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A FUZZY LOGIC APPROACH FOR URBAN TRAFFIC MONITORING USING NOISE MEASUREMENTS

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ABSTRACT
The present communication reports a recent research to synthesise an efficient area traffic management and control structure. This structure makes use of advanced Automatic Control and Operations Research tools at the control level while at the management level, Fuzzy Logic techniques are introduced to monitor the current traffic conditions from noise measurements.

1 - INTRODUCTION
In fact, a completely new approach is proposed to monitor current traffic conditions. Traffic noise, which has been regarded for many decades only as a nuisance, while its structure and intensity are directly related to the current traffic conditions, is considered to be a rich source of information about traffic. So, the possibility to extract, through the use of Fuzzy Logic techniques, traffic patterns from traffic noise measurements is investigated. In the first part of this communication, relations between traffic parameters and conditions and noise levels are displayed. In the second part a fuzzy representation of traffic noise is introduced. Afterwards, the proposed approach for on-line area traffic control is shown.

2 - TRAFFIC NOISE GENERATION AND MODELS
Urban traffic noise varies according to the volume of traffic, the type of vehicles comprising the traffic stream and the mode of traffic operation. The sound field depends on various factors such as road alignment, land topography, obstacles and reflection effects from the environment.
Figures 1 and 2 show time histories of urban traffic noise measured along an urban street at 100 m upstream and 50 m downstream from a controlled intersection on a one way street. Here the time level characteristics of traffic noise depend on the nature of the traffic flow and the resulting noise emission rather than from the characteristics of propagation.

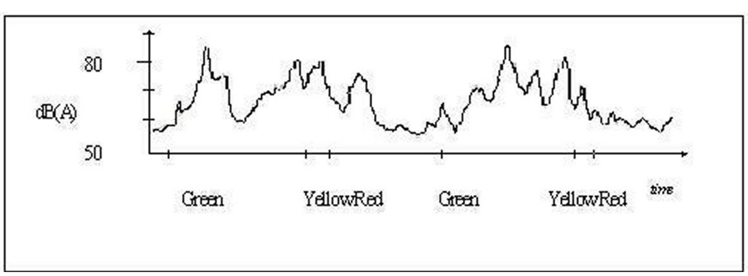

Figure 1: Urban traffic noise measured downstream a traffic light.

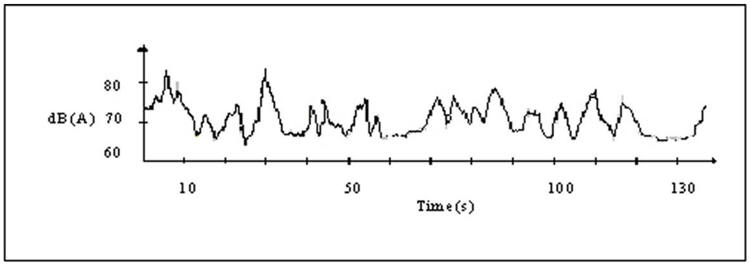

Figure 2: Urban traffic noise measured upstream a traffic light.

Upstream, the vehicles mainly decelerate or stop at the rear of the traffic queue, while downstream, noise presents variations according to the traffic light phases. Under these conditions, the downstream traffic position produces greater noise fluctuations than the upstream traffic for a similar mean value [1].
Considering mean traffic parameters (speed and flow) and mean noise levels, it is possible to get theoretical relationships between these three parameters (figure 5) [1].
Adopting the following assumptions: the noise from a vehicle originates from a point located on a reflecting plane moving with the flow mean speed V, the propagation time and the Doppler effect can be neglected and there are no reflected sound waves over the receiver, the noise level attenuation results only of the distance between the source and the reception point, it can be shown that the mean noise level over a T period of time $\overline{L}_{eq}^{T}$, is given by an expression such as:

$$\overline{L}_{eq}^{T} = L_W + 10\log_{10}(Q/V) + A \tag{1}$$

where A is a constant whose value is related to T, and where Q is the mean flow over a T-period of time [2].
Experimental results displayed on figure 3 corroborate this theoretical expression.

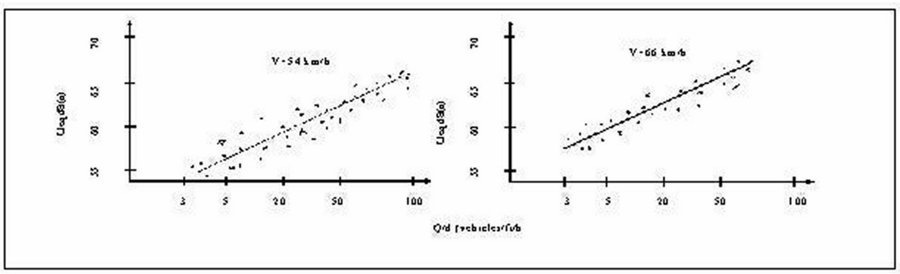

Figure 3: Experimental mean noise levels for different flows and speeds.

