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Editorial

Multimodal Imaging and Hybrid Scanners

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There is an old tale of three blind men who were brought to the zoo for the first time and allowed to touch the elephant. On their way home, they shared this exciting experience. "An elephant is a long, flexible, and cylindrical creature," said the man who had touched the elephant's trunk. "No! It is a thin and flat creature," said the man who had touched the elephant's ear. "No, no! An elephant is rough and rigid like a tree stem," disagreed the third person who had touched the elephant's leg. And the truth is that all three men were right!

When trying to see the invisible with our medical imaging systems, we are much like those three blind men. With each imaging modality, we shed some light on a different aspect of the general physiological picture. Although in some cases one modality may suffice to provide a definitive clinical answer, this is not the case in many other situations. Multimodal imaging (MMI) is needed for three basic reasons: (a) to acquire *complementary* information which may be needed to reach a definitive diagnostic conclusion, exclude certain pathologies, or obtain quantitative values (e.g., [1, 2]); (b) to create *synergism* by data fusion (i.e., to provide added information and new images which are more informative than the individual source images); (c) to plan *therapeutic* procedures and monitor treatment (e.g., [3, 4]).

An ideal MMI system or method should be capable of performing all three tasks mentioned above. Naturally, that requirement might be too demanding in terms of technological capabilities and operational considerations. Hence, diagnostic and therapeutic systems are commonly separated. However, one may see in the near future more system integration in the form of image-guided therapy.

There are several technical issues that are associated with MMI. A prerequisite is to obtain effective fusion and display of the data (e.g., [5–7]). Accurate spatial (and maybe also temporal) alignment is crucial for effective data fusion. There are basically two approaches for achieving coregistration. The first, which may be called the "hardware" approach, utilizes a hybrid design comprising two (or more) imaging modalities that are contained within a single device. The advantage of this approach is that the imaging modalities acquire data sequentially while the patient lies on the bed. The disadvantage is the need for dedicated MMI equipment which may be cumbersome or costly.

The second approach for achieving coregistration is the "software-" based approach. With this approach, image properties and tissue geometry and texture are used as clues for aligning the data sets. Alignment is thus achieved by manipulating the acquired data under certain optimization constraints or 3D model to achieve the best (most probable) match (e.g., [8–11]). Of course this approach is susceptible to noise and artifacts, but on the other hand it allows better versatility, and in many cases may be applied successfully to scans performed on different occasions and at different locations. Nevertheless, it is now widely recognized that the merger of information is more efficiently achieved by the hardware approach. The recent (2001) introduction of hybrid scanners has led to an expansion of this approach through the rapid adoption of the technology into the clinical arena.

One of the most promising examples of MMI hybrid systems that is currently demonstrating a significant clinical impact is the combination of CT with nuclear imaging, and specifically positron emission tomography (PET). Following the development of a prototype in the late 1990s [12], the first commercial combined PET/CT scanner was introduced in 2001 and since then, close to 2000 of such devices from different vendors have been installed in clinics worldwide. Both CT and PET technologies continue to advance and since 2006, new PET scanners are now only available in combination with CT. The MMI technology available clinically has demonstrated particular impact in staging malignant disease [13, 14] and in monitoring response of the disease to therapy. The recent incorporation of high-speed, multislice CT scanners with PET also opens up the potential for applying this technology to cardiac disease.

Another attractive modality for MMI is MRI. Although MRI imposes severe restrictions on the imaging environment, it offers a broad spectrum of scan types and image contrast. Compared with CT, MRI offers greater soft-tissue contrast, better capability for quantitation of function (e.g., measurement of blood flow or tissue metabolism), and potentially new types of molecularly targeted contrast agents. Efforts for combining MRI with other modalities (e.g., PET/MRI and ultrasound/MRI) are currently under development.

Another aspect of MMI is the development of multimodal contrast enhancing materials. Such materials can be used in the form of a "fit-all" type of marker (e.g., [15]). Thus, their signals can be used as control points for 3D alignment. Alternatively, they can be used as standard contrast agents used for disease detection and characterization (e.g., [16]).

In conclusion, considering the current tends in radiology, it can be expected that MMI devices will become increasingly available in the clinical arena. PET/CT has already made an important clinical contribution to patient care for oncology, while the new combined SPECT/CT designs are enhancing SPECT applications and improving physicians' confidence with image interpretation. No doubt, new combinations of hybrid devices will appear in the clinical arena and in many situations. As demonstrated by PET/CT in the oncology field, they will become the primary imaging option. A PET/MR design for simultaneous acquisition of PET and MR has recently acquired the first patient images, and a combined PET and ultrasound device is also under development for breast imaging. For many reasons, therefore, hybrid imaging devices are finding widespread acceptance within the clinical environment and some are already contributing to patient care and management. There is little doubt that this trend will continue in the future with an increasing reliance on MMI devices for medical imaging, thereby ensuring that all involved can be satisfied that they will eventually obtain a true and consistent picture of the elephant.

