Wavelet-Based Resolution Enhancement of Omnidirectional Images*

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Abstract

In this paper we present an approach for resolution enhancement of omnidirectional images based on wavelet transform. First, the degradation model of omnidirectional image is given. Second, the resolution enhancement of an image is achieved by using local extrema extrapolation of wavelet coefficients. Then, fusion operation is applied to the coefficients of registered pixels in the enhanced images of an image sequence. Finally, a fine resolution enhancement image is reconstructed via inverse wavelet transform. The experimental results show the proposed approach is feasible and efficient for resolution enhancement of omnidirectional image.

Key Words: omnidirectional image, resolution enhancement, wavelet transform, image fusion

1. Introduction

Omnidirectional cameras have several distinguished merits compared with conventional cameras. Omnidirectional cameras can easily identify slim rotation from translation without ambiguity due to its 360° view field [Nayar,1997][Kang and Weiss,1999]. Especially, the rotation invariant of an omnidirectional image is suitable for surveillance, robot navigation, image-based rendering and video-conferencing [Onoe *et at.*, 1998][Boult, 1999][Gaspar *et at.*, 2000]. Unfortunately, non-uniformity and low resolution of omnidirectional images limit its application. One way to solve this problem is trying to compensate the non-uniform projection with a special CCD array particularly designed for a omnidirectional camera, but it is very expensive. Another way is to enhance resolution with a computational compensation. A lot of work has been done on resolution enhancement and much progress has been reported [Hunt, 1995][Elad and Feuer,1999][Freeman and Pasztor,1999] [Schultz and Stevenson,1996]. Most of existing approaches fall into the following three categories: frequency-based, spatial-temporal-based and hybrid methods [Tekalp, 1995] [Sementilli *et at.*,1993][Lorette *et at.*, 1997]. Resolution enhancement is an ill-posed inverse problem, and a spatial domain approach can conveniently integrate a priori knowledge for the regularization of the problem. As a result, spatial domain approaches are used more often than frequency domain approach. More attention has been paid to the interpolation of non-uniform spaced samples and nonlinear models capable of bandwidth extrapolation [Cyetkovic and Vetterli, 1995][Aizawa *et at.*, 1991].

In this paper, we present an approach to resolution enhancement of omnidirectional images. We integrate single frame enhancement and image fusion from an image sequence based on the addition theorem, spatial-temporal consistency and self-similarity of wavelet transform. The experimental results demonstrate that the proposed algorithm is feasible for resolution enhancement of omnidirectional images.

2. Degradation Model

An omnidirectional camera consists of a catadioptric mirror and a CCD camera. The mirror shape can be spherical, parabolic, and hyperbolic [Ollis *et at.*, 1999].

The imaging procedure can be treated as the combination of a projection from a scene to the surface of the mirror and a reflection from the mirror to the CCD array. Both are nonlinear projections (see Fig. 1), and reflection results in a non-uniform sampling.

The non-uniform resolution of omnidirectional images can be verified with a simple calculation: corresponding to the same ken, the inside track of the image which contains fewer pixels has lower resolution in comparison with the exterior track of the image.

Let $x_{sc}(m_1,m_2)$ be a scene containing $m_1 \times m_2$ visible points, and $x_o(n_1,n_2)$ the omnidirectional image with size of $n_1 \times n_2$ The procedure of imaging can be written as

$$x_o(n_1,n_2) = T_r T_p x_{sc}(m_1,m_2) + n(n_1,n_2) \quad (1)$$

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