Laserscanner Based Cooperative Pre-Data-Fusion

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Abstract

The Cooperative Pre-Data-Fusion is a novel approach for a cooperative environment perception system. It is being developed within the integrated research project SAFESPOT under the subproject SAFEPROBE which specifies and develops an in-vehicle sensing platform. This paper describes the approach of fusing Laserscanner data with information of surrounding vehicles, transferred to the host-vehicle using wireless network technology in a cooperative way.

1 Introduction

SAFESPOT is an integrated research project co-funded by the European Commission Information Society Technologies among the initiatives of the 6th Framework Program. The objective is to understand how intelligent vehicles and intelligent roads can cooperate to produce a breakthrough for road safety. Therefore, the general aim of the project is to create a Safety Margin Assistant, detecting potentially dangerous situations between road users of any kind in advance [1].

For a clear project structure, the development of the sensing platforms is separated from the application development. This yields two subprojects, one for the in-vehicle platform called SAFEPROBE and one for the infrastructure platform referred to as INFRASENS.

Although the architectures of both platforms have strong similarities and also foresee the Cooperative Pre-Data-Fusion, this paper describes and focuses on the Cooperative Pre-Data-Fusion of the in-vehicle platform developed within SAFEPROBE specifically.

The remainder of this paper is organized as follows: In the second chapter, the purpose of the Cooperative Pre-Data-Fusion is described. The third chapter explains the architecture and the full data processing chain in detail. The paper will close with a conclusion and acknowledgments.

2 Cooperative Pre-Data Fusion

The Cooperative Pre-Data Fusion is a new approach for an environment perception system using the in-vehicle SAFEPROBE multi-system platform.

Conventional automotive data fusion systems for environment perception data fuse all relevant information gathered by in-vehicle sensors only. This might be laserscanners [3] and camera systems or radar sensors.

This new approach fuses information about other road users, transferred to the host-vehicle using wireless network technology, in a cooperative way. Within SAFESPOT and therefore in the remainder of this paper, the data transferred via the wireless network is referred to as Vehicular Ad-hoc Network data (VANET-data).

The fusion of environment perception data gathered by thelLaserscanner with VANET-data is performed prior to object-level fusion with further sensor data such as radar or camera system data.

Therefore, this approach is referred to as Cooperative Pre-Data-Fusion (CPDF).

3. System and Data Fusion Architecture

3.1 Data Sources

The CPDF makes use of four data sources feeding into different levels of the pre-data fusion process as shown in Fig. 2.

- laserscanner data: range profile of the environment of the host vehicle [3]
- VANET-data: static and dynamic information transferred from one vehicle to the host vehicle using wireless network technology [5]
- Motion data of the host vehicle
- Static map data: precise digital map [4] provided by the Local Dynamic Map (LDM) running on the main PC

The output of this fusion process is a reliable and robust object description in the field of view of the laserscanner. The object description contains state estimation and classification information for basically any road user detected (e.g. passenger cars, trucks, bikes, and pedestrians).

3.2 Laserscanner Sensor

The key component of the CPDF is the laserscanner installed into the front bumper of the host vehicle. The host vehicles are conventional passenger cars as well as trucks. The processing and fusion of the data is performed on a laserscanner ECU which is connected to a VANET-router, a vehicle gateway, and a main PC providing access to a digital map.

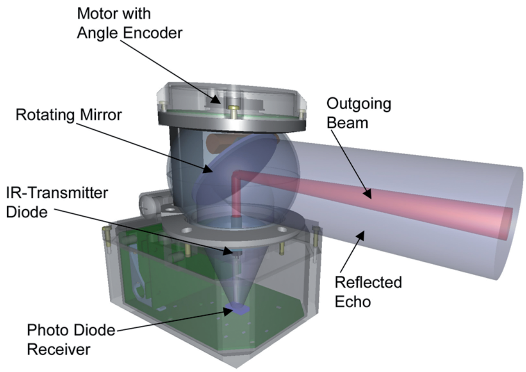

Fig. 1. Schematic of the used laserscanner

The laserscanner (shown in Fig. 1) observes its environment horizontally and gathers a range profile of the host-vehicles vicinity of up to 200 meters. The rotational frequency of the mirror guiding the laser beam is 12.5 Hz. The measurement frequency enables distance measurements every 0.25 degrees horizontally. The applied multi-echo technology ensures proper performance even under adverse weather conditions like rain, snow, or any other precipitation.

The range profile gathered during one revolution of the laser beam is referred to as one laser scan, which in turn consists of many scan points (distance measurements).

3.3 Pre-Processing

Fig. 3a shows a range profile captured by the laserscanner for the example environment scene of an intersection. The captured raw data is sent to the scan data pre-processing and segmentation sub-module of the CPDF.

