A MODIFIED LOCAL FEED-BACK RAMP METERING STRATEGY BASED ON FLOW STABILITY

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Abstract: In this contribution a modification of the ALINEA local on-ramp control strategy is presented. In this modification, as in ALINEA, the metering rate is determined by a feedback mechanism where the occupancy rate downstream of the merge area is used, yet a correction procedure is added, where the stability of the flow upstream of the merge area is used in order to fine-tune the metering rate. Preliminary results from microscopic simulation show that this alternative strategy may yield a significant higher throughput of on-ramp without deteriorating freeway operations.

Keywords: Capacity, Control algorithms, Stability, Correcting feedforward

1. INTRODUCTION

In the past fifty years ramp metering has proven to be an effective method to improve freeway operations. Since the first implementation, many different strategies have been developed, that can be categorized as:

pre-timed control where the metering is not directly influenced by mainline traffic
local-actuated control where metering is influenced by real-time local conditions
system control where real-time information on total freeway conditions is used to determine the metering rate

In this contribution we will deal with local-actuated ramp control. This type of ramp control is either based on the feed-forward or feedback philosophy. Well-known example of a feed-forward strategy is the demand-capacity strategy (Koble *et al.*, 1980), where upstream volume (demand) is compared with capacity downstream the merge area. Example of a feed-back strategy is ALINEA (Papageorgiou *et al.*, 1989) which is based on the occupancy rate downstream the merge area.

Most strategies use macroscopic data to determine the metering rates. Commonly used quantities are: average freeway speed, occupancy, capacity and flow. They are based on the assumption that traffic conditions change from non-congested state to a congested state at capacity or at critical density (or occupancy). Various studies however show that this is not necessarily the case. E.g. capacity can vary not only between roads but also during time at the same location. In fact, even when variables like time of day, traffic composition or weather are identical, there appears to be a range of flow or occupancy values where the traffic flow changes to the congested regime. Elefteriadou and Lerworawanich (2002) concluded that the maximum sustained flow at a certain freeway section varies and does not necessarily occur in conjunction with breakdown. Hence, for equal flows breakdown may or may not occur. Flows at the moment of breakdown may vary and can indeed be lower than maximum observed flows or capacity flow.

These phenomena may be considered as completely random, yet also a traffic flow may contain qualities that are not captured using the macroscopic variables as average speed, flow or occupancy (Elbers, 2005).

In fact this is the avenue that will be followed in the remainder of this contribution. The question that is addressed is whether a local ramp metering strategy can be improved by taking into account not only macroscopic but other, also more microscopic qualities of the main-line flow.

The basic goal in ramp metering is to release as many vehicles as possible from the on-ramp to the main-line traffic, yet to maintain the uncongested regime in the bottleneck downstream the merge area. Considering the findings above however, using only predefined macroscopic qualities as fixed capacity or optimal density may yield sub-optimal results. In some instances breakdown will occur while demand has not reached predefined capacity or desired occupancy. In other occasions, for instance when circumstances are very stable (though busy), the metering rate could have been increased such that flow or occupancy exceed predefined values.

One possibility to overcome these problems may be to include some form of microscopic strategy. An example is the so-called release-to-gap strategy. Here it is tried to synchronize the merge of on-ramp vehicles into gaps that were measured upstream the merge area. This is done by determining the moment of release at the ramp meter. However, because of the large variety in accelerating characteristics of on-ramp vehicles, and the heavily changing on-ramp gaps, this strategy has proven not be very successful (Ran *et al.*, 1999).

In an alternative approach it is tried to modify a traditional ramp metering strategy where other flow characteristics are included in order to determine the optimal metering rate.

2. ALTERNATIVE APPROACH

2.1 Combining macroscopic and mesoscopic flow characteristics

As was demonstrated above, ramp metering strategies that are based on macroscopic assumptions insufficiently reflect the stochastic character of capacity and breakdown, while those that are based on microscopic assumptions depend on too many uncertainties. Therefore it was decided to combine a macroscopic feed back strategy with a mesoscopic feed forward strategy. The base-metering rate is determined by a macroscopic strategy, and

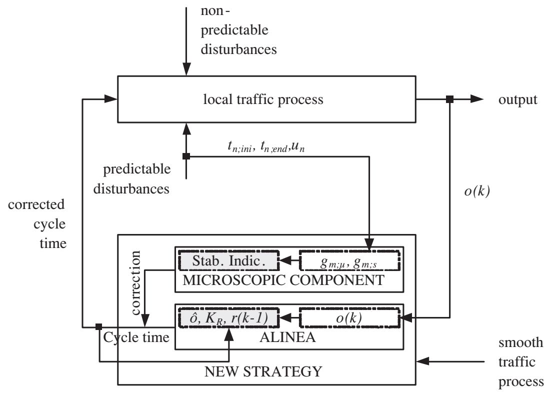

Fig. 1. Control scheme of the new strategy, based on Papageorgiou, 1991

this rate is than adjusted based on mesoscopic flow characteristics.

Elbers (2005) studied the probability of breakdown and concluded that indicators for flow stability may be used to better predict breakdown. In this contribution one of these indicators will be used as a mesoscopic flow characteristic.

2.2 Components of the new strategy

Currently coordinated and pro-active metering strategies are not able to outperform respectively local and reactive strategies due to hard parameter calibration and data gathering (Zhang *et al.*, 2001). Therefor it was decided to use a local actuated strategy. In this way, only local processes will affect the performance of the new strategy and differences in output will be due to differences in control strategy. Here the ALINEA strategy (2.3) was chosen as the basis for the alternative strategy. This means that the base-metering rate is determined using ALINEA, and this rate is adjusted using information on local stability upstream of the merge area. This is done, using the stability indicator (see 2.4) as developed by Elbers (2005). This is shown in figure 1.

2.3 ALINEA

Of all local actuated strategies, ALINEA is probably the most widely studied and implemented strategy. Simulation studies (Hasan *et al.*, 2002) as well as field experiments (Papageorgiou *et al.*, 1997) prove that it is an effective strategy for multiple measures of effectiveness (MOE) like: increasing throughput, reducing congestion and increasing speeds.

ALINEA is a simple feed back control mechanism, based on (1).

$$r(k) = r(k-1) + K_R[\hat{o} - o_{out}(k)] \qquad (1)$$