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Image and Vision Computing 23 (2005) 791–798

image AND vision COMPUTING

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A fast edge-oriented algorithm for image interpolation

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Received 30 January 2004; received in revised form 28 April 2005; accepted 5 May 2005

Abstract

This paper introduces a fast algorithm for image interpolation. By using this method, real-time enlargement of video images is accessible. The basic idea of the algorithm is to partition digital images into homogeneous and edge areas based on the analysis of the local structure on the images. In addition, in order to have better performance on interpolating images, specified algorithms are assigned to interpolate each classified areas, respectively. Experimental results show that the subjective quality of the interpolated images is substantially improved by using the proposed algorithm compared with that of using conventional interpolation algorithms. The computational complexity of the proposed algorithm is much lower than those of others mentioned in this paper. We also successfully implemented real-time enlargement of QCIF video sequences to CIF sequences with better image quality in low bit-rate environment.

Keywords: Interpolation; Zooming; Enlargement; Video image; Real-time; Edge

1. Introduction

Multimedia communication plays an important role in modern networks. Image transfer is one of the main applications in multimedia communication. Efficient manipulation of large amount of image data in a system with limited bandwidth is considered as a key issue in this process. Digital images and video sequences essentially result in huge volume of image data. With huge volume of image data and limitation of network bandwidth, the quality of the transferred images is often unacceptable and poor performance, such as jitters and flickers can occur. The bandwidth for image transfer can be saved much more and image quality can be improved if the low-resolution video sequences is coded in encoder end and the low-resolution video sequences is afterward enlarged to high-resolution ones using interpolation techniques in decoder end.

Image interpolation can be used in image enlargement and local image zooming. Several commonly used interpolation algorithms have been suggested, such as zero-order interpolation [1], linear interpolation [1] and cubic convolution interpolation [2]. However, image artifacts like blurring or zigzag on edge may occur when these interpolation schemes are used. In order to reduce the effect of image artifacts, other algorithms have been proposed [3–10]. The method proposed in [3] is based on directions in spatial domain. Interpolated values along different directions are calculated using directional weights. The weights are dependent on the variation in the directions. The algorithms in [4–5] are convolution-based interpolation methods. Pixels to be interpolated are classified into two decimations in which pixels are interpolated by different specified filters. A hybrid of convolution and median-based scheme splits the interpolation into two directional stages [6]. The soul of the algorithm in [7] is based on variation models with smoothing and orientation constraints. The algorithm in [8] is applied to an image after it was expanded using either bilinear or bicubic interpolation. Edges in the expanded image are obtained by use of canny edge detector. The values of pixels around the edges are modified to yield a crisper and less zigzagged picture. Another algorithm of adaptive re-sampling analyses the local structure of an image and applies a near optimal and least time-consuming re-sampling function that can preserve edge locations and their contrast [9]. Algorithms described above [3–9] have better performance than common interpolation algorithms introduced in [1–2]. Another robust algorithm, New Edge-Directed Interpolation (NEDI), performs good subjective

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doi:10.1016/j.imavis.2005.05.005

quality for image enlargement. The method initially estimates local covariance coefficients from a low-resolution image and then the estimated covariance are used to adapt the interpolation at a higher resolution based on the geometric duality between the low-resolution covariance and the high-resolution covariance. By comparing to other algorithms, the algorithm of covariance-based interpolation has higher computational complexity [10].

The basic concept of the algorithms mentioned above is to interpolate images using the feature of pixels. Determination of pixel feature by these methods needs higher computational complexity. Consequently, these algorithms are unable to achieve real-time (30 frames/sec) image enlargement in video sequences. To solve the problem, we propose a new interpolation algorithm, which provides better subjective quality and lower computational complexity for image enlargement.

This paper is organised as follows. Section 1 describes the importance of interpolation to communication and gives a brief review of previous algorithms. Our proposed algorithm is introduced in Section 2. The experimental results are provided in Section 3. Conclusions of this paper are made in Section 4.

2. Proposed algorithm

2.1. General concept of the proposed algorithm

The proposed algorithm is expected to achieve two major goals: lower computational complexity and better subjective quality. Hence, the new method can be practically applied to video sequences and videoconference.

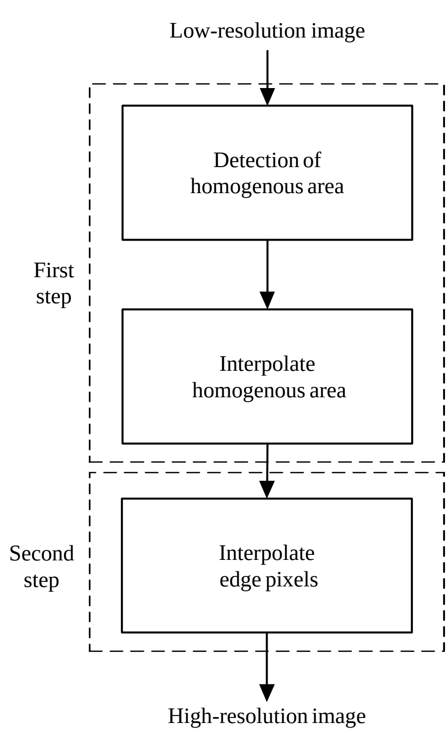

Fig. 1. The procedure of the proposed algorithm.

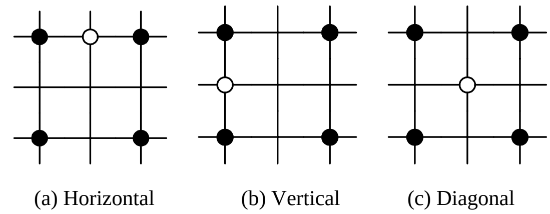

Fig. 2. The differences of four directions (one for horizontal, one for vertical and two for diagonal).

Our proposed method interpolates images based on analysing the local structure of the images. The original images are classified into two categories: homogenous areas and edge areas. The interpolation of pixels in the different classified areas is accomplished by using individual interpolation algorithm, respectively. The conceptual procedure of our proposed algorithm is illustrated as Fig. 1.

Determination of pixels to be either homogenous pixels or edge pixels is based on a preset threshold value. First, the differences of pixels values along horizontal, vertical and diagonal directions are determined in a 3×3 window, respectively. Choice of the 3×3 window can significantly reduce computational loading and structural complexity of our proposed algorithm. We determine the differences of pixel values of the four directions one by one. Fig. 2 gives a schematic illustration to the four directions, one for horizontal, one for vertical and two for diagonal directions. If the difference is less than the preset threshold value, a non-interpolated pixel (white dot) will be classified as a homogenous pixel. Non-interpolated points in the homogenous areas are simply filled using bilinear interpolation. If the difference of pixel values is larger than the threshold value, the non-interpolated point is assigned as an edge pixel. After the first step, some non-interpolated pixels are remained as points in the edge areas. These pixels on edges will be left for further processing in the second step. An example of the result of the first step is demonstrated in

Fig. 3. The result of the first step of the proposed algorithm for Lena image.