3D-PIV application for autonomous vehicles using monocular vision

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***Abstract*—**

I. INTRODUCTION

Monocular vision has been demonstrating a flourishing field in autonomous vehicles. Several applications have presented solutions to current problems. Although systems of low computational cost and effectivity are a challenge to field.

The Particle Image Velocimetry (PIV)[2] is used in many fields of knowledge [7], [9], to calculate the velocity of fluids in different parts. Here, PIV was adjusted for situation of autonomous vehicles, using PCC [6] and KITTI's bank of dates[4].

II. THEORETICAL FUNDAMENT

A. PEARSON CORRELATION COEFFICIENT - PCC

PCC is used in statistical analyses, pattern recognition and computer vision. Applications include disparity measurement and object recognition, comparing two images. The followed equation describes PCC for monochrome digital images[3]:

$$r_i = \frac{\sum_i (x_i - x_m)(y_i - y_m)}{\sqrt{\sum_i (x_i - x_m)^2}\sqrt{\sum_i (y_i - y_m)^2}} \tag{1}$$

Where, x_i is the intensity of the i-th pixel in image 1, y_i is the intensity of the i-th pixel in image 2, x_m is the mean intensity of image 1, and y_m is the mean intensity of image 2 [6].

B. PARTICLE IMAGE VELOCIMETRY - PIV

PIV is a method to determine a velocity field from images of seeded flows[2]. Its result is given as as field of vectors, demonstrating direction, sense and intensity of velocity in each particle. Moreover, it is possible to calculate rapidly the velocities of any part of image.

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III. SYSTEM DESCRIPTION

The purpose of this algorithm is tracking objects, producing added informations about the followed target. The algorithm developed takes as inputs sequential frames and Region Of Interesting(ROI). They are important to define the parameters used to generate the tracking of objects and other details as: the relative velocity, the factor of approaching and of departure

With ROI determined, the system enters in looping to follow the target as shown in the fig. 1.

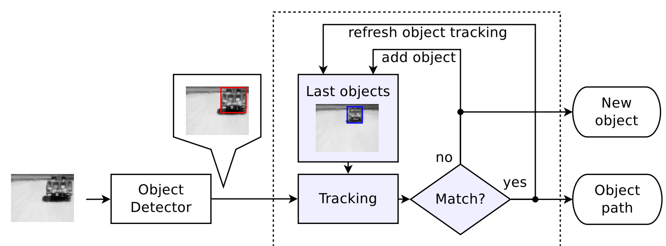

Fig. 1. With object detected, the highest value of PCC in the Window Of Search (WOS) of next frame identifies the target, and the result of search is a vector. Which its beginning and its end are on the first and last position, respectively. After, these processing is made again for next frames.

In 2 dimensions, the objects are tracking and given information about its horizontal or vertical relative velocity. When the target moves in 3 dimensions, outputs are the resultant of relative velocity and the factor of approaching or departure. There isn't a factor in 2 dimensions, since approaching or departure don't exist in this situation.

IV. ALGORITHM DESCRIPTION

A. MULTI-RESOLUTION MATCH CRITERIA

Method to track object at image is based on PIV. Figure 2(a) shows the application in 2 dimensions and the next in 3 dimensions.

(a) (b)

Fig. 2. The red box in figure (a) shows the ROI and black box is WOS. In the figure (a), ROI is compared with first portion on the left top of WOS, and these comparisons are made pixel by pixel for whole WOS. The black boxes, in the figure (b), are the WOS used to different layers of search in 3 dimensions

To track the object, the ROI defines the size of WOS and, verify the similarity of ROI and parts of WOS using PCC. The highest coefficient of Pearson determines new place of object. The figure 2(b) reveals how the dimension of depth was included and, the search is made in different layers. In 3 dimensions, the target also is found from the highest PCC among WOS, but the object may be bigger or smaller, depending in which layers was.

1) MULTI-LAYER 3D APPROXIMATION: The multi-layer is a technique to track objects that move in 3 dimensions. The layers are organized of the smallest to the biggest, there is a rate which layers increase. With this proceeding, the algorithm is capable of track objects that in second scene was larger than first.

2) FACTOR OF APPROACHING - RELATIVE VELOCITY: Factor of approaching is a dimensionless number related to the rate of approaching or departure of an object to the camera. The factor is determined how showed at equation 2:

$$f_a = \frac{Area_r}{Area_f} \tag{2}$$

Where f_a is the factor of approaching, $Area_r$ is area of ROI and $Area_f$ is area of current frame.
The factor has two means, e.g., if the rate of approaching increase quickly, so the target is approaching. Or the apposite, if factor decreases, thus object is departing.
Relative velocity is calculate using a simples equation of kinematic in physics:

$$v = \frac{\Delta s}{\Delta t} \tag{3}$$

Where v is relative velocity, Δs is difference in between two pixels and Δt is time of proceeding.
Velocity calculated is relative for simple reason that it is impossible to know the real distance between the camera and object in this condition.

B. RENEW ROI CRITERIA

Region of Interesting is an important element of algorithm because this decides what will be found at image. The mean question in this case is the best moment to change ROI. When the comparison of images reaches the threshold 0.925, then ROI is changed. The threshold adopted is 0.8 to match case[3].

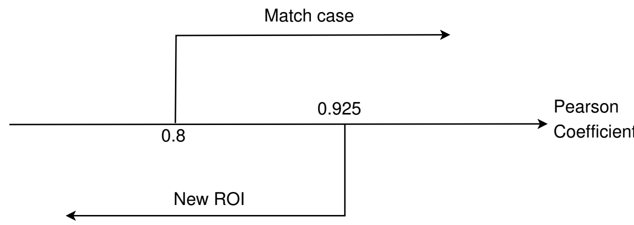

Fig. 3. When the comparison is more than 0.8, including numbers bigger than 0.925, the target was matched. But if two images are compared and PCC is less than 0.925, so the ROI changes to the last ROI compared.

The system needs to have high level of reliability, so the threshold adopted contributes to an operation with minimum of mistakes.

V. NUMERICAL RESULTS

VI. CONCLUSIONS

PIV has presented satisfactory results. Different kinds of information that can be concluded, like: estimate collision, tracking of objects in 2 or 3 dimensions and factor of approaching and removal. The simulations in Matlab has given promissories results.

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