MOTION - A NEW ON-LINE TRAFFIC SIGNAL NETWORK CONTROL SYSTEM

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HERMES is a DRIVE II project which focuses mainly on the enhancement and application of traffic control strategies that are based on on-line Origin/Destination information and Automatic Incident Detection. The biggest workpackage within HERMES aims at the development of a new on-line traffic signal network control system named MOTION (Method for the Optimization of Traffic Signals In On-line controlled Networks).

This work is to some extent based on results already achieved previously in a project study made for the SIEMENS AG [1] and in the DRIVE I project ODIN [2 and 3], where algorithms for the on-line estimation of Origins and Destinations of the major streams at single intersections and in wider urban road networks have been developed together with initial concepts for the use of this information in traffic control. Simulation results have already shown that improvements of 8% to 20% in the traffic performance are possible, if signal control schemes are based on O/D-information.

MOTION determines on-line:

- split as a function of traffic volume and actual turning movements at the intersection,
- cycle time mainly according to the traffic volumes at critical intersections,
- number of stages and stage sequence initially as a function of the minimum sum of intergreen times and the geometric situation resulting from automatic time-space-diagram design, but stages can then be added or omitted on actual demand, and
- offset by minimising stops and delays for all traffic, but in particular for the major traffic streams in the network as identified by the O/D estimation.

In line with the needs identified in most European cities today, MOTION also makes provision for giving special priority to public transport vehicles.

MOTION is being developed by Siemens AG, The MVA Consultancy, Heusch/ Boesefeldt GmbH and the Technical University of Munich.

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THE OVERALL CONCEPT

The basic idea of MOTION is to combine the advantages of well designed Green Waves for the major traffic streams in a network with the flexibility of an immediate response of the local signals to the actual state of traffic. To enable this flexible control, all components of a signal program are optimised: cycle time, stage selection and sequence, offset, and split.

In order to integrate existing control on local level and/or in particular parts of the network and, furthermore, to facilitate the further development of the system, the system was developed in a strictly modular structure.

MOTION distinguishes between three functional levels:

- Cycle time and offset are determined on the *strategic level* (every 10 to 15 minutes).
- The current cycle is modified on the *tactical level* (once per cycle).
- Second by second reactions to the presence of individual vehicles are possible on the *operational level.*

The strategic decisions are made on the network level in the central control computer, while tactical and operational decisions take place on the local level in the local controller. The network control restricts the local control only to the extent that is necessary to guarantee a good coordin-ation in the overall network. On the strategic level, public transport can be given a higher weight than private transport. Within these restrictions a high degree of flexibility for the local level remains.

In figure 1 the individual MOTION modules (or functions) are grouped according to their location in central or local level and according to their correspondence with the four main step in the feed-back loop of traffic control:

- data collection and preprocessing
- traffic modelling and analysis
- calculation and optimisation of control parameters
- evaluation, decision, control.

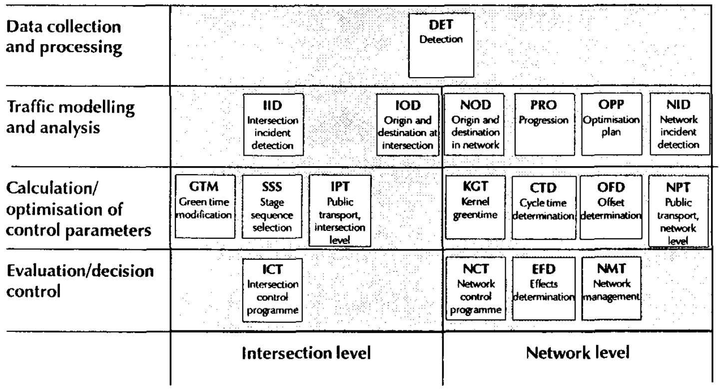

Figure 1 MOTION Functions

THE MOTION FUNCTIONS

The principle sequence in which the MOTION functions are called up is shown in figure 2 and explained further in the following.

Data Collection

The data that is needed for MOTION can be divided into strategic network data and local data. The data needed for strategic decisions is collected at the entries and exits of the network and at critical points within the network at a distance of 100 to 200 m before the stop-line (in the uncongested area). If the full functionality of MOTION is to be achieved, then detectors for the collection of local data for private traffic have to be installed around 40 m before the stop-line for the entry flows and 20 to 40 m behind the intersection for the exit flows (where some of these detectors are missing, the flexibility for local modification would be reduced). The exit detectors can usually be used at the same time as strategic detectors within the network. The original data collected by the detectors (number of vehicles, occupancy, gaps) are preprocessed in the function *Detection* to obtain the data that is relevant for calculation of the control parameters: traffic volumes, cyclic flow profiles, degree of saturation, travel times, delays and number of stops.

