Chapter 11
Combining Focus Measures for Three Dimensional Shape Estimation Using Genetic Programming

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ABSTRACT

Three-dimensional (3D) shape reconstruction is a fundamental problem in machine vision applications. Shape from focus (SFF) is one of the passive optical methods for 3D shape recovery, which uses degree of focus as a cue to estimate 3D shape. In this approach, usually a single focus measure operator is applied to measure the focus quality of each pixel in image sequence. However, the applicability of a single focus measure is limited to estimate accurately the depth map for diverse type of real objects. To address this problem, we introduce the development of optimal composite depth (OCD) function through genetic programming (GP) for accurate depth estimation. The OCD function is developed through optimally combining the primary information extracted using one (homogeneous features) or more focus measures (heterogeneous features). The genetically developed composite function is then used to compute the optimal depth map of objects. The performance of this function is investigated using both synthetic and real world image sequences. Experimental results demonstrate that the proposed estimator is more accurate than existing SFF methods. Further, it is found that heterogeneous function is more effective than homogeneous function.

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INTRODUCTION

Inferring three-dimensional (3D) shape of an object from two-dimensional (2D) images is a fundamental problem in computer vision (Ahmad & Choi, 2005; Nayar & Nakagawa, 1994; Thelen, Frey, Hirsch, & Hering, 2009). Broadly, 3D shape recovery algorithms based on optical reflective model can be categorized into active and passive techniques. In active techniques, depth of the object of interest is computed by investigating transmission or reflection of signals such as ultrasound or infrared rays. While, passive methods infer the depth of the object by analyzing information from the captured images. The shape from focus (SFF) is one of the passive methods to estimate 3D structure of the object based on image focus analysis. It is a famous one in the paradigm of shape from X, where X denotes the cue used to infer the shape as stereo, motion, shading, de-focus, and focus. The SFF technique has been successfully utilized in many industrial applications, i.e. microelectronics (Niederost, Niederost, & Scucka, 2003), industrial inspection (S. O. Shim, Malik, & Choi, 2009), medical diagnostics (Boissenin et al., 2007), 3D cameras (Malik & Choi, 2007a), TFT-LCD color filter manufacturing (Ahmad & Choi, 2007), and roughness comparison of polymers (Malik & Choi, 2009). In addition, it has also been employed to measure roughness, and geometry of large components, such as engine blocks and aircraft turbines (Kyte, 2010).

In SFF, an image sequence is acquired by translating object along the optical axis. It is important to note that acquired images from lenses with limited depth of field have both the areas in and out of focus. However, it is possible to compute the well-focused image from the image sequence taken at different focus levels by computing the high frequency image contents. A criterion, usually known as focus measure, is used to compute focus quality of each pixel in the image sequence. Focus quality is computed for each pixel in the image sequence and an initial depth map is obtained by maximizing the focus measure along the optical axis. In the literature, many focus measure operators are reported in spatial (Helmli & Scherer, 2001; Krotkov, 1988; Subbarao & Tyan, 1998) and transform domains (Mahmood, Choi, & Choi, 2008; Mahmood, Shim, & Choi, 2009; Malik & Choi, 2008; Sun, Duthaler, & Nelson, 2004; Xie, Rong, & Sun, 2007). Once an initial depth map is computed, some approximation technique is applied to further refine these results (Malik & Choi, 2007b; Nayar & Nakagawa, 1994; Subbarao & Choi, 1995). Most of these techniques use a single focus measure to estimate initial depth map. Due to the diverse nature of real images, it is not possible for a single focus measure to perform equally well under different scenarios. Therefore, it is difficult to choose a suitable focus measure for specific conditions. Another drawback with existing techniques is that the error introduced in computing initial depth map is propagated to the approximation step. In such scenario, there is a demand of a new generalized optimal depth estimator that may effectively incorporate useful information from more than one focus measures.

In this connection, we propose a novel idea of combining initial depth and focus values extracted from various focus measures. Using this concept, the advantages of one focus measure can overcome the shortcomings of others. However, the problem is how to combine in a best possible way. Under such circumstances, we introduce genetic programming (GP) based technique that optimally combines the initial information extracted from one or more focus measures. GP approach works on the principles of natural selection and recombination to search the space for possible solutions under a fitness criterion. Due to the flexibility of adjustable parameters, GP optimization technique (dos Santos, Ferreira, Torres, Gonlves, & Lamparelli, 2010; Kouchakpour, Zaknich, & Brnl, 2009; Koza, Streeter, & Keane, 2008; Langdon, 2000; Mallipeddi, Mallipeddi, & Suganthan, 2010) has been widely used in the applications of image processing (Petrovic & Crnojevic, 2008), pattern

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