Exploiting Spatial Variability for Disparity Estimation

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Abstract—**In this correspondence a block-matching strategy for disparity estimation is introduced. In the proposed approach the size of the matching window is adapted according to the spatial variability of the matching areas. That is, the window size is constrained by the variations of the image intensity. A modified semivariogram function is proposed to measure the spatial variability of concerned sampling positions. Results of computer experiments aimed at validating the performance of the proposed approach are reported. As expected, using adaptive matching window size provides better disparity estimations than those obtained by using a fixed window.**

***Index Terms*—Adaptive window size, block matching, motion/disparity estimation, semivariogram function.**

I. INTRODUCTION

THE main goal of stereo image analysis is to recover the 3D scene structure by estimating depth from corresponding points. Corresponding points in images taken from different perspectives are called disparities and can be seen as a vector field mapping one stereo image into the other. The estimation of this vector field is called the correspondence problem. Several methods have been proposed for solving the correspondence task. Most of them use iterative non-linear techniques subject to complex constraints to control the instability of the problem [1], [2], [3]. These approaches tend to fail in occluded and low textured areas of the image. Another powerful technique is based on area. It finds displacement vectors measuring the similarity of the corresponding surrounding areas in the first and second images [4]. Usually, the surrounding areas have a rectangular shape and are called *matching windows. D*isparity estimation by block-matching is a basic technique in computer vision [5], [6]. Although a large variety of block-matching based methods have been developed in the past, most of them use matching windows of fixed size and shape.

Only a few approaches from the literature adaptively change the shape of the matching window. A pioneering work in this direction was introduced by Levine *et al.* [7] in the early 1970's. They adapted the window size according to the intensity variation. Using windows, as Kanade *et al.* pointed out, requires "*the surface to be covered by a window to have the same disparity*". Kanade *et al.* suggested that "*a window size must be selected adaptively depending on local variations of intensity and disparity*" and proposed an iterative algorithm that controls the size and the shape of the window using a measure of uncertainty of the disparity estimation [8]. Different strategies have been proposed for selecting the size of the window [9], using different size of the windows [10], [11] and enforcing the inter-window dependency [12].

In this paper, an approach for selecting adaptively the window size is proposed. The approach exploits intensity variation using a relevant statistical measure. A modified semivariogram function is introduced for measuring the intensity variation or spatial variability in the surrounding areas. Experimental evaluations showed better estimations of disparity vectors by using adaptive window size.

II. EXPLOITING SPATIAL VARIABILITY FOR WINDOW SIZE ESTIMATION

To increase estimation accuracy the matching window size should depend on the spatial variability of the matching areas. For large variability of the surrounding areas a small matching window is required. On the other hand, a large matching window deliver better results for flat matching regions. Consequently, spatial pixel dependences can play a critical role in solving the correspondence problem using matching techniques. The autocorrelation function for measuring spatial dependence is called *semivariogram* [13]. It provides a measure of spatial dependences. It depends on the distance at which two points are separated and compares all pair of points at the same distance. In this work, we are interested in determining the window size based on the similarity between the intensity value at a given point p and intensity values in surrounding areas. A modification of the semivariogram function is proposed for this application.

Let $I(p)$ be the intensity value at a given position $p=(u,v)$. The modified semivariogram is given by

$$\gamma_p(h) = \frac{1}{2N(h)} \sum_{\forall\, p+h} (I(p) - I(p+h))^2 \,, \qquad (1)$$

where the $N(h)$ is the number of points at distance h.

While the modified semivariogram (1) measures local variations, the variance measures global variations. Moreover, local variations can be regarded as global when there are abrupt discontinuities or change in intensity values. Consequently, the window size can be selected according to the local variations. A suitable size for the matching window can be determined as the distance at which the modified

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a) Sequence SAXO

b) Sequence PIANO

Fig. 1: Selected interest points plotted on the first image at the middle and their estimated corresponding points plotted on the second image at the left calculated using adaptive window size and at the right calculated using a 5x5 window size.

semivariogram equals the variance:

$$\sigma^2(h) = \frac{1}{(2h+1)^2} \sum_{i=-h}^{h} (I(p+i) - \bar{I})^2 . \qquad (2)$$

III. Experimental Evaluation

The performance of the method presented has been verified by processing a set of stereoscopic test sequences. All experiments reported here were conducted according to the following procedure: Initially, interest points were extracted using the Canny detector. A bi-directional local maximisation algorithm was then used to estimate correspondences for selected interest points. The Pearson correlation coefficient was used as measure of similarity between matching windows.

The proposed adaptive window approach (ADPT) was compared with a similar approach using a fixed 5x5 window size (FIX). Results obtained using the sequences SAXO and PIANO are presented in Fig. 1. It can be observed that in both cases the proposed ADPT approach (left) outperforms the conventional FIX technique.

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