

# Fusion in Image Processing

FUSION 2008

Tutorial proposal

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**Duration:** half day (approx. 4 hours)

**Keywords:** multifocus, multiview, multitemporal, multimodal fusion, blind deconvolution, superresolution, energy minimization, image registration, feature detection, feature matching.

## **Objective:**

- To provide a comprehensive reference source for researchers involved or planning to be involved in image fusion, regardless of their particular application areas (a supplementary written material containing many references will be at participants disposal).
- To present recent development in the field, particularly in superresolution imaging via fusion.

## **Abstract**

The tutorial reviews recent as well as traditional fusion methods in image processing. Special emphasis is paid on fusion for restoration and superresolution purposes. The reviewed approaches are classified according to the type of the input images and according to the fusion purpose. Main contributions, advantages and drawbacks of the methods will be discussed in the tutorial. Many practical examples from various application areas (surveillance, medical imaging, remote sensing, robot vision, and astronomy) will be demonstrated. Problematic issues of image fusion and outlook for the future research will be discussed as well.

## **Target audience**

The target audience of the tutorial are researchers from all application areas who need to integrate and fuse *image data* of various kind as well as the specialists in image fusion interested in a new development of this field.

## Detailed Outline

The term *fusion* means in general an approach to extraction of information acquired in several domains. The goal of *image fusion* (IF) is to integrate complementary multisensor, multitemporal and/or multiview information into one new image containing information the quality of which cannot be achieved otherwise. The term “quality”, its meaning and measurement depend on the particular application.

Image fusion has been used in many application areas. In remote sensing and in astronomy, multisensor fusion is used to achieve high spatial and spectral resolutions by combining images from two sensors, one of which has high spatial resolution and the other one high spectral resolution. Numerous fusion applications have appeared in medical imaging like simultaneous evaluation of CT, MRI, and/or PET images. Plenty of applications which use multisensor fusion of visible and infrared images have appeared in military, security, and surveillance areas. We talk about multiview fusion, if a set of images of the same scene taken by the same sensor but from different viewpoints is fused to obtain an image with higher resolution than the sensor normally provides or to recover the 3D representation of the scene. Yet another fusion type common in image processing is multitemporal, which recognizes two different aims. Images of the same scene are acquired at different time instances either to find and evaluate changes in the scene or to obtain a less degraded image of the scene. The former aim is common in medical imaging, especially in change detection of organs and tumors, and in remote sensing for monitoring land or forest exploitation. The acquisition period is usually months or years. The latter aim requires the different measurements to be much closer to each other, typically in the scale of seconds, and possibly under different conditions.

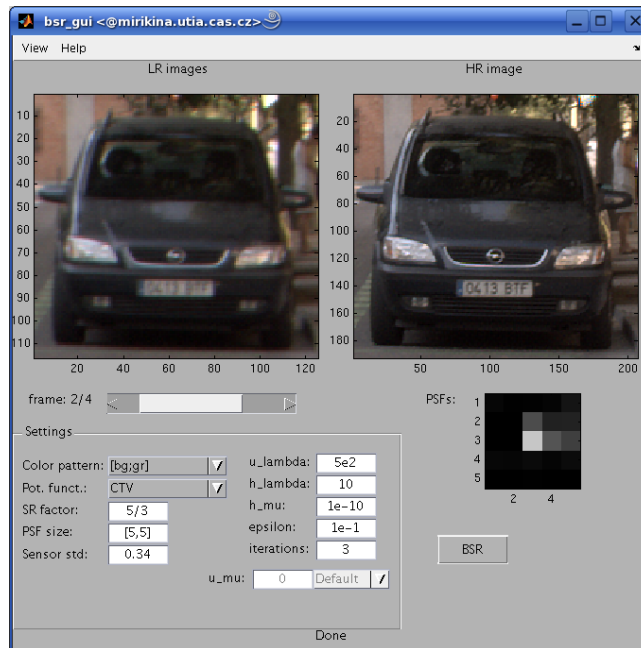
The list of applications mentioned above illustrates the diversity of problems we face when fusing images. It is impossible to design a universal method applicable to all image fusion tasks. Every method should take into account not only the fusion purpose and the characteristics of individual sensors, but also particular imaging conditions, imaging geometry, noise corruption, required accuracy and application-dependent data properties.

## Tutorial structure

In this tutorial, we categorize the IF methods according to the data entering the fusion and according to the fusion purpose. We distinguish the following categories.

- *Multiview fusion* of images from the same modality and taken at the same time but from different viewpoints.
- *Multimodal fusion* of images coming from different sensors (visible and infrared, CT and NMR, or panchromatic and multispectral satellite images).
- *Multitemporal fusion* of images taken at different times in order to detect changes between them or to synthesize realistic images of objects which were not photographed in a desired time.
- *Multifocus fusion* of images of a 3D scene taken repeatedly with various focal length.
- *Fusion for image restoration*. Fusion two or more images of the same scene and modality, each of them blurred and noisy, may lead to a deblurred and denoised image. Multichannel deconvolution is a typical representative of this category. This approach can be extended to superresolution fusion, where input blurred images of low spatial resolution are fused to provide us a high-resolution image.

In each category, we explain basic principles, briefly review known methods, and provide examples from different application areas. No prior knowledge of the field is required of attendees. However, more in-depth discussion will continue in the last category of fusion for image restoration. We will guide the attendees through this category providing some mathematical description of image restoration methods, and we conclude by many interesting examples and possible live demo of our image restoration MATLAB tool. The discussion will be self-content and therefore no prior knowledge is necessary. A real-data example of superresolution and blind deconvolution using our MATLAB tool is shown below.



