Applying swarm intelligence to manage multimodal traffic and transport flows

DIT4TraM

Distributed Intelligence & Technology for Traffic & Mobility Management

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Our mobility ecosystem is becoming increasingly complex, especially in urban areas. This makes it virtually impossible to manage traffic in the traditional centralized way. Is another approach conceivable? In the EU project DIT4TraM we apply *swarm intelligence*: with little or no control from above, yet still achieving a common goal. This approach is tested in six different pilots.

It's a fascinating spectacle—tens of thousands of starlings that form beautiful moving patterns in the air. Their aim is to scare off their natural enemies, biologists explain. The great thing is that they succeed in doing so without any direction or guidance from above. How do they do that? The swarm creates harmonious patterns because all birds individually follow a small set of local rules. These rules are also remarkably simple, like 'keep enough distance from the neighbors, but not too much.'

Swarm intelligence

Traffic participants also have a common interest, namely a smooth and safe flow of traffic. To achieve these goals, road authorities use centralized traffic and mobility management to control and correct the traffic flows. But our mobility ecosystem has become so complex over the years that controlling traffic 'from above' is no longer tenable—especially if we want to manage it in a multimodal way and include new transport services as well.

This forces us to think about a completely different approach to our traffic and mobility management. In this context, can we learn from the starlings and stop regulating centrally and top-down, and instead start regulating *locally* and *bottom-up*?

In the DIT4TraM project, Distributed Intelligence and Technology for Traffic and Mobility Management,

twenty knowledge institutions, companies and governments are investigating for the first time whether this 'swarm intelligence' approach is feasible for traffic and transport. Our focus is on individual travelers, connected cars, smart bicycles, and intelligent traffic control systems. Simply put, we are exploring how we can get these *agents* to communicate and interact locally in such a way that they automatically contribute to the greater goal of a smooth and safe traffic flow.

Four applications

DIT4TraM runs from 1 September 2021 to 1 September 2024. Our goal is to develop control concepts and algorithms based on swarm intelligence for the widest possible range of applications during this project period. We're including different modalities, from pedestrians to cars to subsystems. And we focus on different use cases, from local traffic control to regional traffic and mobility management.

We are, of course, looking at *fully decentralized* solutions with one hundred percent self-organization, drawn up according to the so-called 'mechanism design' concept. But we also include solutions with *distributed* intelligence: solutions that are local where possible and centralized where necessary. In this case, central intelligence, such as a traffic management system at the traffic center, monitors the situation in general and only interferes if the local intelligence falls short.

Six pilots

To test and develop all new knowledge and insights in practice, six pilot studies in four EU countries are organized: in France (Bordeaux), Greece (Glyfada and Athens), the Netherlands (Amsterdam and Utrecht), and Spain (AP-7 freeway). With these pilots we test the gains to be achieved for traffic flow, safety and liveability and look at the effects on reliability and resilience.

With these results, we create a better understanding of which principles of swarm intelligence can be used for traffic and transport. And this knowledge is expected to lay the foundation for a 180-degree paradigm shift in our traffic and mobility management.

Four applications

1 Cooperative connected traffic management

How do we optimally distribute traffic at the micro level of, say, an intersection? Traditionally, the local traffic management system distributes the green of the traffic lights among the traffic participants. But in DIT4TraM we investigate the extent to which (connected) traffic participants themselves can achieve optimum green-time allocation. Such a local solution requires information about the type of road user, the destination, and the preference, combined with a set of 'priority rules' and incentives.

2 Cooperative distributed traffic management

In this application, traffic control systems, ramp metering systems and other local systems work together to optimize the network. To this end, they negotiate with their 'neighbors' about the measures. For example, does dosing traffic here not cause inconvenience further down the road? How do we ensure that pedestrians, cyclists, shared cars, and public transport get the priority they deserve, while coordinating the flow of car traffic as well as possible?

3 Decentralized demand management

In this application field we work with tradable multimodal travel permits. The idea is that travelers buy or sell their 'permit' to a ride among each other, depending on the demand at that moment. Those who need to travel to a busy destination at a busy time will automatically pay more. Those who are more flexible can save money by postponing a planned ride, sharing the ride or traveling with another modality. We investigate the extent to which this decentralized approach leads to fewer peak loads and a better distribution of passengers. Where necessary, the government will intervene by, for example, capping the number of permitted (car) trips.

4 Cooperation between transport services

Public transport companies and commercial mobility services have different objectives and are, in a way, competitors. Here, too, we examine the extent to which the mutual interactions between these actors organize themselves into a stable, possibly optimal situation and the extent to which (limited) interventions, such as agreements on mutual coordination, can prevent a suboptimal situation.

Six pilots

Bordeaux, France 1

Real-time auctioning for prioritizing traffic at intersections

Bordeaux is testing a new scheme for intersections with intelligent signal control, where (connected) road users negotiate priority. The two main test cases are: priority for cyclists and priority for shared car users. We will focus on more complex processes where multiple vehicles with different priority levels request priority within the same signal cycle.

Utrecht, the Netherlands 2

Distributed regional traffic management

The city of Utrecht was one of the first cities to experiment with multimodal and multi-objective regional traffic management on a large scale. In this DIT4TraM pilot, we test a distributed form of this regional approach. At least eight traffic control installations and three ramp metering installations will coordinate traffic management 'locally'.

Amsterdam, the Netherlands 3 4

Resilient mobility management through cooperation between travelers and stakeholders

The Amsterdam pilot takes the form of a massively multiplayer simulation game: human decisions are combined with a dynamic simulation to determine the consequences of decisions for multimodal transport networks. The pilot revolves around the cooperation between travelers themselves and between providers. For travelers it is about auctioning mobility permits, for stakeholders to try to harmonize private and public objectives.

Glyfada, Greece 3 4

Optimized on-demand services for complex urban settings

The city of Glyfada in Greece wants to strengthen the public transport network with flexible, demand-driven mobility services. The idea is that the different services will work together and not compete. To this end, Glyfada will lean on concepts and algorithms developed in DIT4TraM for passenger flow management, fleet management, and optimal vehicle allocation. The city is also deploying tradable mobility permits.

Athens, Greece 2 3 4

Integrated distributed management for urban mobility

A simulation is planned in Athens to test almost all the concepts and systems being developed in DIT4TraM. The intention is to integrate the modules, model-wise at least, into the Athens traffic management system. After that, the effect of the 'swarm intelligence paradigm' can be calculated on traffic flow, safety, liveability, and resilience—and this for situations as diverse as high summer, normal working days, accidents, and so on.

Barcelona, Spain 1 2 3 4

Integrated distributed management for interurban mobility

For this project, the northeastern section of the Mediterranean AP-7 highway was selected for the use case. The 37-kilometer section between La Roca del Valles and La Jonquera has been accurately modeled at a microscopic level and equipped with a plug-in to represent the Infrastructure to Vehicle (I2V) communication. We investigate what happens if the current approach of toll collection is replaced by a system of distributed traffic and mobility management, based on the DIT4TraM concepts.

1 2 3 4 > *applications* (see overleaf).

DIT4TraM is a collaboration between twenty knowledge institutions, companies, and governments. The project is funded by the European Union's Horizon H2020 Program, has a duration of three years and a budget of almost 5 million euros. TU Delft is assigned as the coordinator of DIT4TraM.

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