents the contract net protocol have been identified as a possible solution. Initial results have already been collected with a simplified prototype based on the JADE [11] agent framework [12]. For the use in a cyber-physical system planned in a later project phase, a separation between agent framework and simulation environment is aimed at. For this purpose it is planned to connect BDI agents implemented in Jadex with the Matsim simulation environment [13].

5. Planned Evaluation

The capability of the developed multi agent system will be evaluated by using simulations. One part of the evaluation will take place in the former described ride-hailing scenario. Therefore it is planned to use different configurations to compare the actual influence of the the special abilities of the system (ability to communicate, to delegate trips, proactive charging and parking trips) with different evaluation criteria. Criteria such as the energy consumption of the entire fleet, waiting and travel times, and the loss of customers due to delays can be used for the evaluation. Corresponding tests are to be repeated with different scheduling strategies, parking behavior and loading behavior. It is also planed to measure the benefits of the MAS compared to a much simpler, already available ride-hailing system and an centralized optimization approach.

It is considered to evaluate the capability of the MAS in an other application scenario to show the universal applicability. This could for example be a garbage collection scenario. In the process, the MAS will control autonomous trucks that must efficiently collect trash from various locations. The details of the evaluation of this scenario and the XAI component are not yet elaborated.

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