[DRAFT] - Stage Oriented Design of an Intersection Management System Based on Laser Scanner Data

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Abstract

The supervision of vehicular intersections is a major need for improving transporation systems because intersections are complex scenarios where different transit actor interact between them. Recently, laser-based systems have been proposed and implemented to sense and to monitor intersections, giving good result as those based on cameras. In this work a stage-oriented design of an intersection management system based on laser scanner sensor data is proposed. The main objectives of the proposed architecture is that it should have scalability, modularity and high integrability. In order to achieve those objectives, the process flow of an intersection management system (IMS) is divided into four stages: preprocessing, feature analysis, pattern recognition, and situation assessment. Each of these stages and some common techniques used are described. Finally, we present an example implementation using a laser scanner dataset,and compare the performance between a single laser and a multi-laser approach.

1 Introduction

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2 Stages Definition

In the designing of an IMS, there are four main stages that have to be performed from the data source to final output: preprocessing, feature analysis, pattern recognition and situation assessment.

The aim of the first stage is to extract data of interest from the raw sensor information, using filtering and background subtraction techniques to get the foreground of the scene, remove noise and irrelevant data. Spatio-temporal alignment of data is also performed in this stage. In the second stage, the objective is to identify elements within the foreground and extract relevant features of them. The third stage receives the set of features from the previous stage and performs recognition and classification tasks. Also, tracking and prediction of objects' state is performed based on historic information. In the fourth stage, object behaviour and inter-objects interaction are analysed to identify context and detect situation or events of interest.

The output of the fourth stage could be delivered to an optional fifth stage of decision and control, to a human operator, or to a traffic agent or institution, to take immediate actions on traffic control, issue traffic tickets, warn drivers about possible incidents or improve transportation policies in a long-term basis. In figure 1, previously described stages are depicted, and also is shown how the data volume is reduced while data meaning increases in the last stages.

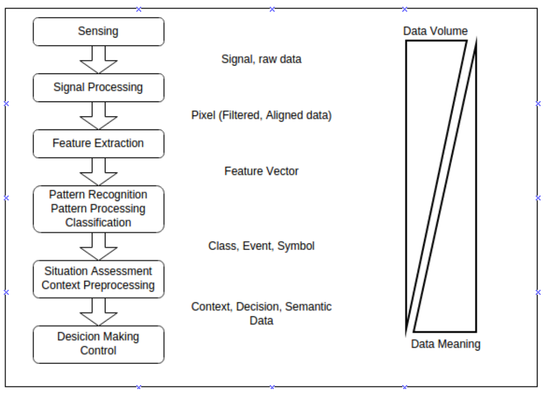

Figure 1: Dataflow through processing stages in an IMS.

Different tasks could be performed in each aforementioned stages, as is referred in figure 2. Below there is a description of common concepts and techniques associated with each of these tasks.

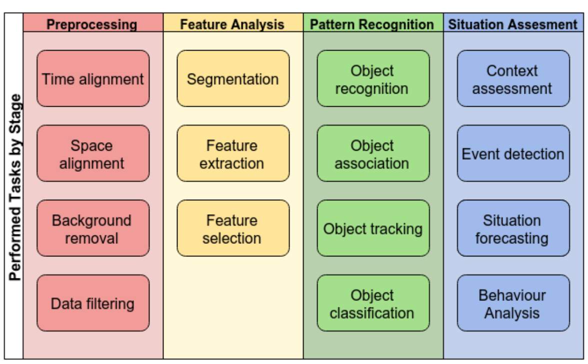

Figure 2: Processing stages and tasks performed.

2.1 Preprocessing

In the preprocessing stage raw data from sensor is received and the purpose is to enhance this data through filtering, removing noise and discarding corrupted data. Also, space and time alignment is done in this stage.

2.1.1 Background Removing

In order to extract meaningful information, background removal techniques are applied in this stage. For doing this, a background model should be generated. One typical approach to generate a background model is to use a threshold to determine if certain measure corresponds to background or foreground. This threshold is computed based on a peak value found in histogram of the measure within a time window. Another approach consist in describe the data using a probability distribution function, using maximum likelihood estimation, commonly of a gaussian model.

Sometimes, the threshold technique is enough for modeling static backgrounds like walls, buildings or ground. But in other cases, it could be found a non-stable background, for example, when there exist moving vegetation or object borders, and a mixture of models may retrieve a better representation of the data instead.

2.1.2 Space and Time alignment

In some cases, it could be desired to have a fixed base of time for trigger sensor readings, for synchronisation purposes or for implement fusion between different sensors within a time slot. Is for this reason that time alignment of data is done.

