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# A clustering of range sensory data by integrating stereovision information for tracking objects in urban environment

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## 1. Introduction

The aim of the presented work is to develop a vehicle having the ability to navigate autonomously in various urban environments. The research developments are based on an experimental platform consisting of an electrical vehicle with an automatic control, equipped with several sensors and communication interfaces. To reach the objective, the first primary task is to develop a perception system for detecting, localizing and tracking objects in this type of environments. In this paper, we present a laser data association method enriched by stereovision information in order to detect coalescing objects in difficult situations that cannot be resolved without sensors fusion.

The paper is organized as follows. Section 2 presents the laser data association method, the stereovision technique and the information fusion procedure. Before concluding, experimental results are presented in section 3 to demonstrate the effectiveness of the proposed approach.

## 2. Data association

Data association is an important part of multiple-objects tracking. We use laser raw data points clustering with tract-to-cluster correlation to achieve the preliminary data association and to detect the three following possible situations: new object appearance, separate objects tracking, coalescing objects tracking. Each of the detected situations is treated separately in terms of data association. The objects are represented by Oriented Bounding Box (OBB) [6, 8].

The reliability of data association methods depends on the points clustering correctness. In general cases, threshold clustering gives satisfying

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results [7, 2, 9]. However, there are situations where, without additional information, it is impossible to cluster raw data points correctly. One of these situations is illustrated in Figure 1. The configuration (a) represents the raw data points corresponding to the rear of a vehicle, seen by the LRF. The configuration (b) could correspond to two possible situations. The first one (c) represents the vehicle, which turns to the right from its former position (a). The second situation (d) represents two vehicles: the first one (a) and a second vehicle, which was occluded.

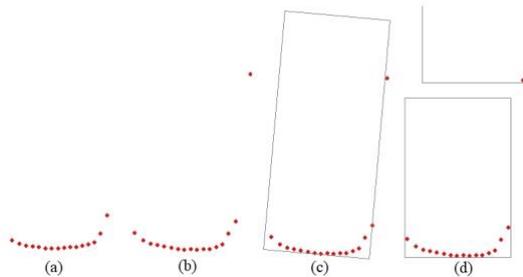


Figure 1. *Example of problematic scenario.*

Using only Laser Range Finder (LRF) data threshold based clustering, it is impossible to achieve a correct discrimination between these two situations. To resolve the described problem, we propose to fuse LRF data and stereovision information. The difference between the proposed approach and standard existing algorithms is that the stereovision information is produced only between the laser raw data points, which are projected into the images. The starting point of the proposed approach is a threshold based clustering. For each two points, which are produced by neighboring laser rays, if the distance between them is greater than a certain threshold, the stereovision analysis is achieved to make a correct decision.

### 2.1. Binocular stereovision method

Stereovision provides 3D information of an observed scene. It is then possible to obtain depth information needed to differentiate different objects (vehicles in our case) when LRF data cannot perform correctly the goal.

Various correlation methods of grayscales stereoscopic images exist in the literature. We use the ZSAD (Zero mean Sum of Absolute Differences) method [1], which is an extension of the SAD [3, 4, 5] (the most popular correlation method) and less sensitive to illumination changes. In this paper,

we have extended this approach to color images. For that, the similarity values are calculated on each component of the RGB color space. The color similarity value corresponds to the average of the three components.

Figure 2 shows the two difficult situations (previously described), where stereovision is useful: a vehicle, which turns to the right (image 1); and a vehicle occluded by another (image 3). In order to visualize better the detected regions, labeled images are determined (image 2 and 4) from the disparity maps. In these images, each detected region corresponding to a disparity value is represented by a different color.

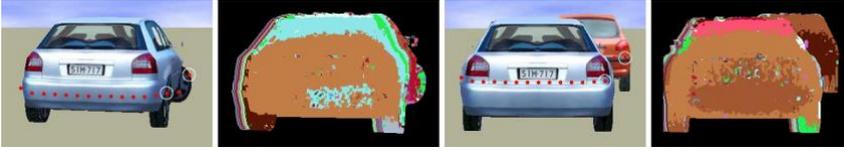


Figure 2. Disparity maps calculated (left to right: initial image and its disparity map with colored regions for the first situation (image 1 and 3) and for the second situation (image 2 and 4)).

