Traffic News by Dynamic Fuzzy Classification

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Abstract. A necessary prerequisite for numerous services in traffic telematics is a good knowledge of the current traffic situation by location and time. An interdisciplinary solution[1] is presented, which provides a location-time-dynamical description of the traffic situation by revealing traffic domains with uniform traffic states. For this pattern recognition task in a dynamical process with even chaotic traffic state transitions, the underlying measurements are classified into different traffic states. Some specific problems arising in this context are solved: 1) Data from different sources and of different units of measurement, e.g. velocities, flows and densities, which are only sparsely available with respect to location and time are combined ("data fusion"). 2) "Floating Car Data (FCD)" is integrated using morphological filters and recognizing its location-time relation compared to other data. 3) The stochastic data are filtered without suppressing significant state transitions. 4) The subjective feeling of road-users, that it is difficult to distinguish between different traffic states, is taken into account by fuzzy-classification. 5) Using a region growing method the segmentation problem of traffic domains is solved without being restricted to a predefined coarse road segmentation. 6) Good stability is obtained despite contradictory demands for a high resolution, a short reaction time and the differentiation of more than two traffic states. The chosen approach is confirmed by results with actual traffic data. The author knows of no other procedure with comparable capabilities.

1 Introduction and Problem Description

Due to the complexness of traffic dynamics states can change rapidly causing obstructions and even road accidents. Therefore there is a high demand for timely and location-exact information about traffic states. Especially important is the recognition of traffic states which typically precede traffic jams, for example dense and stop-and-go traffic.

Traffic domains, for which a particular uniform traffic state is predominant, spread, grow, shrink, move, divide themselves, until they finally disappear and free traffic prevails again. **Therefore the challenge is to find, localize, classify and keep track of these traffic domains**. This information must then be prepared in a form suitable for presentation to road-users. This paper presents a new and robust procedure for the automatic generation of traffic news in which **interdisciplinary methods from diverse fields like pattern recognition, segmentation, data fusion and morphology are combined**.

[1] It's patent pending in some countries.

2 Properties of Measurements

At present, essentially only three types of traffic measurement systems are being used on a large scale: 1) induction loops imbedded in the roadway (VIZ), 2) stationary installed infrared or radar systems (SES), and 3) mobile systems, which provide so-called "Floating Car Data (FCD)". Induction loops provide average traffic volumes (in cars/time) and velocities from fixed locations and constant averaging periods. SES-detectors provide the same, but for economic reasons their data transmission is event triggered. On the other hand floating-cars provide only velocities from non-predefined locations. Due to the limited number of detectors and their different characteristics and due to temporary failures, traffic measurements are only sparsely and irregularly available with respect to location and time.

3 Other Traffic State Detection Methods

In some traffic information centers (VIZ) a traffic news generating procedure is used which classifies single velocity values by a binary threshold: congested or free. Consequently it produces relatively instable traffic news.

There are also methods based on road-segments, which balance the traffic volume at the beginning and the end of a segment [1,2]. Such methods can detect a congestion before it is seen at a measuring point. Substantial drawbacks however are that 1) these methods pose higher demands on the properties of the available measurements. 2) Asynchronous data streams (SES) or asynchronous data from variable locations (FCD) are difficult to handle. 3) Measuring errors cause stability problems for flow balance. 4) They are restricted to predefined road-segments.

4 Difficulties Describing Dynamic Traffic States

The special challenge when describing dynamic traffic states is to differentiate between several traffic states quickly, stably and consistently using incomplete and stochastic traffic data originating from different physical measurements. To compound matters, according to the subjective feeling of road-users does not make clear distinctions between different traffic states.

Since traffic domains are highly variable with respect to location and time, we are here not only faced with a dynamic segmentation problem, but also with stably tracking these domains. To do this, a description is necessary which allows a similarity comparison between traffic domains with respect to their traffic states. In addition, a restriction to a predefined coarse road segmentation has to be avoided. Otherwise the true dynamic of the traffic cannot be adequately captured and described.

The art is to achieve a high stability for traffic announcements despite the contradictory demands for:

1. a high local resolution of the traffic description,
2. a short reaction time to changing traffic conditions and
3. the differentiation of more than two traffic states.

