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Density and Accuracy Improvement of Phase-Based Disparity

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Abstract

This paper tackles the recurrent problem of disparity estimation. The measurement of image disparity is a fundamental precursor to binocular depth estimation. The mapping from disparity to depth is well understood, while the automatic disparity extraction is still subject to errors. We propose to use the image derivatives with the phase-based approach to overcome the tuning problem of the filter. Moreover, we propose a quadratic model for the singularities neighborhood detection and the phase quasi-linearity will be revisited. The approach is characterized by the simplicity of its implementation. It also provides dense and accurate disparity maps. A numerical error analysis against a ground-truth shows that the results are very satisfactory.

1 Introduction

This work aims at the perception and the understanding of three-dimensional scenes in computer vision. 3D information is widely used in a large number of practical applications: robot navigation, aerial or satellite mapping, medical imaging, and part inspection to name a few. Stereo is one of the 3D structure extraction techniques. Stereo allows the computation of the depth using two images of the same scene, taken with two cameras having different viewpoints. The primary task of stereo is to locate pairs of pixels that are images of the same point of the scene.

Many approaches have been proposed for disparity measurement. These approaches differ from one another in the matching primitives, the density of the results, the accuracy of the estimates and the underlying computation time. The most reported methods in the literature are feature-based, correlation-based and energy minimization-based matching. Recently, several works proposed phase-based techniques to disparity estimation. One of the first applications to exploit phase was the Kuglin-Hines method [1]. The method, which is conceptually simple, uses only the Fourier phase and assumes that the two images are related by pure translation. Sanger [2] proposed a method using complex Gabor filter. He extracts the phase from the complex response of Gabor filter, and uses the Fourier shift theorem to compute the disparity. Other earlier algorithms expressed the computational task as a nonlinear differential equation that must be solved at each image point [3]. The solving of a differential equation at a large number of image points and disparities makes the algorithm unsuitable for real time computer applications. Many other authors have used Gabor filter since the work of Sanger [4, 5]. The work of Fleet [6] and Fleet *et al.* [7] improved this approach. Fleet [7] employs a coarse-to-fine strategy, first used in this application area by [8], in order to allow the filter's frequency to vary. However, the disparity estimates are not accurate when phase at coarse scales is unavailable. Weng [9] used the windowed Fourier phase. He proposes the use of a set of variable-size windows to compute the disparity.

In this paper, we will motivate the choice of the bandpass filter which will be used for disparity estimation. Furthermore, a theoretical study showed that for some functions the phase is either linear or quasi-linear [10]. This finding allows us to assume without loss of generality that the phase of the response is linear or locally linear. We propose to use the images and their derivatives instead of a set of filters to overcome the tuning problem. Furthermore, the linear model used in the singularity neighborhood detection is improved by the quadratic model which seems to better approximate the data. In section 2, we present the disparity as Fourier phase difference and motivate the use of the Gabor filter. The phase behavior, the singularities detection and the algorithm are subject of section 3. In section 4, we show the experimental results.

2 Disparity as phase difference

Let us suppose that the disparity Δx is constant over the image. Then, according to the Fourier shift theorem, a shift in the spatial domain transforms to a modulation in the frequency domain:

$$f(x - \Delta x) \circ\!\!-\!\!\!-\!\!\!-\!\!\bullet\ \mathcal{F}\{f\}(\omega)\ e^{-j\omega\Delta x} \qquad (1)$$