Chapter 15
Multi-Scale Exemplary Based Image Super-Resolution with Graph Generalization

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ABSTRACT

Exemplary based image super-resolution (SR) approaches decompose low-resolution (LR) images into multiple overlapped local image patches, and find the best high-resolution (HR) pair for each LR patch to generate processed HR images. The super-resolving process models these multiple HR/LR patches in a Markov Network where there exists both confidence constraint between the LR patch and the selected HR patch from database, and the harmonic constraint between neighboring HR patches. Such a graphical structure, however, makes the optimization process extremely slow, and therefore extensive research efforts on improving the efficiency of exemplary based SR methods have been reported. In this chapter, the focus is on those methods that aim at generating high quality HR patches from the database, while ignoring the harmonic constraint to speed up processing, such as those that model the problem as an embedding process, or as a feature selection process. As shown in this chapter, these approaches can all be regarded as a coding system. The contributions of the paper are two-fold: First, the chapter introduces a coding system with resolution-invariance property, such that it is able to handle continues-scale image resizing as compared to traditional methods that only support single integer-scale upsizing; second, the author generalizes the graphical model where the typical non-linear coding process is approximated by an easier-to-compute function. In this way, the SR process can be highly parallelized by modern computer hardware. As demonstrated by the chapter, the proposed system gives very promising image SR results in various aspects.

DOI: 10.4018/978-1-4666-1891-6.ch015

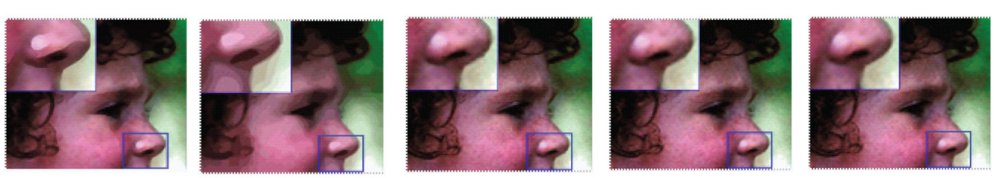
INTRODUCTION

Visual data is usually represented in two digital formats, specifically the raster image or the vector image. Raster image is a rectangular grid of pixels, and the human perceptual clarity of a raster image is decided by its spatial resolution which measures how closely the grid can be resolved. Although higher pixel density are usually desirable in many applications, such as high resolution (HR) medical images for cancer diagnosis, high quality video conference, high definition television broadcasting, Blu-ray movies, etc, raster images are resolution dependent, and thus cannot scale to an arbitrary resolution without loss of apparent quality. The other format, the vector image, represents the visual data using geometrical primitives such as points, lines, curves, and shapes or polygon. For instance, the widely used "SVG" (Scalable Vector Graphics) format uses 14 primitives including paths, shape, text, and color (SVG). The vector image is totally scalable, which largely contrasts the deficiency of raster representation.

The idea of vectorizing raster image for resolution enhancement has long been studied. Recently, Ramanarayanan *et al.* (2004) added the vectorized region boundaries to the original raster images to improve sharpness in scaled results; Dai *et al.* (2007) represented the local image patches using the background/foreground descriptors and reconstructed the sharp discontinuity between the two; To allow efficient vector representation for multi-colored region with smooth transitions, gradient mesh technique has also been attempted (Sun, 2003). In addition, commercial softwares such as (Vector-Magic) are already available. However, vector-based techniques are limited in the visual complexity and robustness. For real photographic images with fine texture or smooth shading, these approaches tend to produce over-segmented vector representations using a large number of irregular regions with flat colors. To illustrate, Figure 1(a) and (b) are vectorized and grown up to $\times 3$ scale using methods in (Dai, 2007) and (Vector-Magic). The discontinuity artifacts in region boundaries can be easily observed, and the over-smoothed texture regions make the scaled image watercolor like.

Alternatively, researchers have proposed to vectorize raster image with the aids of a suitable bases set to realize higher modeling capacity than those simple geometrical primitives. For example, in image/video compression domain, pre-fixed bases, such as the DCT/DWT bases adopted in JPEG/JPEG-2000 standard, and the anisotropic bases such as countourlets (Do, 2006), have already been explicitly proposed to capture different 2-D edge/texture patterns, because they lead to sparse representation which is very preferable for compression (Hong, 2006). In addition to pre-fixed bases, to capture the significantly different geometric structures and/or statistical characteristics in natural images, adaptive mixture model representations were also reported. For example, the Bandelets model (Erwan, 2005) partitions an image into squared regions according to local geometric flows, and represents each

Figure1. Comparison of scaling vectorized image and the author's method



(a) method by (Dai, 2007) (b) method by (Vector-Magic) (c) ~ (e) our method using NN, LLE and SC models respectively