An Iterative Method for Improving *Bas-relief* Ambiguity

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Abstract

When using small motion model, the problem of "structure from motion" has inevitably the ambiguity between translation and rotation motion. For solving it, conventional methods adopt a single line methodology; first they try to find exact corresponding points with only image brightness, and then motion parameters and scene depths are estimated on the basis of it. But, considering that the previous corresponding methods may have large errors and it is difficult to define its error model, the single line methods cannot improve such ambiguity although they introduce any robust statistical estimator. Therefore, on the assumption that corresponding points and motion estimation have to be iteratively refined, we propose a new method for improving those ambiguities with stereo image sequence.

1. Introduction

For visual reconstruction and robot navigation, structure from motion (SFM) is an active issue in computer vision community and its properties are also becoming well understood. As a drawback in SFM, it is well known that the SFM methods, using small motion model such as optical flow based method and direct method, have inevitably motion ambiguity between translation and rotation, which is called *bas-relief ambiguity*. In this paper we present an iterative method for improving those ambiguities, which is based on the robust direct method using stereo image sequence [1].

As for the bas-relief ambiguity, Weng [2] implemented its error modeling with Cramer-Rao bounds and tested the limits of small motion with various simulations and experiments. Recently, Szeliski and Kang [3] performed its analysis based on the singularities of the Hessian of the information matrix. As tools for overcoming such ambiguities, some methods also have been suggested in computer vision community: they used planar-parallax model [4] and linear transformations [5]. Soatto and Brockett [6] recently suggested a probably convergent algorithm that is robust to large noise, and showed that the bas-relief ambiguity is intrinsic to SFM.

However, when we consider the problem of SFM from practical point of view, it is most important how we obtain exact corresponding feature points. As noted in [6], the previous corresponding methods, such as optical flow or corner finding method, can have large locating errors, and its error distribution cannot be modeled [1]. Therefore, the previous linear methods cannot cope well with its ambiguity. Moreover, when we consider that the shape of cost function under the bas-relief ambiguity can be like narrow diagonal valley [7], we cannot improve the errors with only any non-linear optimization method although it introduces robust statistics. It again means that it is the first settlement for overcoming its ambiguity to achieve exact corresponding feature points as much as possible, of which error distribution cannot be modeled beforehand.

In this paper for improving the estimation error due to bas-relief ambiguity, we basically are to use a robust and direct motion estimation method [1]. It gives a lot of approximated corresponding points. Therefore, based on it, we proposed a new method that can implement stereo and motion correspondence under the sub-pixel accuracy, and then we can refine motion and depth estimates with robust statistical method again.

The next section describes the details of an iterative refinement process and overall algorithm. In section 3, we show the experimental results, and we make conclusions in section 4.