Any image fusion methodology consists of two basic stages: image registration, which brings the input images to spatial alignment, and fusion itself, i.e., combining image functions (intensities, colors, etc) in the area of frame overlap. Image registration works usually in four steps.

- *Feature detection.* Salient and distinctive objects (corners, line intersections, edges, contours, closed-boundary regions, etc.) are manually or, preferably, automatically detected. For further processing, these features can be represented by their point representatives (distinctive points, line endings, centers of gravity), called in the literature *control points*.
- *Feature matching.* In this step, the correspondence between the features detected in the sensed image and those detected in the reference image is established. Various feature descriptors and similarity measures along with spatial relationships among the features are used for that purpose.
- *Transform model estimation.* The type and parameters of the so-called *mapping functions*, aligning the sensed image with the reference image, are estimated. The parameters of the mapping functions are computed by means of the established feature correspondence.
- *Image resampling and transformation.* The sensed image is transformed by means of the mapping functions. Image values in non-integer coordinates are estimated by an appropriate interpolation technique.

We present a survey of traditional and up-to-date registration and fusion methods and demonstrate their performance by practical experiments from various application areas.

## Why FUSION 2008?

The attendees of FUSION 2008 may be theoreticians and/or people coming from different application areas. Fusion methodologies very much depend on the application and its input data. Image processing goes across many scientific fields and in particular image fusion is gradually gaining more attention. This tutorial aims to give a thorough overview of fusion methodologies related to image processing and pinpoint some of its peculiarities. The attendees without any experience in image processing will get a good introduction to the field. Others, with more experience in image processing may find state-of-the-art methods in fusion for image restoration. This fusion category is important for producers and users of low-resolution imaging devices such as mobile phones, camcorders, web cameras, and security and surveillance cameras.

## Authors' biography

**Jan Flusser** received the M.Sc. degree in mathematical engineering from the Czech Technical University, Prague, Czech Republic in 1985 and the Ph.D. degree in computer science from the Czechoslovak Academy of Sciences in 1990. Since 1985 he has been with the Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic, Prague. Since 1995 he has been holding the position of a head of Department of Image Processing. Since 1991 he has been also affiliated with the Faculty of Mathematics and Physics, Charles University, Prague and with the Czech Technical University, Prague (full professorship in 2004), where he gives undergraduate and graduate courses on Digital Image Processing and Pattern Recognition. Jointly with B. Zitova he gives specialized graduate course on moment invariants and wavelets.

Jan Flusser has a 20-year experience in basic and applied research on the field of invariant-based pattern recognition. He has been involved in applications in remote sensing, medicine, and astronomy. He has authored and coauthored more than 100 research publications in these areas. Some of his journal papers became classical and are frequently cited. Jan Flusser is a Senior Member of the IEEE.

Jan Flusser is an author/co-author of several invited and keynote talks at international conferences (Digital Image Computing DICTA'07, Computational Statistics COMPSTAT'06, Workshop of Information Optics WIO'06, NATO ASI Workshop on Imaging for detection and localization 06, Int'l. Conf. Computer Science ICCS'06, to name the most recent ones).

**Filip Šroubek** received the M.Sc. degree in computer science from the Czech Technical University, Prague, Czech Republic in 1998 and the Ph.D. degree in computer science from the Charles University, Prague, Czech Republic in 2003. From 2004 to 2006, he held a postdoctoral position in the Instituto de Óptica, CSIC, Madrid, Spain. He is currently with the Institute of Information Theory and Automation and partially also with the Institute of Radio Engineering and Electronics, both part of the Academy of Sciences of the Czech Republic, Prague.

Filip Šroubek is an author of three book chapters and over 30 journal and conference papers on image fusion, blind deconvolution, super-resolution, and related topics.

**Barbara Zitová** received the M.Sc. degree in computer science from the Charles University, Prague, Czech Republic in 1995 and the Ph.D. degree in computer science from the Charles University, Prague, Czech Republic in 2000. Since 1995 she has been with the Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic, Prague. She also gives tutorials on Image Processing and Pattern Recognition at the Czech Technical University. Jointly with J. Flusser, she gives specialized graduate course on moment invariants and wavelets.

Barbara Zitová has a 10-year experience in image analysis. She is an author of a book chapter in *Invariants for Pattern Recognition and Classification* (M.A. Rodrigues ed., World Scientific, 2000) and over 30 journal and conference papers on moment invariants and related topics. Her paper "Image Registration Methods: A Survey", *Image and Vision Computing*, vol. 21, pp. 977-1000, 2003, has become a major reference in image registration.

Jan Flusser, Barbara Zitova and Filip Sroubek are the co-authors of the tutorial "Image Registration: A Survey and Recent Advances" presented at the *IEEE Int'l. Conf. Image Proc. ICIP'05*, Genova, Italy, September 2005, and of the tutorial "Image Fusion: Principles, Methods, and Applications" presented at the *European Signal Proc. Conf. EUSIPCO'07*, Poznań, Poland, September 2007. Both attracted considerable attention (the second largest audience among all ICIP'05 tutorials). In addition, Jan Flusser and Barbara Zitova presented the tutorial "Moments and Moment Invariants in Image Analysis" at the *IEEE Int'l. Conf. Image Proc. ICIP'07*, San Antonio, USA, September 2007.