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Time-frequency signal processing is a well-established area with applications ranging from bioengineering and wireless communications to earthquake engineering and machine monitoring. Signals in these applications are typically nonstationary and as such require joint time-frequency analysis. The objective of this special issue is to bring together theoretical results and application of time-frequency methodologies from investigators in the wireless communications and bioengineering disciplines.

While novel theoretical results and applications of time-frequency signal processing in wireless communications and biomedical systems will be preferred, applications in other areas will also be considered. Likewise, this issue will emphasize methodologies related to Priestley's evolutionary spectrum and the fractional Fourier transform, but other methodologies will also be considered.

The intended focus of this issue will be on presenting time-frequency signal processing applications to wireless communications and biomedical systems using evolutionary spectral techniques and fractional Fourier transform.

Topics of interest include, but are not limited to:

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Special Issue on Vehicular Ad Hoc Networks

Call for Papers

Recently, due to their inherent potential to enhance safety and efficiency measures in transportation networks, vehicular ad hoc networks (VANETs) have gained eye-catching attention from the wireless community. Traffic congestion wastes 40% of travel time on average, unnecessarily consumes about 2.3 billion gallons of fuel per year, and adversely impacts the environment. More importantly, traffic accidents are held responsible for a good portion of death causes. Annually more than 40 000 people are killed and much more injured in highway traffic accidents in the United States alone. Recently, intelligent transportation systems (ITS) have been proposed to improve safety and efficiency in transportation networks. The allocation of 75 MHz in the 5.9 GHz band for dedicated short-range communications (DSRC) by the FCC was a move toward this goal, which was further complemented by the introduction of the vehicle infrastructure integration (VII) initiative by the US Department of Transportation. VII proposes to use dedicated short-range communications (DSRC) to establish vehicle-to-vehicle and vehicle-roadside communications to deliver timely information to save lives, reduce congestion, and improve quality of life.

Despite the much attracted attention, there still remains much to be done in the realm of vehicular ad hoc networks. Signal processing plays a major role in vehicular ad hoc networks. The aim of this special issue is to present a collection of high-quality research papers in order to exhibit advances in theoretical studies, algorithms, and protocol design, as well as platforms and prototypes which use advanced signal processing techniques for vehicular ad hoc networks. Topics of interest include but are not limited to:

- Estimation and detection techniques in VANETs
- Localization techniques in VANETs
- Clock synchronization in VANETs
- Security and privacy in VANETs
- Sensing in vehicular environments
- Channel modeling for V2V communications
- MAC, routing, QOS protocols, and analysis for VANETs
- VANET smart antenna technologies
- Dynamic spectrum access and cognitive radios for VANETs
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Special Issue on
Signal Processing in Advanced Nondestructive Materials Inspection

Call for Papers

Nondestructive testing (NDT) is a noninvasive technique widely used in industry to detect, size, and evaluate different types of defects in materials, and it plays an important role whenever integrity and safe operation of engineered components and structures are concerned. Efficient and reliable nondestructive evaluation techniques are necessary to ensure the safe operation of complex parts and construction in an industrial environment for assessing service life, acceptability, and risk, as well as for reducing or even eliminating human error, thus rendering the inspection process automated, more reliable, reproducible, and faster. Examples of widely used conventional nondestructive techniques are ultrasonics, radiography, computed tomography, infrared thermography, and electromagnetic-based techniques.

As nondestructive testing is not a direct measurement method, the nature and size of defects must be obtained through analysis of the signals obtained from inspection. Signal processing has provided powerful techniques to extract information on material characterization, size, defect detection, and so on. For instance, in the case of images, the major processing and analysis methods include image restoration and enhancement, morphological operators, wavelet transforms, image segmentation, as well as object and pattern recognition, facilitating extraction of special information from the original images, which would not, otherwise, be available. Additionally, 3D image processing can provide further information if an image sequence is available.

Nowadays, techniques of nondestructive testing have evolved greatly due to recent advances in microelectronics and signal processing and analysis. For example, many image processing and analysis techniques can now be readily applied at standard video rates using commercially available hardware, in particular, to methods that generate TV-type image sequences, such as real-time radiography, pulse-video thermography, ultrasonic-phased array, laser ultrasonics, and shearography.

The main objective of this special issue of “Signal processing in nondestructive materials inspection” is to promote a comprehensive forum for discussion on the recent advances in signal processing techniques applied to nondestructive material inspection.

Topics of interest include, but are not limited to:

- Signal processing and analysis in advanced NDT
- Image processing and analysis in advanced NDT
- Materials characterization using advanced NDT
- Defect detection and characterization using advanced NDT
- Pattern recognition and classification for advanced NDT
- 3D image reconstruction from advanced NDT data
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- Algorithms development for signal processing and analysis in advanced NDT
- Software development for defect detection and characterization in NDT images

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