5 The Procedure for the Generation of Traffic News

The procedure allows spatial resolution information and reaction times to be parameterized over a wide range while preserving exact information about the length and the position of a traffic event within the traffic announcement.

Preprocessing of Measurements and Feature Extraction: In order to determine the traffic situation the spatial and temporal properties of traffic measurements have to be considered without reducing the reaction time. The target here is the extraction of features from the traffic measurements or patterns, which characterize the traffic situation in a unique way.

First, incorrect measurements are eliminated. Then, all measurement vectors are written in sliding history windows spanning the locations and times of interest, which are updated with the aggregation period of the induction loops. Values older than 20 minutes are deleted. These windows are evenly divided in cells, each of them is 200m by 1 minute. This gives sliding time functions of the measurements by maintaining the location/time relation, which is essential for the incorporation of FCD (Fig. 1 left/middle).

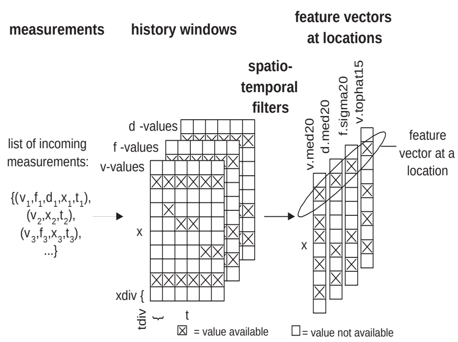

Fig. 1: Sketch of the processing line.

Due to the stochastic properties of the data, spatial and temporal filters are necessary to reduce the strong fluctuations in the velocity and density values without suppressing significant state transitions. The analysis of time functions shows that a median filter is more suitable than the common averaging filter.

The standard deviation of the traffic flow and the dilated TopHat function of the velocity quantify temporal changes of the traffic and are used as features to identify stop-and-go traffic: $(TopHat(v) = v - Opening(v))$, [3]. Temporal gaps can be easily taken into account by these filters.

This preprocessing provides a feature vector (Fig. 1 right): $(v.med20, d.med20, f.sigma20, v.tophat15)^T(x)$. This description based on features is the necessary prerequisite for stably classifying traffic states with good spatial and temporal resolution.

Fuzzy Classification: Now the traffic state is classified in one of four classes: congested, stop-and-go, dense and free traffic.

Taking into account the subjective feeling of road-users, that it is difficult to distinguish between different traffic states, the feature space is partitioned by discriminant fuzzy-functions (Fig. 2) [4]. Each subfunction evaluates a feature and quantifies the degree of existence of a traffic state. The corresponding borders in the feature space smoothly turn from one state to the other. The continuous description is necessary to get stable classification results. Otherwise gradual changes in the input could lead to repeating state transitions, and the gradual spatial-temporal information of the traffic states would be lost. This is why binary decision techniques are completely inadequate.

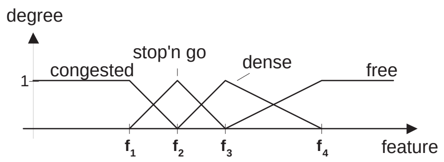

Fig. 2: Example of a fuzzy-division of a feature.

In addition, by using gradual state vectors, classification results for features of different physical units of measurement, e.g. velocities, flows and densities, can be combined in a consistent way, e.g. by summation and normalization (Fig. 3). All the different features contribute to the final state vector. At this point the results from segment based balancing methods can be integrated to provide additional information between measurement locations.

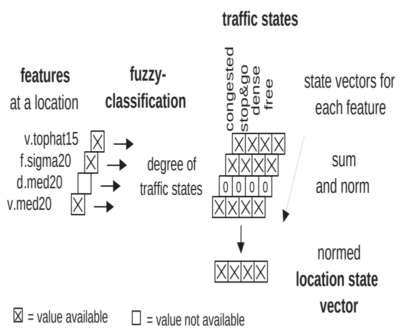

Fig. 3: Normalized local state vectors from state vectors for each feature.

The result of the fuzzy-classification is a state description at locations, where measurements were available and features could be calculated.

Extrapolation of Local Traffic State Vectors: In order to bridge the gaps in the traffic state description of a road, the state vectors available at measurement locations are extrapolated along the road by a gaussian filter, which allows the locally reliable fuzzy-descriptions to be expanded to other locations, but with a decreasing amplitude reflecting the increasing distance from a real measurement location. The spatial resolution of the traffic news can be adjusted by the parameters of the gaussian filter. In addition, a temporal autoregressive smoothing of the state vectors is carried out [5].

