travolution

City-wide optimization of light signal control with Genetic Algorithms

Communication between driver and traffic light

A milestone in road traffic technology

Results from the Bavarian research project

travolution

Project Partners

Office for Traffic Management and Geoinformation, City of Ingolstadt

Audi

Technische Universität München, Chair for Traffic Engineering

GEVAS SOFTWARE

Supported by Bavarian State Ministry of Economics, Infrastructure, Traffic and Technology

Introduction

The name of the project did not come by chance: TRAVOLUTION means **TRA**ffic and e**VOLUTION**, which makes clear that urban traffic control is significantly improved with the help of **evolutionary mathematical optimization techniques**.

When the project was launched in spring 2006, it has been the intention of all project partners to reduce waiting times and stops in the whole major road network of Ingolstadt by applying state-of-the-art traffic technology. The positive effects on traffic should not only be a real improvement for motorists, but as well reduce veritably the negative aspects of urban traffic for the environment.

TRAVOLUTION followed two major approaches:

First, optimization of light signal control is used in the whole main road network for all individual traffic at the same time, whereas Genetic Algorithms are applied on-line for the first time in Germany. By mathematically imitating the process of natural evolution, the complex problem of optimization can be realized within the available time period, which is normally 5 to 15 minutes for a macroscopic cycle. In traffic-adaptive network control, 'Green Network Waves' are calculated, which can deal with forecasted traffic flows much better than previous vehicle-actuated control methods.

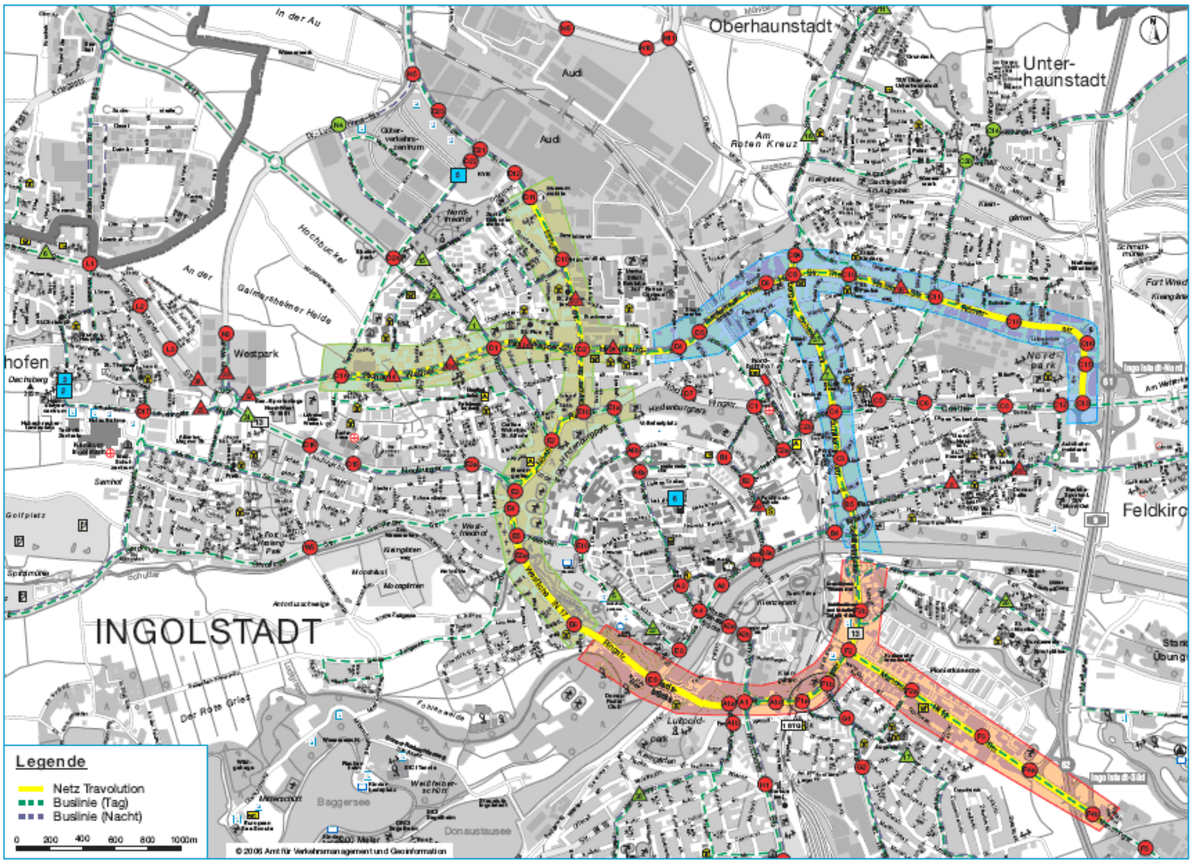

Figure 1: Main road network in Ingolstadt equipped with BALANCE

The second TRAVOLUTION idea is in the responsibility of project partner AUDI. As a premium car manufacturer, AUDI is always working on first-class driver assistance systems. In order to provide drivers early with important information, it is essential that the vehicles can communicate with their surrounding infrastructure.

In the TRAVOLUTION project, a **car2infrastructure communication** has been tested for the first time in Germany. At three busy intersections, light signal control was enabled to inform the approaching vehicles about traffic signalling expected for the following seconds and minutes. With an intelligent display, drivers can adapt their speed, so they don't have to stop at red lights in almost any case. Such an intelligent way of driving consequently reduces fuel consumption, air pollution and noise.