Information on public transport vehicles (trams or buses) is required at least for one entry point, but the system can take account of pre-announcement (expected arrival time 20 to 40 seconds in advance), main announcement, departure from stop-line, line number and course number, and information about any delays towards the schedule. Accordingly, information may either come from simple local detectors, from local beacon and radio systems, or from the public transport management centre.

Network Strategies for Private Traffic

The initial basic calculations of MOTION require several transfers of data between local and network level: The first important step is the estimation of all individual traffic streams at the intersection *(Origins and destinations at intersection)*. The origins and destinations of all streams are calculated on the basis of the preprocessed detector data or, more accurately, on the basis of disaggregate traffic counts. The O/D estimation is carried out on the intersection level, but the results are then passed on from there to the network level.

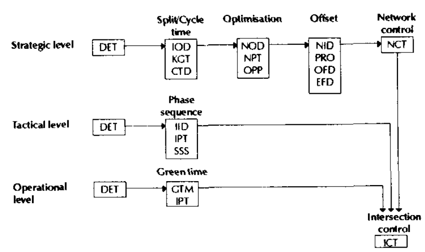

Figure 2 Simplified Principles of Sequence of Functions

There, the resulting intersection streams provide the basis for the calculation of the necessary green times for all signals and the minimum cycle time *(Kernel green times)*. A common network cycle time is then calculated from the individual minimum cycle times of all intersections in the network *(Cycle time determination)*. This network cycle time is then passed back to the *kernel green times* function, which determines the necessary core green times and the resulting available buffer times for all possible stage sequences under this cycle time.

The second important input to the calculations on the network level are the origin/destinations of the major streams in the overall network *(Origins and destinations in network)*. These are estimated in the network controller, again on the basis of disaggregate traffic counts. They are then assigned to routes, and ranked according to their volume. On this basis, the *optimisation plan* determines the coordination sequence for the intersections.

The final input to the offset optimisation is provided by the *progression* module. Here, the actual progression speeds are calculated for each link on the basis of distance between intersections, traffic volume and length of congestion.

With all this information the so-called frame signal plans are determined for every single intersection in the *offset determination*, which constitutes the most central function of MOTION. The Frame Signal Plans (FSP) contain

- the signal program that would be used in every cycle if the actual traffic demand was exactly the same as the one that has been used as a basis for the network optimisation, and

- the restrictions within which the signal program can be modified by the local controller on actual demand.

These restrictions are given as earliest and latest green start and end times for those signals that are critical for the green waves. They limit the so-called buffer times which are available for the local modification.

The *offset determination* uses an algorithm which is a further development from SIGMA, a program for the off-line optimisation of network signal control [4]. If the *network congestion detection* raises an alarm, special signal plans, which have been prepared off-line and comprise particular congestion clearance strategies and are defined and stored in the *network management*, are used and no further calculations and modifications are allowed.

In all other cases, the *offset determination* distinguishes between two principal possibilities: either the optimisation plan, the network cycle time and the possible stage sequences are different from or they are equal to those of the previous period, ie the previous 10 or 15 minutes.

If the optimisation plan is new, the offset determination starts from scratch, ie it builds completely new signal plans that may bear no relationship with those from the previous period. The offsets in this case are calculated in a three step process:

- In the first step, two alternative offsets are calculated: one offset that aims at minimising delays for all traffic, and one offset that provides a coordination on green start which allows in-turning flows to clear the stopline before the arrival of the priority stream.

The second offset tends to work towards a coordination on green end, so that the two resulting solutions tend to provide the most extreme alternatives. The variables for both solutions are not only the offset, but also the stage sequence and the distribution of the buffer times between the different stages at each individual intersection.

Both solutions undergo an *effects determination*, which assesses the quality of the resulting green waves for all priority streams. The performance indicator for each individual intersection, each priority stream, and the whole network is the index KAPPA which is a normalised index ranging from 0 to 1 and indicates the number of stops and the delays which the traffic streams experience during their journey through the network.

- In the second step, the two solutions are compared on the basis of KAPPA, and their best elements (ie the best offsets between individual intersections) are combined to provide a third network solution. This solution is again assessed with KAPPA. The best of all three solutions, ie the one with the highest network KAPPA, is selected for further use.

- In the third step, the selected solution is investigated with regard to the freedom that can be given to the local level for modification of the individual signal program without destroying the green waves. This results in a set of restrictions which are handed down through the *network control program* to the local controllers together with the selected split, stage sequence and offset as part of the FSP.

If, on the other hand, the optimisation plan remains unchanged from the previous period, the new offset is optimised on the basis of the previous one in a similar way to other existing network control programs. The arrival pattern, ie the cyclic flow profile in the entry to the link, is compared with the current split and offset. A special procedure investigates whether through well controlled changes to offset and split a better match between green times and flow profiles can be achieved. Any changes to the previous signal program that may result from this investigation are again assessed with the *effects determination* in order to determine the restrictions for local modification, and are then handed down through the *network control program* to the local controller.