However since the experimental dispersions around the least square mean values remain important, it appears interesting to introduce here a fuzzy scaling for the generated traffic noise levels (ΔL is a decreasing function of the mean speed), see figure 4:

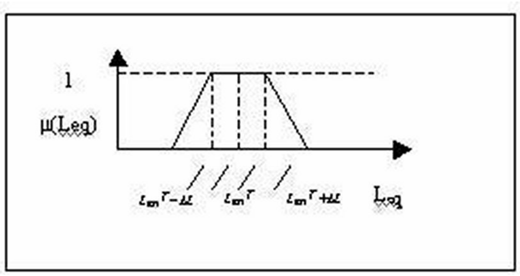

Figure 4: Noise level membership function.

3 - THE PROPOSED AREA TRAFFIC CONTROL APPROACH

Urban areas can be represented in general as directed graphs whose nodes denote elementary sections of traffic and whose directed links represent elementary traffic flows. The dynamics of the queue of lane

from the beginning of one cycle to the beginning of the next cycle can be represented by a set of discrete state equations jointly with several capacity constraints.
In the case of congested urban traffic, different goals can be pursued depending of the chosen strategy. Some possible goals are: maximise the throughput of the area during a given period, minimise the mean queue size over the planning period, minimise the mean queue size at the end of the planning period, minimise the stock of vehicles at the end of the planning period.
Once one of the above criteria has been chosen, the considered optimisation problem turns out to be a large-scale (time and space) Linear Programming (LP) problem. Different LP algorithms are available to solve this problem. Here a new optimisation over a receding horizon is stated at the end of each cycle, while adopting for the current cycle duration the optimised traffic control parameters determined at the last call of the optimisation procedure. Then, at the beginning of a new cycle, the solution of the LP problem must be updated and to avoid excessive computing time, some adaptations must be carried out [3].

4 - SUPERVISION OF THE TRAFFIC PLAN GENERATION

The analysis of the current traffic situation and the projections provided by the solution of the recurrent optimisation process allows the evaluation of the adequacy of the current and future states of each link in terms of its functionality with respect to congestion.
Given the mean traffic flow and the mean traffic noise level, it is possible to estimate from relation (1) a value for the mean traffic speed V in a street. Then using the V-Q diagram, it is possible to estimate the degree of saturation of the traffic in this street through a set of fuzzy rules. It is also possible to corroborate the performed traffic diagnosis by the introduction of a set of fuzzy rules relating directly Q and L_{eq} to the saturation level. They are summarized in figure 5.

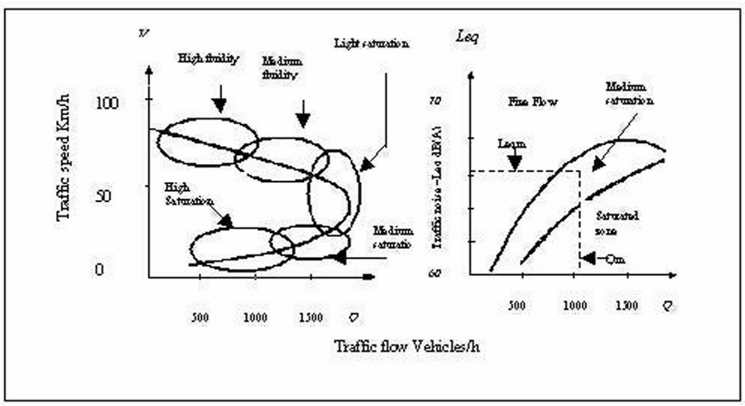

Figure 5: Degree of saturation of traffic.

Then, according to the estimated traffic conditions a new set of weightings can be established for the criterion function of the current Linear Optimisation problem. Here also, the use of a systematic technique to set these weightings appears most desirable. Fuzzy Logic turns out to be appropriate since a qualitative evaluation is necessary. So, an If-Then base of rules, which are applied to predefined linguistic variables describing traffic saturation levels, must be developed. These rules are for instance such as:

- for bottleneck links: "if link presents high saturation then "queue weight is very high",
- for storage links: "if link presents low saturation then queue weight is small",
- for junction links: "if link presents a low flow then flow weight is small".

Finally, the whole proposed approach is sketched in figure 6.

5 - CONCLUSION

In this communication a new methodological approach has been proposed for the management and control of traffic in urban areas. This approach which is adaptive in order to adjust control decisions to the high level of unpredictability of congested traffic, makes use of traffic noise measurements to achieve traffic diagnosis and to enforce the reactivity of the proposed control structure to current traffic conditions. To fully validate the proposed approach, extensive field and simulation experiments remain

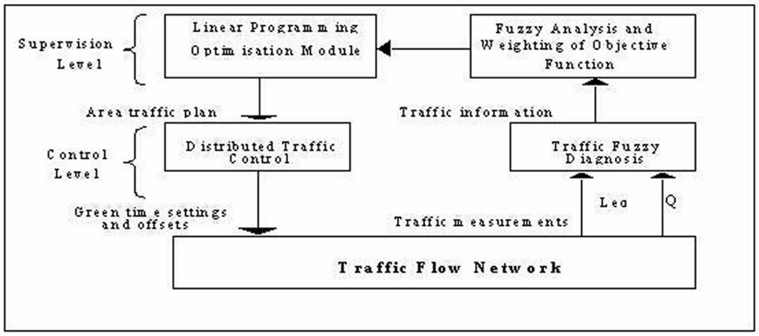

Figure 6: Supervised traffic control system.

to be performed but the preliminary results obtained are promising and incline towards the feasibility of the proposed traffic monitoring technique.

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