PIACON: POLYOPTIMAL INTELLIGENT AND INTEGRATED TRAFFIC CONTROL METHOD

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1 INTRODUCTION

The observed increase in socio-economical activity of urban population, lead to the rapid rise in transportation demand. Such a situation has caused intolerable increase of traffic volumes in urban networks and consequently has lead to heavy congestion. Well known symptoms of congestion to became visible first of all as decrease of; travel safety, travel efficiency (delays, stops, queues, longer trip times), travel economy (excessive fuel and energy consumption), are accompanied by essential increase of negative environment impacts from transport (noise, air pollution) and transport fatigue. It is important that all these congestion effects occur mainly in central parts of cities, where many trip destinations are concentrated and due to compact building there are difficult natural cleaning conditions for toxic air pollution ingredients. The observed energy and ecological economise requirement, has insert the social and energy context into the transportation problems. In such situation a high demand and strong social pressure is placed on the possibilities of efficient solutions of road traffic problems. The problem-oriented effective integrated traffic management, surveillance and control methods are the cornerstone of successful minimisation of enormous transportation costs expressed roughly in terms of perceptible transport service standards, energy consumption and environmental impacts. To achieve essential benefits however, it is necessary to integrate of the potential of existing new telematics, communication technologies and hardware capabilities in traffic control systems with completely new traffic control philosophy which is based on truly adaptive, intelligent and multi-criteria traffic control and surveillance methods (Adamski 1986,1994,1996,1998). In the paper the new intelligent version of the PIACON method is presented and illustrated by practical examples.

2 THE PROPOSAL OF INTELLIGENT VERSION OF THE PIACON

The PIACON (Polyoptimal Integrated traffic Adaptive CONTROL) method is dedicated to urban traffic control systems. The main points of this control approach which determine its practical utility and efficacy are as follows: (Adamski 1996,1998). Integrating system mechanisms: Multilayered functional hierarchical control structure (Fig1) with four layers Direct Control, Optimisation, Adaptation and Management and Co-ordination respectively. This layers naturally integrates and vertically orders (with respect to time scale, frequency of interventions, degree of aggregation) the wide spectrum of decision-making functions equipped with integrated bases (data, knowledge, criteria, strategies, tools). Horizontally it makes also possible to co-ordinate the actions of various overlapping transport related systems (ATIS, AID,RG, bus-taxi) via effective communications means. Multicriteria approach which naturally integrates different control tasks by representation of various trade-
offs between criteria to be in conflict, requirements of different users (e.g. priority treatment of public transport), human environment (pollutant emission), economy (fuel consumption) and aggregation of potentially optimal solutions into N-Set of non-dominated solutions or into Nominal Working Points after preference selection. In particular, it is claimed, that the traffic control efficiency on an intersection cannot be judged on the basis of one ex post selected universal criterion, therefore, variety of traffic dependent control aspects, conflicts and trade-offs among various possible goals are judged in the multicriteria fashion. which in natural way represents these conflicts (Adamski 1994). In PIACON the variety of trade-offs between control criteria are adequately represented. These criteria at the intersection level correspond to operating efficiency (capacity, delays, stops, queues, congestion (see Fig 2)), traffic intrusion into environment (pollutant emission), economy (fuel consumption) and occasional requirements of various road user groups e.g. priorities for public transport vehicles. The main operating criteria to be minimised (number of vehicle stops, delays, capacity reserve, queue length, drivers discomfort and measure of differences from their demand for occasional requirements) are included in corresponding "control modes" called accordingly, stop SM, delay DM, capacity CM (see Fig. 2), queue QM, jam JM and dedicated DEDM modes. Different control aspects represented by these control modes are integrated by means of a given preference order on an optimal non-dominated index surface (i.e. the N-Set) in criteria space. The other control modes (e.g. fuel consumption FM, pollutant exhaust emission EM) are represented in the N-Set as appropriate points /regions. The minimal values of all operating criteria create in the criteria space the reference ideal point which in reality may correspond to the multilevel traffic junction. The final selection of the multicriteria solution from the parameterised N-Set called the Nominal Working Point (NWP) of intersection may be determined among others as the nearest one in some sense to this reference point. The diversity of traffic situations encountered on the approaches to the intersection are aggregated into "traffic modes" ranging from sparse to immobile traffic (e.g. through the automatic rough sets classifiers tools (Adamski 1996)) using the features extracted from the traffic data. In general, various approaches to the intersection may be working at different traffic modes Fig.3. For a given traffic modes, defined in the real-time way corresponding control aspects are represented by appropriate compromises of control modes i.e. points in N-Set. This is possible because the N-Set is parameterised both by traffic parameters and control variables and it dynamically evolves with traffic demand fluctuations. It is very attractive feature of PIACON which makes it possible to realise automatic on-line adaptive control actions by the selection of appropriate NWP on the current N-Set by means of proper adjustment of the preference structure. Moreover these control actions may posses robust features (at each control step the explicit sensitivity measure of the solution may be immediately determined and robust traffic control action selected) and secure a smooth transfer between different working points. The PIACON intersection control idea have been transferred in natural way to the higher levels and layers of system hierarchy (see Fig 3) for pictorial illustration (Adamski 1996, 1998, 1999).