Figure 2: Inside an AUDI test car

Traffic-adaptive network control with Genetic Algorithms

What are Genetic Algorithms?
Genetic Algorithms, short GA, are part of so-called Evolutionary Methods in modern mathematics. These methods are very successful in solving optimization problems which are too complex for conventional methods. Urban traffic can be seen as such an 'insolvable problem'. Mathematicians speak of 'very large solution spaces', which means that hundreds of parameters have to be determined simultaneously, so that a weighted system optimum can be reached.

In TRAVOLUTION, coordinated light signal control optimally adapted to the expected motorized traffic is regarded as a 'living creature'. Every creature has certain characteristics, which are passed on to following generations in a process of reproduction. The necessary information is in the creature's genes. Now technical terms from normal genetics – like mutation, combination, selection, re-combination – can be used in traffic technology as well.

The creatures evolving over many generations are either 'fit' or 'not fit'. What does the term 'fit' mean for road traffic technology? In a simulation of expected traffic flows, the sum of waiting times, stops and travel times is calculated for a network control. Now one can see how good the network control deals with traffic. If the network control is 'fit', it can reproduce itself. The less fit control is not reproduced – that's nature! In the process of evolution, the control becomes better and better, until the fittest variant emerges.

In TRAVOLUTION, these Genetic Algorithms were developed by GEVAS software in cooperation with Technische Universität München. The first large scale test took place in Ingolstadt, a city with 130.000 inhabitants and more than 30.000 people working at the AUDI factories. The test area covers a major part of the city's road network, has 46 light signal systems and two connections to the A9 autobahn.

Ingolstadt's very successful public transport acceleration is not affected negatively by traffic-adaptive network control. Because public transport prioritization is executed decentrally at the light signals every second (the buses register at the light signals via radio), there is no conflict at all with network control, which is working in the acle of minutes. Public transport priorization in general, however, sometimes has negative impact on individual traffic. Those impacts are detected by network control, which then tries to minimize them temporally and spatially.

Results from traffic-adaptive network control

The TRAVOLUTION effects were evaluated in three test series with Floating Cars and automatic license plate recognition.

The **starting point** for the measuring was the existing traffic-actuated light signal control with green waves. In a **second step**, the values for BALANCE without Genetic Algorithms were measured. That version of traffic-adaptive network control uses a Hill-Climbing Algorithm, a heuristic search method which does not cover the very large solution space entirely. However, this was made possible in the **third step**: traffic-adaptive network control BALANCE with Genetic Algorithms, which were developed for the TRAVOLUTION project.

Consequently, there were three scenarios for the test series.

Scenario 1: Comparison between the existing traffic-actuated control with green waves and BALANCE with Hill-Climbing Algorithm (BALANCE-HC)

Scenario 2: Comparison between traffic-adaptive network control BALANCE with Hill-Climbing Algorithm and BALANCE with Genetic Algorithms (BALANCE-GA)

Scenario 3: Comparison between the initial traffic-actuated control and traffic-adaptive network control BALANCE with Genetic Algorithms

The table shows **reduction of time loss** at light signals in the three scenarios:

Time period	**Scenario 1:** Compares basic control to BALANCE-HC	**Scenario 2:** Compares BALANCE-HC to BALANCE-GA	**Scenario 3:** Compares basic control to BALANCE-GA
6:30 – 9:00	-12%	-8%	**-19%**
9:00 – 15:00	-5%	-4%	**-9%**
15:00 – 19:00	-21%	-15%	**-32%**
Daily average: 6:30 – 19:00	**-12%**	**-10%**	**-21%**

The last column shows the comparison between the initial situation (vehicle-actuated green waves) and traffic-adaptive network control BALANCE with Genetic Algorithms. Over one day, average time loss (waiting times) at the light signals has been reduced by 21%.

Compared to previous BALANCE with hill-climbing optimization, the waiting times have been reduced by another 10%. BALANCE-HC, however, is already 12% better than conventional basic control.

During peak time between 15.00 and 19.00, lost time at light signals was reduced by 32%.

The **number of stops** has decreased by 17% average over one day.

From these results, the environmental improvements can be calculated: reduction of fuel consumption by 19%, which means 700.000 liters of fuel less per year and 1.600 tons less of CO_2 in the air.

The informed driver

Three intersections in the west of Ingolstadt were equipped with Road Side Units (RSU) including WLAN hotspots, which are able to communicate with specially equipped test cars in an area of 200 to 300 meters around the light signal. In addition, software components have been installed in the light signal controllers, which calculate the following green intervals. This is highly complex, since these light signals are operated with a vehicle-actuated control method and buses always have the highest priority.

The following image shows a display in a test car. In the upper part of the display, drivers see the 'green carpet' and an optimal driving speed. If the car is driven at recommended speed, it can pass the next intersection without having to stop at red lights.

Figure 3: 'Green carpet'-display in an AUDI test car

The tests carried out by AUDI have received very positive feedback. It can be expected that communication between car and infrastructure will advance further in the near future.

Future prospects

The TRAVOLUTION results have exceeded the expectations of all project partners. The large scale test in Ingolstadt has proven the potential of modern information technology in urban traffic control, which leads to overall economic savings.

Drivers save fuel, environmental pollution is reduced and driving in cities becomes more relaxed. It can be assumed that drivers recognise – and appreciate - a reduction of travel times by one fifth.

Munich, July 2008