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Guest Editorial

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The January 2009 Computer Journal special issue focuses on the super-resolution (SR) of images and video. The term SR is used to describe the process of obtaining a high-resolution (HR) image, or a sequence of HR images, from a set of low-resolution (LR) observations. This process has also been referred to in the literature as resolution enhancement (RE). SR has been applied primarily to spatial and temporal RE, but also to hyperspectral image enhancement.

SR techniques are being applied to a variety of fields, such as obtaining improved still images from video sequences (video printing), high-definition television, high-performance color liquid crystal display (LCD) screens, improvement of the quality of color images taken by one CCD, video surveillance, remote sensing and medical imaging. New application areas of SR are also emerging, such as the incorporation of SR techniques in the development of new video codecs.

The topic of SR or RE as described in this special issue first appeared in the early 1980s. Since then the topic has been active, with some of the early exciting results appearing in the 1990s. The last five or so years, however, have witnessed an enormous resurgence in SR activity. This assessment is supported by the number of the recent papers on the topic and also by the ongoing R&D projects on SR in various segments of the industry and various research laboratories. We believe that the SR/RE area has matured enough to develop a body of knowledge that can now start to provide useful and practical solutions to challenging real problems. This indeed provides an explanation for the renewed interest in it. Due to the strong interplay between the tools and techniques developed for SR and a number of other inverse problems encountered in signal processing (e.g. image restoration, motion estimation), advances in the solution of the other inverse problems has also fueled the activities in SR.

We therefore believed that the time was appropriate to undertake the creation of this special issue where the recent advances in the field are described in a comprehensive way. It is our hope and expectation that this special issue will serve as a good reference to the graduate student or the practicing engineer who works in this area, but also to the person completely outside of this research area who would like to 'just find out what this excitement is all about!' As we have already alluded to above, the material in this special issue can also serve well the scientist in applying some of the tools and results to other related problems.

More specifically, in this special issue we have collected papers that cover, in our opinion, most of the core aspects of SR: SR image registration, learning in SR, SR from a single image, enhancement of Bayer CFA-sampled images, SR and dynamic range enhancement, a new use of the Papoulis–Gerchberg (PG) approach in SR, inpainting, medical and multispectral applications, the joint estimation of blur and motion in SR using the coprime concept and Bayesian modeling and inference in SR. A brief summary of the papers in the issue is provided now.

In the paper by M. Gevrekci, B.K. Gunturk and Y. Altunbasak the authors present POCS-based algorithms for multiframe RE of Bayer CFA-sampled images. They investigate two approaches: demosaicking and super-resolution (DSR) and only super-resolution (OSR). With the DSR approach, they separate the restoration process into two parts. The first part consists of multiframe demosaicking, where missing color samples are estimated. The second part consists of super-resolution reconstruction, where subpixel level resolution is achieved. With the OSR approach, a super-resolution image is reconstructed without demosaicking, using Bayer pattern masks only for computing the residual of each color channel.

In the second paper, by M. Elad and D. Datsenko, the authors describe how examples can be used effectively for the regularization of inverse problems and in particular for the SR reconstruction from a single image. They review the main contributions along these lines in the literature and organize this information into major trends and directions. A description of the state-of-the-art in this field, along with supporting simulation results on the image scale-up problem are given. The paper concludes with an outline of the outstanding challenges in this field.

The paper by D. Robinson, S. Farsiu and P. Milanfar addresses the very important problem of registration in SR imaging. They describe an approach to multiframe registration that exploits the concept of variable projections to achieve very efficient algorithms. Their method could be thought of as an integration on the image to estimate first the registration parameters, which is also related to variational distribution approximation. They show that the proposed algorithm offers accurate estimation under various conditions.