In order to minimise the disruption caused by the change between the FSPs every 15 minutes special transition plan procedures are used.

Local Strategies for Private Traffic

While the strategic control decisions have been made on the network level, the local level is, as indicated before, solely responsible for the tactical and operational decisions.

The main module that is important for private traffic on the tactical level is the *intersection incident detection*. If an incident is detected on a single link, the local controller will try to alleviate the situation through modifying the split according to predefined clearance strategies (in contrast to incidents which effect several links, and which are dealt with through the network incident detection). The second tactical module is the *stage sequence selection* which will mainly introduce or omit stages for minor links which may not require green time in every cycle.

Finally, on the operational level, changes to the split are made in the *green time modification*. Limitations to these modifications are given through the kernel green times and the restrictions handed down from the offset determination. Within the available buffer times, green times can be shortened in any second when gaps on each lane in the entries which currently have green exceed a certain threshold, or when congestion is being detected in one of the streams of the following stages.

Public Transport Priority

For giving priority to public transport vehicles, several opportunities exist both on network and on local level. There are a number of levels of priority that can be predefined by the operator, with the main distinction being absolute priority, ie "Zero delay at all intersections, independent of what happens to the private traffic", and relative priority, ie "Priority is given to public transport only, if the delay for other traffic does not exceed a range of predefined thresholds".

Information on priority levels and on the density of the schedule is provided through the function *public transport on network level*. If all or certain public transport lines are to receive absolute priority <u>and</u> their frequency exceeds a certain threshold (eg > 1 vehicle per 2 cycles), then the disruptions to private traffic, that would be caused through frequent signal changes in favour of buses or trams regardless of their position in the cycle, would be intolerable. Therefore, in this case, the need to accommodate public transport is already being taken into account in the *offset determination* on network level. This is done through limiting the range of options for optimising stage sequence, split and offset for private vehicles to those which provide a green time window for public transport vehicles at their expected average arrival times. Although this still does not yet guarantee zero delay for buses and trams at all times, it reduces the likelihood substantially that their green time request cuts into the middle of a green wave, and gives the opportunity to arrange the coordination for private traffic on strategic level as good as possible around the need for priority for public transport.

But, it is the local level, that in the end provides the green time to buses and trams where and when it is actually needed. Information on their requests come from the function *public transport on local level*. Any decisions on the level of requested priority, and therefore the control decision whether public transport should be given special green time at a given moment, is also made in the local public transport function. They are then used as input in the *stage sequence selection* and the *green time modification* which, in this case, only have an enabling function by carrying out the commands given to them.

This double consideration on network and local level allows a high degree of priority and a high degree of flexibility in the treatment of public transport while minimising the negative impact on private traffic.

THE FIELD TRIAL IN COLOGNE

The German city of Cologne is currently realising a new concept for the entire city under the heading of Traffic System Management. This concept aims at providing priority to public transport with parallel demand management towards a change in modal split from private to public transport. Furthermore, Cologne is active in the DRIVE program as one of the three partners in the SCOPE project, together with Southampton and Piraeus. On this background, the city supports the implementation and test of MOTION in the centre of Köln-Deutz.

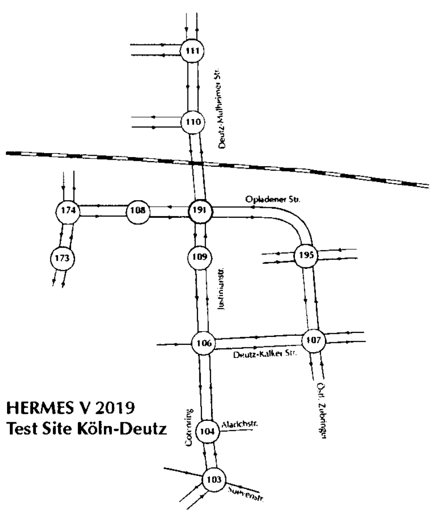

Figure 3 Test Site Köln-Deutz

Figure 3 shows the test site. It comprises 12 intersections, with K191 being the most important one crossed by all major traffic streams as well as several tram and bus lines. The traffic in the area is mainly characterised by

- through-traffic to the Cologne city centre which is on the other side of the Rhine (most of the traffic going westwards from K191 aims at one of the main bridges across the river)

- heavy traffic flows at several weeks of the year, which has its destination respectively origin in the Cologne trade fare ground which has its main entries and exits through intersections 174, 110 and 111.

The tests are carried out as before/after studies during 1994. Results concerning the effectiveness of MOTION will be available before the end of the year.

LITERATURE

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