On the other side, in the case of laser scanners, the measures are referenced to its own coordinate systems. Calibration is needed to transform those measures to a global coordinate systems which represents the whole intersection scenario.

2.2 Feature Analysis

After obtaining the foreground of the scene, it is needed to extract relevant points that could represent objects of interest. Clustering is used to group points that belong to the same object, specially algorithms where estimated number of cluster is not needed.

2.3 Pattern Recognition

-TODO-

2.4 Situation Assesment

-TODO-

3 Laser-based System Implementation

3.1 Dataset

The dataset used for this work was provided by POSS research group and was used for [2]. The dataset consist of ten minutes of laser scanner raw data from six sensors arranged horizontally over an intersection near Peking University. Background model and calibration data for each laser scanner is also provided. Additionally, dataset contains trajectory info of objects in the scene, generated by their algorithm. Figure 3 show intersection scenario, indicating position and orientation of each laser scanner inlcuded in dataset.

3.2 Preprocessing

As mentioned before, the dataset provides a background model for each laser scanner. This model was generated using a histogram of each sampling angle of scanning, then a peak is found indicating a motionless object, considered as background. With the peak values at all sampling angles the background model is obtained. Now, when a new frame comes from the laser scanner, the measure at certain angle is compared with the peak value associated with that angle. If the difference is larger than a given threshold, the measured value is considered to belong to a moving object at the intersection. In figure 4 is described the background removal process.

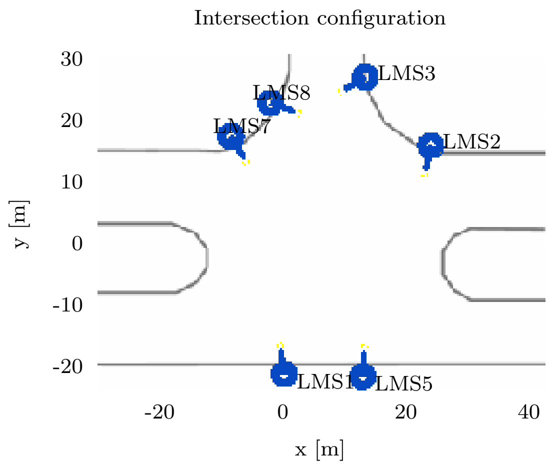

Figure 3: System setup

3.3 Feature Analysis

With the set of points marked as foreground, clustering is performed to identify the set of points belonging to the same object. The algorithm used in this implementation is DBSCAN, which stands for Density-Based Spatial Clustering of Applications with Noise. This algorithm does not need an estimated number of clusters as input, instead of this, it requires only two parameters: a minimum number of points per cluster, m, and a neighbourhood measure, ϵ. A detailed description of the algorithm, can be found in [1].

3.4 Pattern Recognition

-TODO-

3.5 Situation Assesment

-TODO-

4 Results

-TODO-

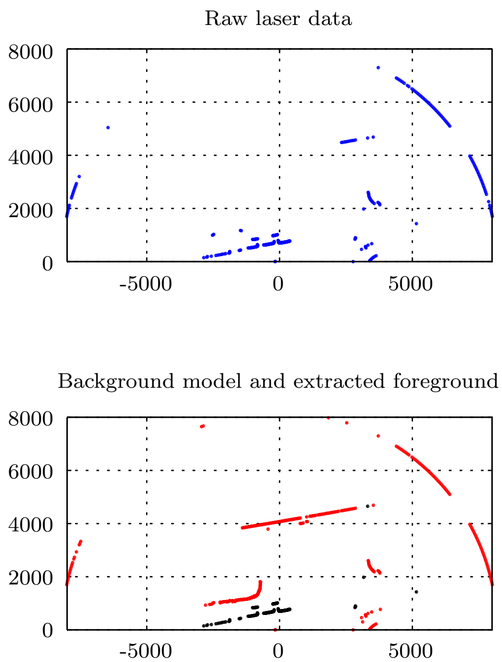

Figure 4: Example of background removal applied to frame 123 from laser scanner 2 of dataset. In the upper plot, the raw data from the laser scanner is depicted. In the lower plot, red points represent the background model estimated based on peak values of the histogram. Black points are those marked as foreground after comparison of raw data with background data. The threshold used was 20. (Axis in centimeters).

5 Conclusions and Future Work

-TODO-

References

[1] Martin Ester, Hans-peter Kriegel, and Xiaowei Xu. A Density-Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise.

[2] Huijing Zhao, Jinshi Cui, and Hongbin Zha. Sensing an Intersection Using a Network of Laser Scanners and Video Cameras. *IEEE Intelligent Transportation Systems Magazine*, pages 31–37, 2009.