The paper by H. Greenspan provides a complete review of the SR research in medical imaging applications, an area, in our opinion, of great potential but for which not much work has been reported. Many medical imaging modalities exist. Each imaging system has a characteristic resolution, which is determined by the physical constraints of the system detectors that are in turn tuned due to signal-to-noise and timing considerations. A common goal across systems is to increase the resolution, and as much as possible achieve true isotropic 3-D imaging. SR technology can be used to advance this goal. Research on SR in key medical imaging modalities, including MRI, fMRI and PET, has started to bear fruit in recent years and is reviewed in the paper.

M.J. Fadili, J.-L. Starck and F. Murtagh tackle in their paper the inpainting problem. By representing the image to be inpainted with an appropriate sparse representation dictionary, and combining elements from Bayesian statistics and modern harmonic analysis, they introduce an expectation maximization (EM) algorithm for image inpainting and interpolation. The EM framework gives a principled method to establish formally the idea that missing samples can be recovered/interpolated based on sparse representations. They introduce a sparse representation-based iterative algorithm for image inpainting and derive its theoretical convergence properties. They also suggest some guidelines to automatically tune the regularization parameter.

P. Chatterjee, S. Mukherjee, S. Chaudhuri and G. Seetharaman study the PG method and its applications to domains of image restoration such as SR and inpainting. They show that the method performs well under certain conditions and suggest improvements to the method to achieve better SR and inpainting results.

In their paper H. Shen, M.K. NG P. Li and L. Zhang propose an SR reconstruction algorithm applied to real moderate-resolution imaging spectroradiometer (MODIS) remote sensing images in the same spectral band. To obtain accurate photometric and geometric parameters among the observed images, they use a truncated quadratic cost function to exclude the outliers in the subpixel registration part. Then, they obtain a MAP estimate of the desired HR image with the use of a robust L1 norm data fidelity term and an edge-preserving Huber prior.

L. Pickup, D. Capel, S.J. Roberts and A. Zisserman present a novel method of Bayesian image SR in which marginalization is carried out over latent parameters, such as the geometric and photometric registration parameters and the image point spread function. Related Bayesian SR approaches marginalize over the HR image; however, their method allows for more complex image prior distributions since the integration is not performed on the image.

In the paper by J. Choi, M.K. Park and M.G. Kang, the authors review the approaches to enhance the spatial resolution and dynamic range of images, and propose an SR reconstruction algorithm that simultaneously enhances the spatial resolution and dynamic range. The image degradation process including limited spatial resolution and limited dynamic range is modeled and the MAP estimates of both the response function of the imaging system and a single HR and HDR image are obtained.

A. Mohammad-Djafari in his paper first provides a short review of a variety of SR problems and focuses on the multi-input single output and multi-input and multi-output SR problems. He also describes in detail a new method, particularly appropriate for piecewise homogeneous images, which provides not only an SR image, but also simultaneously an optimal segmentation of an HR image. Finally, he discusses some future challenges in SR.

F. Sroubek, J. Flusser and G. Cristobal introduce an SR and deconvolution method that assumes no prior information about the shape of the degradation blurs, incorporates the registration parameters into the process and is properly defined for any rational (fractional) resolution factor. The method minimizes a regularized energy function with respect to the HR image and blurs, where regularization is carried out in both the image and blur domains.

Finally in the paper by M. Vega, J. Mateos, R. Molina and A.K. Katsaggelos the authors propose and analyze a globally and locally adaptive SR Bayesian methodology for pansharpening of multispectral images. The methodology incorporates prior knowledge on the expected characteristics of the multispectral images, uses the sensor characteristics to model the observation process of both panchromatic and multispectral images and includes information on the unknown parameters in the model in the form of hyperprior distributions.

We hope you enjoy reading the papers in this special issue as much as we enjoyed its preparation. Let us close this guest editorial by thanking all the authors for their participation in the project, the former Editor-in-Chief of the Computer Journal Dr Fionn Murtagh for inviting us to prepare the issue and finally the current Editor-in-Chief Dr Erol Gelenbe for making happen the publication of this editorial.