## 2.2. Information fusion

To decide if two consecutive laser points (produced by two neighbouring laser rays) belong to the same object, it is assumed that their projection into the images belong to the same surface. To verify this condition, the continuity of the disparity is analysed between the tested points. If a discontinuity is found, it means that the points do not lie on the same surface, and, thus, they do not belong to the same object. The algorithm is expressed as follows. After projecting the considered two laser points into the images, the disparity values of the pixels situated between the projected points are computed. Let  $Disp_{diff}$ ,  $d$  and  $T_d$  be the difference between the disparity values of the projected points, the 3D distance between the laser points and a distance threshold respectively. A disparity threshold  $T_{disp}$  is then computed according the following expression:

$$T_{disp} = \frac{T_r \times T_d \times Disp_{diff}}{d}$$

where  $T_r$  is a weighting coefficient.

In the next step, for each couple of consecutive disparity values, a discontinuity is detected if the absolute value of the difference of the disparity values is greater than the threshold  $T_{disp}$ .

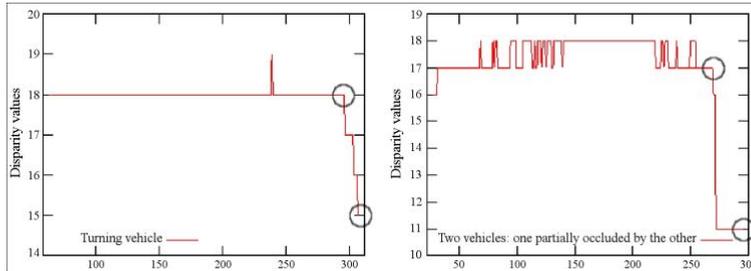


Figure 3. *Disparity values corresponding the two described situations for the pixels situated between the projected laser points.*

### 3. Experimental results

To evaluate the proposed approach, two scenarios are tested. In the first one, there is a vehicle turning to the right. In the second scenario, there are two vehicles, the one of them is partially occluded by the other.

Figure 4 presents results of the clustering for the first (a and b) and the second (c and d) scenarios. The images (a) and (c) show the results obtained with LRF-stereovision fusion. The images (b) and (d) show the results without fusion (only with LRF data). The gray rectangle corresponds to the real objects. The gray points represent the LRF raw data points. The red rectangle represents the raw data points cluster.

One may see from Figure 4 that the proposed fusion based approach provides good points clustering. In both scenarios, the correct number of objects is detected. In opposition, the approach without fusion correlates badly the LRF data. Indeed, one can find a suitable threshold to process the two situations separately, but it is difficult, even impossible, to perform the laser data clustering with a general threshold, which could take into account different situations.

### 4. Conclusions

A LRF data and stereovision based data association method for objects tracking is presented. The proposed method uses a threshold procedure to cluster the laser raw data points in general cases. When difficult situations appear, stereovision information is integrated to differentiate coalescing objects. The stereovision process is achieved only for the pixels situated in a region of interest, defined by consecutive laser points that meet a distance condition. The proposed approach is evaluated to demonstrate its

effectiveness by considering different simulated scenarios.

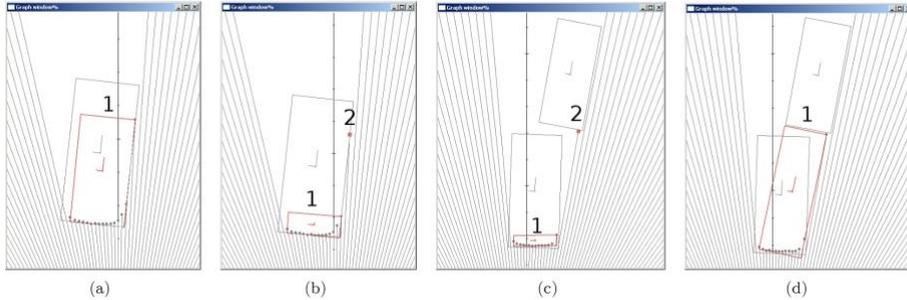


Figure 4. *Experimental results for scenarios 1 and 2 (with fusion (a-c), without fusion (b-d)).*

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