Intelligent Supervision: It is known that most of traffic adaptive control strategies usually work satisfactorily within a limited range of operation conditions and typical problems concern congestion and unforeseen traffic events. To overcome this problem the supervision level (third feedback loop) to monitor traffic range violations is proposed. This additional knowledge-based level supports primary control feedback loop enhancing their performance by using expert type qualitative practical knowledge. For this purpose high quality real-time decision environment with new AI data/knowledge completion and analysis methods (AI, GA, ANN, Rough sets reasoning tools, traffic situations markers, well data equipped estimation methods, restored spatio-temporal traffic congestion patterns) is proposed. It seems
that the use of frames for store and knowledge representation provides convenient environment for these tasks. The intelligent real-time self-tuning management /control structure which makes it possible to cope with congestion and unforeseen traffic events is shown in Fig. 4. The adaptive controller performs two main functions: on-line identification and estimation of traffic process parameters. Self-tuning algorithms coverage if process and noise models structures correctly correspond to the real traffic processes, estimated parameters lie within stable ranges, desired control actions can be attained on time by the actuators. In practice these conditions may be violated therefore the supervision level is necessary. The supervising level performs the following tasks: monitoring the convergence and supervising the performance of parameters estimates in real-time (better behaviour of parameter estimates, quickly reactions to sudden traffic changes), supervising the controller performance e.g. use a network preference recommendations and off-NWP threshold values to choice the linear/non linear ranges of operation, preferences for acyclic/cyclic type of signal control. The expert controller through traffic markers alphabet determines the control preference structure for PIACON. The PIACON control mechanisms realise several tasks recurrently: determine N-sets in the criteria and control spaces for a given preference structure, define new potential Nominal Working Point (NWP) with its robustness indicator and proximity measure with respect to the last NWP, checking the robustness and proximity tests for a given new potential NWP point, transfer to the new NWP. To illustrate the use of PIACON some illustrative results are given for its application to the junction with 9 signal groups. In Figs. 5-7 N-Sets in criteria spaces and Green times (corresponding to the points 1-4 marked on these sets) for bicriterial Stops-Delay, Stops-Queue, Delay-Capacity, problems are presented.

3 CONCLUSION

The proposal offers a new truly Polyoptimal Integrated and Intelligent Adaptive CONtrol approach (many criteria, control representations, all levels of demand) with essential advantages dedicated to urban integrated traffic control systems: Integration: External: It is nested in the greater integrated whole including among others public transport, parking and individual vehicles guidance and pro-ecological control subsystems and new generations of traffic video-detectors. Internal: The control and management chain: data (different traffic situations)- local control (different control actions) - co-ordination control (different junctions, zones)- network -wide intelligent control (different strategies) is in natural way integrated i.e. by aggregate of corresponding traffic and control modes with co-ordination and reasoning tools. Intelligence: Intelligent supervision technology responding to wide-spectrum of traffic situations. The control and management realised in the „opportunity„ modes after detection of favourable conditions. Adaptability: to the control plant features (e.g. uncertainty and ambiguity), various users requirements, different control tasks and decision problems, wide-spectrum of various preferences new existing technologies. Control: The integration of supervision, scheduling and control tasks, dynamic intelligent traffic control feedback, robust features of control problem solutions, reduced computational complexity
CO-ORDINATION: with other systems and system environment

MANAGEMENT: *individual and public transport, traffic even (congestion, incidents), zones, routes, critical network elements

* Intelligent supervision, global network status estimation and prediction, Network Nominal Working Points (NNWP) selection and tracking, strategic control recommendations (global preferences, constraints), DSS for strategic traffic management

* ATIS, DRG, environmental monitoring,

ADAPTATION

- Network-wide control: LQ off-zones, off-routes NNWP deviations minimization
- Diagnosis of the traffic situations, movement conditions, environmental state
- Estimation of traffic demand in the time-space context and NNWP preferences
- Rekurent tuning of the models parameters used in all layers
- Dynamic traffic assignment: directions and routes recommendations (VMS)

OPTIMIZATION

- Intelligent supervision: (multi-criteria dynamic junctions co-ordination and zones synchronisation, intelligent congestion avoidance/relief control, supervision and intelligent control of critical network elements)
- Co-ordination tools management and integration (consistency checking)
- Estimation of area-based traffic parameters and traffic situation markers

Junctions Nominal Working Points (NWP) selection, updating and trade-offs

Fig. 1. HIERARCHICAL TRAFFIC CONTROL SYSTEM IDEA
1. PIACON:

Figure 2. N-Set in the STOPS-DELAY-CAPACITY Criteria Space

Figure 3. Integrated functional structure of the PIACON control
Figure 4. Block diagram for the knowledge-based PIACON adaptive controller

Figure 5 N-Set Stops -Delay
Figure 6. N-Set Stops - Queue

Figure 7. N-Set Delay – Capacity
REFERENCES