Dynamic Segmentation of Traffic Domains: The aim is to capture the actual spatial and temporal dynamics of the traffic without being limited to predefined fixed divisions of the road. This dynamic segmentation is achieved by a region growing method, which starts at a location and successively combines locations with similar traffic state descriptions to a traffic domain. The result is a complete partition of a road in traffic domains.

Up to now all calculations on the traffic state descriptions by the filter and the domain-segmentation have been based on fuzzy concepts. No binary decisions have taken place. Therefore, the domain state vectors still contain the complete information which is particularly important in the case of gradual state transitions and is a requirement for the stability of the following management system for traffic news.

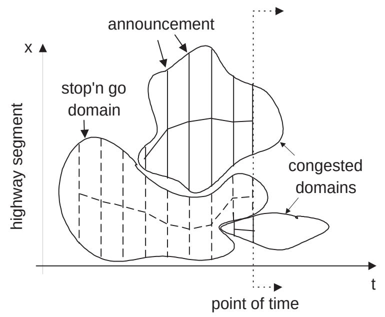

Fig. 4: Visualisation of the results.

Domain Tracking and Management of Traffic News: The traffic domains are updated every 3 minutes and stored in a list. Using a continuous similarity measure a matching of the previous domains to the actual domains which considers the domain state vectors, the locations and the lengths of the domains is undertaken. Then the new domains, those which no longer exist and those which have undergone substantial changes are identified. Accordingly, delete-, new- and update-announcements are generated.

At this point the final decision about the traffic state based on the maximum component of the domain state vector is made. The result is a dynamic tracking of domains with similar traffic states and a list of announcements which is permanently kept up to date (Fig. 4).

Visualisation: For visual monitoring during operation of the traffic news generating system the domains that belong to the traffic announcements are displayed in the foreground along with the interpolated traffic measurements in the background. The time increases from left to right. Domain regions are depicted by vertical lines, and horizontal lines connecting them show their temporal assignment during the tracking in successive updates (Fig. 4). In Fig. 5 an actual congestion situation is shown. In the background, interpolated velocities are displayed as grey values (dark = low v-values).

This presentation provides a visual impression of the quality of the results of the traffic dynamics analysis and an overview of the traffic conditions in the network of roads.

6 Results from current Operation

The DDG already has considerable experience with the implementation and operation of this classification procedure. Typical reaction times are 5-10

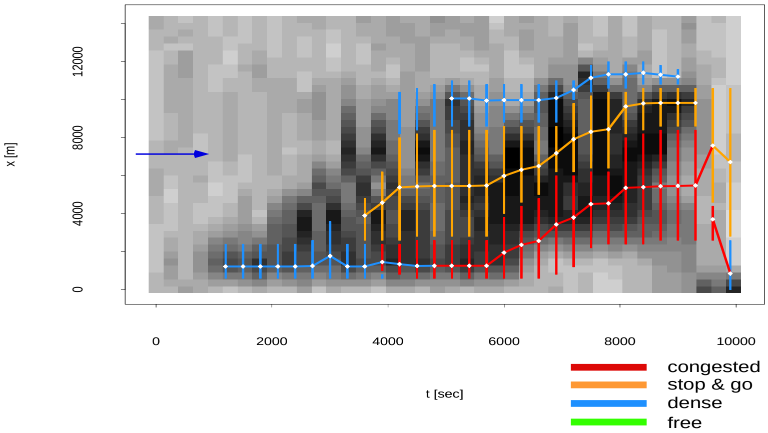

Fig. 5: Traffic messages produced for a real world congestion situation.

minutes starting from the moment when a congestion situation is ”seen” by a detector. In most cases however, it’s possible to warn of an overload congestion earlier by announcing dense or stop-and-go traffic, which usually precedes the congestion. First experience with FCD measurements shows that some congestion situations can be detected earlier than by other detector systems.

7 Outlook

An increase in the traffic information through additional measurements, e.g. by FCD, will allow more precise traffic news spatially as well as temporally without any change in the presented procedure. Further improvements can be achieved by the use of traffic flow models which will provide calculated measurements as additional input.

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