FUZZY GROUP MODEL OF TRAFFIC FLOW

Mariusz Kaczmarek
Institute of Computing Science – Poznań University of Technology
E-mail: Mariusz.Kaczmarek@cs.put.poznan.pl

1 INTRODUCTION

Simplicity and accuracy of models are crucial criteria of their construction in general and in road traffic systems especially. The quality of models is indeed a trade off between them because to complicate models are computational inefficient and can not be used in on line control and simulation of large systems. These goals fulfil the group model of traffic flow (Kaczmarek 1986), in which vehicle moving dependently are grouped in one object, so at the level of abstraction, models are enough detailed for control and simulation purposes.

There are many non-linear relationships in traffic flow process, so the low of superposition does not be used. Application of aggregated input data of traffic parameters in models, as their mean values may produce substantial errors in output data as performance indexes.

The aim of this work is to present a fuzzy version of the group model of traffic flow lack of the disadvantage. The paper consists of short presentation of group model, definition of fuzzy vehicle group and its fuzzy transformations.

2 VEHICLE GROUP MODEL OF TRAFFIC FLOW

2.1 Model elements

The group model worked out by Kaczmarek (1990) is an analytical model of traffic flow in a street network. The basic elements of the model are groups of vehicles $G = (h, p, q)$ characterised by three state variables: $q$ [E/s] - mean volume in the group, $p$ [s] - time length of the group, $h$ [s] - time position of the beginning of the group. Thus $qp$ is the number of vehicles in the group and $h+p$ is the time position of the end of the group and the saturation flow volume is $s$.

2.2 Model transformations

Movement of traffic between to points of a street network is described in the model by means of seven elementary transformations:

$$T_I, T_O, T_K, T_S, T_R, T_Z, T_C$$

(1)
They change the position of vehicle group h and/or its shape q and p as a result of the influence of traffic signals or road on the movement of vehicle group.

2.2.1. 1-1 Transformations

$T_I$ transformation. It does not change any state variable of the group and is used to show that there is no influence on the movement of the vehicle group at some point of a street network.

$T_O$ transformation. It changes only h - the time position of the group - and can be used for modelling travel or delay of vehicle group.

$T_K$ transformation. It changes p and q without changing e and is used for modelling a compression and dispersion of the group.

2.2.2. 1-2 Transformations

$T_S$ transformation. It divides group into two (ones) in such a way that $p = p_1 + p_2$, and is used for model the influence of the traffic signal changing from green to red on the movement vehicle group.

$T_R$ transformation. It always divides group into two but it such a way that $q = q_1 + q_2$, and is used for modelling the partition of the group at a junction.

$T_Z$ transformation. It divides the vehicle group into two so that the first has volume $q_1 = s$ and the second volume $q_2 = q$, and is used for modelling the influence of traffic signal when changing from red to green on the movement of vehicles.

2.2.3. 2-1 Transformation

$T_C$ transformation. It merges two vehicle groups into one when two conditions are satisfied $q_1 = q_2$ and $e_1 + p_2 = e_2$.

2.3 Network flow modelling

The basic (natural) set of, so called elementary, group transformations fulfil a functional completeness, so the way of construction of any state transformation of vehicle groups at the entrance of an intersection and after travel a road between two successive intersections, by means of composition of elementary transformations could be derived. Thus, from abstract point of view, in group model groups are elements and transformations are operations of an algebraic close system.

The main objects in the simulation object oriented implementation of the model are vehicle groups. Its fields are volume, time position and time length. Events are changes of vehicle group time position at selected point in a network. The particular methods correspond to vehicle group transformations and schedule next event. Groups in selected points of
modelled urban street network are transform in chronological order with the bias period is not lengthening the longest way in a network.

The results of caparison to well known TRANSYT model of traffic flow in street network are very similar in delay not only for whole network but also in each link. For better study of congestion conditions in a street network the spatial version of group model was derived. Traffic status is obtain continuously in time and space by giving group transformations dynamic character.

3 FUZZY VEHICLE GROUPS

Using mean values of traffic model parameters is not correct way of representing traffic state because the system is non-linear and super-position law does not work. The fuzzy set vehicle group or meta group, could represent many groups which can occurred at given site of street network in similar traffic conditions. They may have a little different time position h and time length p in several successive traffic signal cycles (fig.1) for instance. To describe such situation lets introduce fuzzy position of beginning edge with range a and ending edge with range b of a vehicle meta group G = (h,p,q,a,b).

Figure1. Fuzzy vehicle group
Thus the movement at given site of street network in time $t$ can take place with different grade of membership induced from crisp groups belonging to fuzzy set of similar vehicle groups. Range of fuzziness of beginning edge and ending edge of meta group are respectively

$$a = \max h_i - \min h_i \quad b = \max e_i - \min e_i$$  \hspace{1cm} (2)

Membership function of meta vehicle group can be express as below:

$$\mu(t) = \min \{\max\{0, a^{-1}(t-h-0.5a)\}, 1, \max\{0, b^{-1}(e+0.5b-t)\}\}$$ \hspace{1cm} (3)

The fuzzy group represent many crisp groups located around the middle group of them (see fig.1). Thus we have obtained trapezoidal membership function and such fuzzy groups we will call proper. Fuzzy set of vehicle groups will be proper if $p > 0.5(a+b)$. In the paper we will consider proper fuzzy groups.

4 TRANSFORMATIONS OF FUZZY VEHICLE GROUPS

The low of extension gives us possible to derive fuzzy vehicle groups after each transformation when there are fuzzy groups at the input. The SISO, SIMO and MISO versions of extension low were applied for appropriate classes of transformations (1). As example extension of vehicle group transformation $T_z$ is presented below.

$$T_z(h, p, q, a, b) = ((h+d, y(1-y)^{-1}d, s, 0, y(1-y)^{-1}a);$$

$$\quad(h + (1-y)^{-1}d, p - (1-y)^{-1}d, q, y(1-y)^{-1}a, b))$$ \hspace{1cm} (4)

Two fuzzy vehicle groups were obtained with new fuzzyness of their position as the result of transformation of fuzzy vehicle group.

The corresponding membership functions of delay associated with fuzzy transformation $T_z$ are as follows

$$\mu(W_z) = \max\{0, (W_{z_{\text{max}}} - W_{z_{\text{min}}})(W_{z_{\text{max}}} - W_z)\}$$ \hspace{1cm} (5)

for $W_z = W_{z_{\text{min}}}$ and 0 otherwise. It worth to notice that even for small $a$ and $d$, e.g. $a=d=10$, we obtain big difference between $W_{z_{\text{max}}}=225$ and $W_{z_{\text{min}}}=25$. Also mean value of delay $W_z$ (calculated for mean vehicle group) $W_z_{\text{mean}}=100$ and delay for $\mu(W_z) = 0.5$, e.g. $W_z=125$ substantially differ, what is exemplification of usefulness of analyses based on fuzzy models.
Figure 2. Fuzzy vehicle group transformation $T_z$
5 CONCLUSIONS

Generic consideration concerning incorporation of imprecision and uncertainty information on vehicle group parameters of group model of traffic flow has been presented. An extended vehicle group definition was introduced including fuzziness of its time position and time length. Then generalization of vehicle groups transformations, mapping one group into one or two and two groups into one, made by law of extension was consequently performed. Finally a general transformer of m fuzzy vehicle groups into n fuzzy vehicle groups was constructed and programmed in Visual C++ with MFC library. The computational experiments confirmed usefulness of worked out fuzzy extension of group model in traffic simulation and control.

REFERENCES