The pre-processing uses its knowledge about the physical characteristics of the laserscanner and its measurement technology to categorize the range profile.

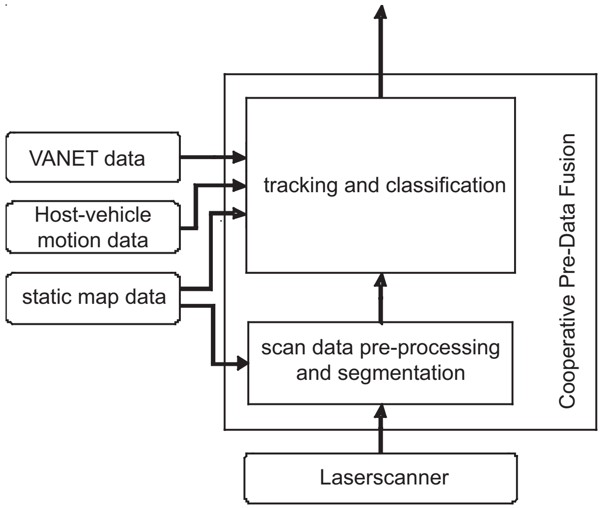

Fig. 2. Architecture overview of the Cooperative Pre-Data-Fusion

This pre-processing includes, for example, a ground detection algorithm, which marks all scan points measuring the road surface in order to exclude them from further processing. This is useful as an ideal range profile would only include scan points reflected by obstacles and road users, but not the road surface.

3.4 Data Fusion and Tracking

Another part of the pre-processing is the background elimination. This step utilizes digital map data which is taken from the highly precise LDM and the knowledge of the host vehicle's precise position calculated by the positioning system. The LDM and the positioning system are both developed within a third SAFESPOT sub-project called SINTECH. Both are part of the onboard SAFESPOT system and therefore always available to the CPDF.

In order to distinguish between background objects (e.g. bushes, buildings, and front yards) and foreground objects (e.g. passenger cars, trucks, bikes, and pedestrians), the surrounding static road and lane geometry is compared to the range profile (see Fig. 3b). All scan points of the current range profile outside the boundaries of the surrounding road, sidewalk, and traffic islands are marked as background and not further processed (Fig. 3c). During this elimination process, it is important to take accuracy estimations of the host vehicle's position and orientation into account as well as accuracy estimations of the digital map. This is needed in order to avoid false elimination of foreground objects. With this background elimination, the overall processing performance and robustness is increased significantly.

Subsequently, a segmentation algorithm is performed that groups single scan points into clusters based on a weighted distance between two scan points. Ideally, one cluster represents one real object such as a passenger car or pedestrian. These clusters are forwarded to the tracking and classification module. Such clusters are called segments.

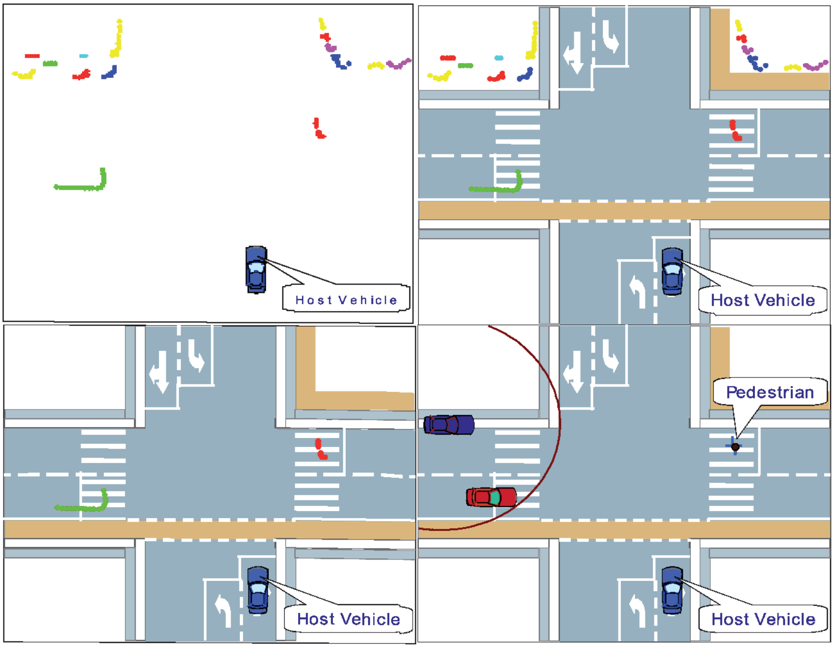

Fig. 3. Steps of the Cooperative Pre-Data-Fusion showing (a) a raw range profile, (b) map association, (c) tracked objects, and (d) cooperative VANET-data association.

