Chapter 10
Image Focus Measure Based on Energy of High Frequency Components in S-Transform

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ABSTRACT

Focus measure computes sharpness or high frequency contents in an image. It plays an important role in many image processing and computer vision applications such as shape from focus (SFF) techniques and multi-focus image fusion algorithms. In this chapter, we discuss different focus measures in spatial as well as in the transform domains. In addition, we suggest a novel focus measure in S-transform domain, which is based on the energy of high frequency components. A localized spectrum, by using variable window size, provides a more accurate method of measuring image sharpness as compared to other focus measures proposed in spectral domains. An optimal focus measure is obtained by selecting an appropriate frequency dependent window width. The performance of the proposed focus measure is compared with those of existing focus measures in terms of three dimensional shape recovery and all-in-focus image generation. Experimental results demonstrate the effectiveness of the proposed focus measure.

INTRODUCTION

Imaging devices, particularly those with lenses of long focal lengths, usually suffer from limited depth-of-field. Therefore, in the acquired images, some parts of the object are well-focused while the other parts are defocused with a degree of blur. Usually, a focus measure is used to compute the image focus quality that plays an important role in many image processing and computer vision applications. For example, the performance of the shape from focus (SFF) techniques and multi-focus fusion algorithms depend on accurate focus measurements (Ahmad & Choi, 2005; Simonov & Rombach, 2009; Wang, Ma, & Gu, 2010). In multi-focus fusion, an all-in-focus image is ob-

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tained from two or more blurred images. In the stack of images, the well-focused regions are distinguished from the blurred regions by commuting the focus quality. The fused image is obtained by combining the well-focused regions. On the other hand, SFF is a passive optical technique, which uses focus as a cue for depth estimating. In this technique, a sequence of images is acquired at different focus levels by translating object along the optical axis. First, focus value is computed for each pixel in the image sequence by using a focus measure. The best-focused pixels among the sequence provide the depth information. A rough depth map is then obtained by maximizing the focus measure along the optical axis. In the second step, an approximation technique is used to refine the initial depth map (Ahmad & Choi, 2005; Simonov & Rombach, 2009; Wang, et al., 2010). These depth estimation techniques generally rely on the accuracy of the focus measure. Thus, in SFF techniques, a robust and accurate focus measure is of fundamental importance. In addition, many focus measure based techniques have been successfully utilized in many industrial applications. Using the variations of the focus, it is possible to measure the surface roughness and metrology(Kyte, 2010; Malik & Choi, 2009). It can also be employed in surface characterization, evaluation of tolerances and wear analysis in 3D, accurate 3D measurement of micro-gear wheels (Kyte, 2010).

Focus measure computes sharpness or high frequency contents in an image. Acquired images through the camera aperture are result of convolution of actual image and low pass filter i.e. point spread function (PSF). Therefore, ideally, a focus measure is a high pass filter that should response to the high frequency contents in an image. In the literature, many focus measures have been reported in spatial and frequency domains. In spatial domain, derivative and statistical analysis of image intensities commonly used to compute the sharpness (Krotkov, 1988; Malik & Choi, 2007; Nayar & Nakagawa, 1994b). In frequency domains, focus measures usually compute total energy of high frequency components. Some focus measures in transform domain calculate the ratio of the high frequency components to the low frequency components (Kautsky, Flusser, Zitov, & Simberov, 2002; Sang-Yong, Kumar, Ji-Man, Sang-Won, & Soo-Won, 2008; Xie, Rong, & Sun, 2007). The studies of these focus measures have revealed that frequency components of different energies affect the focus measurement. For example, in discrete wavelet transform (DWT) based focus measures, high frequency components at the second level have a higher effect on image sharpness (Mahmood, Shim, & Choi, 2009). Similarly, in discrete cosine transform (DCT) based focus measures, frequency components in the middle are of greater interest regarding focus measurement (Mahmood, et al., 2009). The use of optical transfer function (OTF) i.e. low pass filter in frequency domain increases the robustness of the focus measure (Malik & Choi, 2008). In other words, the quality of focus measurements depends upon the frequency spectrum of the image.

Due to a variable window size, a recently proposed S-transform (ST) has certain advantages over DWT and other time-frequency analysis tools, and it has gained considerable attention in signal and image processing (Brown, Zhu, & Mitchell, 2005; Stockwell, Mansinha, & Lowe, 1996). In this chapter, we suggest the use of ST, with modified window width scheme, to compute the image focus. The window width affects the energy of the transformed components. In the proposed method, the window width depends on the variation in frequency along with two adjustable parameters. The optimal values of these adjustable parameters are chosen in such a way that the energy concentration be maximized. The energy of localized spectrum is taken as a criterion to compute the focus quality. Experimental results demonstrate the effectiveness of the proposed method.

In the remaining chapter, we start with the formation of image in convex lens and define focus measure. Different focus measures in spatial and

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