International Journal of Computer Vision 47(1/2/3), 275–285, 2002

A Hierarchical Symmetric Stereo Algorithm Using Dynamic Programming

G. VAN MEERBERGEN, M. VERGAUWEN, M. POLLEFEYS AND L. VAN GOOL
ESAT-PSI, K.U. Leuven, B-3001 Leuven, Belgium

Abstract. In this paper, a new hierarchical stereo algorithm is presented. The algorithm matches individual pixels in corresponding scanlines by minimizing a cost function. Several cost functions are compared. The algorithm achieves a tremendous gain in speed and memory requirements by implementing it hierarchically. The images are downsampled an optimal number of times and the disparity map of a lower level is used as 'offset' disparity map at a higher level. An important contribution consists of the complexity analysis of the algorithm. It is shown that this complexity is independent of the disparityrange. This result is also used to determine the optimal number of downsample levels. This speed gain results in the ability to use more complex (compute intensive) cost functions that deliver high quality disparity maps. Another advantage of this algorithm is that cost functions can be chosen independent of the optimisation algorithm. The algorithm in this paper is symmetric, i.e. exactly the same matches are found if left and right image are swapped. Finally, the algorithm was carefully implemented so that a minimal amount of memory is used. It has proven its efficiency on large images with a high disparity range as well as its quality. Examples are given in this paper.

Keywords: stereo vision, hierarchical stereo algorithm, dynamic programming, disparity computation, symmetric stereo

1. Introduction

The goal of this work is to compute fast accurate disparity maps, even for big images with large disparity ranges. It is assumed that these images are rectified first. The importance of the disparity maps for good 3D reconstruction is well known. The results of research on this topic include a wide variety of algorithms (Dhond and Aggarwal, 1989). Most of these algorithms are minimizing a cost function. The cost has 2 aspects: A first component decides how well a pixel of the left image corresponds to a pixel at the right image, i.e. the dissimilarity between 2 pixels. A second, respectively third component are related to the continuity in the horizontal, respectively vertical dimension of the disparity map. The latter is only dominant if no strong image data are available.

A possible criterion to classify these algorithms is the dimension of the optimization problem. The cost function decides how well a pixel of the left image corresponds to a pixel of the right image (zero dimensional cost function) (Koch, 1996). More robust is to optimize the sum of all costs of all matches in one scanline (one dimensional). The best is to optimize the sum of all costs over the whole image (two dimensional) (Roy and Cox, 1998). This algorithm, like many other algorithms (Cox et al., 1996; Birchfield and Tomasi, 1999), has chosen the second method, because it seems the best tradeoff between robustness and computational complexity. However, we will take into account information of the other scanlines by propagating information between them.

Our stereo algorithm has a number of specific properties. The algorithm is based on the hierarchical solution of the correspondence problem. Using this approach, we will show that the complexity decreases from $O(W \cdot H \cdot \delta^2_{range})$ to $O(W \cdot H)$, where W and H represent respectively the width and height of the pictures. Note that the complexity becomes independent of the disparity search range δ_{range}. The algorithm offers a significant advantage over other algorithms, especially