3.5 Laserscanner Object Tracking

The tracking of established laserscanner objects is performed by comparing one segment's parameters with predicted parameters of known objects from the previous scans. Such parameters are the reference point coordinates of the segment and object. The reference point is the centre of gravity of all scan points belonging to the segment in the most simple case (e.g. for pedestrians). Under certain conditions, the segment's geometry is analysed and geometrical reference points based on the segments shape are used. This is the case for passenger cars, trucks, and busses, already classified. The benefit of this alternative method is a more precise position, velocity, and course angle estimation.

Segments that do not correspond to any object's parameters of the previous scans are instantiated as new objects, initialised with default dynamic parameters.

In order to estimate the object's state parameters, derivatives of the Bayes filter are well known from literature and applied successfully in various applications. Most prominent implementations are the Kalman filter and its non-linear extensions. Another very popular branch of implementations are the nonparametric filters, e.g. the particle filter. With these filters one is able to model complex dynamic models appropriately. An extensive introduction into the current state of the art on probabilistic filter algorithms is given in [2].

For the problem at hand a Kalman filter approach is chosen. Our implementation focuses on a fast and precise object tracking.

The algorithm performing the association of tracked objects with segments of the current range profile is based on the nearest neighbour and global nearest neighbour method. It weights many factors besides the simple distance such as the shape, the velocity, and the object age (how long a laserscanner object has been tracked).

3.5 VANET Data Association and Fusion

An additional improvement of the tracking performance and reliability is achieved by fusing static and dynamic vehicle information transferred via wireless vehicle-to-vehicle communication into the filter.

The major challenge within this cooperative approach is an accurate and robust association of VANET-data to the correct vehicle detected by the laserscanner. In case, the transmitting vehicle's position is based on SINTECH's positioning system, its position accuracy will be fairly high and therefore easy to associate to the correct laserscanner object.

In a more complex but also likely case, the transmitting vehicle is not equipped with such a positioning system. Most likely, the position estimation would be based on a standard GPS signal and therefore be quite inaccurate. As an example, one could assume that the position estimation based on GPS has a circle of 95% probability with a radius of 15 m (see Fig. 3d). This would result in many association candidates for dense traffic scenarios and thus make a correct association based on the position estimates very demanding. Consequently, further parameters are required to find the correct laserscanner object. Most obvious parameters are the object's velocity and course angle, its size (length and width) and also its type (e.g. passenger car, truck, bus, motor bike). Based on this additional static and dynamic information on the transmitting vehicle and the knowledge on the laserscanner object, an association likelihood is calculated for each object. The most likely object is then associated and the object parameters are fused.

Fig. 3d shows a scene where the red vehicle sends its information about itself to the host-vehicle. The transferred position is depicted as a red striped vehicle while the red circle illustrates the circle of 95% probability of the vehicle's true position. In case of an unblocked view and only a few road users, the association is straight forward. However, in dense traffic scenarios more complex analysis and association technique as described above is required.

3.6 Object Classification

The final step of the whole Cooperative Pre-Data Fusion process is the object or road user classification. This process determines the road user's type:

- passenger car,
- truck or bus,
- bike,
- pedestrian, or
- unknown object (default).

The likelihood for each class is calculated by the classification. Currently, it is state of the art to associate the object to one class by comparing its geometric information like its shape and dynamic data such as its velocity to typical representatives of each class.

One optimization is achieved by adapting the probability for an object class based on its position within the static map. One example would be an object on the sidewalk. Its likelihood of being a car would decrease while the likelihood of being a pedestrian would increase. In SAFEPROBE, the procedure is done automatically by feeding all this information into a specialized, well trained artificial neural network (ANN) [5].

On top of this optimization, additional information on the object provided via VANET is fused into the classification process [6]. By performing this fusion, it is assumed that the vehicle's knowledge on its own class is very high and is therefore fused using a high probability value.

After the Cooperative Pre-Data Fusion process is finished, the gathered object information data is sent to the object-level fusion. It fuses and processes the object information collected by all installed environment perception systems specified within SAFEPROBE.

The subsequent time step of the CPDF is triggered by the next scan sent to the laserscanner ECU. The full process starts over again using the road user's position and classification information as optimized through the cooperative fusion.

4 Project Progress

The described system is currently under investigation. A SAFEPROBE prototype system is being built and real-life performance tests are being prepared. So far, the first simulations and tests indicate quite promising results, but quantitative measurements will not be available before mid-2008.

5 Conclusion

As described within the previous chapters, the Cooperative Pre-Data-Fusion increases the reliability and robustness of standard tracking and classification based on laserscanner data only. It therefore enables many safety relevant applications developed within SAFESPOT.

Acknowledgement

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