Interdisciplinary Symposium on
Signals & Systems for
Medical Applications

Program and abstracts of ISSSMA workshop on Medical Imaging

Session 3.1: Computed Tomography
June 3rd, 11:00-12:30, room 314. Chair: T. Rodet

Laurent Desbat - ***TIMC, Univ. Joseph Fourier Grenoble (France)***
Sampling the Radon transform: theory and experiments

Rolf Clackdoyle - ***Laboratoire Hubert Curien, CNRS (France)***
Region-of-Interest Image Reconstruction from Limited Projection Data

Emmanuelle Gouillart - ***Surface du Verre et Interfaces CNRS/Saint-Gobain (France)***
Belief Propagation Reconstruction for Discrete Tomography
Authors: *E. Gouillart, F. Krzakala, M. Mézard and L. Zdeborova*

We consider the reconstruction of a two-dimensional discrete image from a set of tomographic measurements corresponding to the Radon projection. Our work aims at improving the reconstruction of undersampled or noisy tomographic measurements, by using prior information on the image. Assuming that the image has a structure where neighbouring pixels have a larger probability to take the same value, we follow a Bayesian approach with a prior corresponding to a piecewise-constant discrete image. In order to compute the expected value of the pixels under the posterior distribution, we introduce a fast message-passing reconstruction algorithm based on belief propagation. For numerical results, we specialize to the case of binary tomography. We test the algorithm on binary synthetic images with different length scales. We compare our approach to a state-of-the-art convex optimization algorithm based on the total variation of the image and bound constraints. We investigate the reconstruction error as a function of the number of tomographic measurements, corresponding to the number of projection angles. The belief propagation algorithm turns out to be more efficient than the convex-optimization algorithm, both in terms of recovery bounds for noise-free projections, and in terms of reconstruction quality when moderate Gaussian noise is added to the projections.

Session 3.2: Positon Emission Tomography
June 3rd, 16:30-18:00, room 314. Chair: T. Rodet

Claude Comtat - ***SHFJ, CEA (France)***
Advanced reconstruction in PET

Eric Barat - *LIST, CEA (France)*
Bayesian Nonparametric Approaches applied to the dynamics reconstruction of PET data.

We present an approach for the problem of Positron Emission Tomographic (PET) continuous space-time (dynamics) reconstruction in the context of Poisson inverse problems. Namely, observations are discrete projections of detected random emission locations whose space-time probability distribution has to be estimated. We follow a nonparametric Bayesian approach (Hjort et al, 2010) where regularization of the inverse problem relies entirely on the nonparametric prior. We propose to model the random distribution of recorded events emission locations and arrival times using a dependent Dirichlet Process Mixture – dDPM (MacEachern, 1999) –. For brain functional imaging, each component of the mixture is assumed separable in space and time and we use a Normal-Inverse Wishart model as base distribution for the marginalized spatial Dirichlet Process. We account for time dependency through a nested DPM of Pólya Trees, (Lavine, 1992). The resulting hierarchical nonparametric model allows inference on the so-called functional volumes which define regions of brain whose activity follows a particular kinetic. A key point of the approach is to deal with the infinite representations of the distributions without resorting to arbitrary truncation of models. Though based on an exchangeable Pólya urn representation, we develop a conditional sampler for DPM models using an update formula from Pitman (1996) and a slice sampling strategy from recent work of Kalli, Griffin and Walker (2011). This scheme is developed for the space-time DPM as for the nested DPM of Pólya Trees. The MCMC algorithm is thus able to generate draws from the posterior distribution of the space-time intensity in order to estimate desired functionals and point-wise credible intervals. Finally, we present results for synthetic as for real PET data.

Irène Buvat - *IMNC, CNRS (France)*
Advanced quantification in PET

Session 3: Multimodality and Compton Scattering
June 4th, 16:30-18:00, room 314. Chair: T. Rodet

Freek Beekman - *MiLabs/Delft University of Technology (Netherlands)*
1/4 mm SPECT and simultaneous 3/4mm-1/2 mm PET/SPECT

Mai Nguyen-Verger - *ETIS, Univ. Cergy Pontoise (France)*
Compton scattered radiation imaging and Bimodality

Astute exploitation of Compton scattering may usher medical imaging into a new area. Up to now well established radiation imaging has made use only of primary (or non-scattered) radiation. Usually scattered radiation has been brushed off as unwanted noise or as perturbing factor. However it was observed that scattered radiation carries a large part of available information. Thus constructing imaging principles on scattered radiation seems to be an attractive idea. In recent years, we have introduced and developed several imaging processes based on Compton scatter radiation. In emission imaging, instead of collecting emitted primary radiation from a radiating object, we advocate the detection of scattered radiation by a non-moving collimated gamma camera and showed that this data, registered at all scattered energies, can be used to reconstruct the activity density of the emitting object. The mathematical foundation for this imaging principle is the Compounded Conical Radon Transform (CCRT) which was shown to have an analytic inverse. A two-dimensional version is known as Compton scatter emission tomography; it is supported by the so-called V-line Radon transform (V-line RT). More recently, in the context of Compton scatter tomography, a transmission imaging process which uses scattered radiation was established. If primary radiation imaging relies on the classical Radon transform defined on straight lines, Compton scatter radiation imaging is based on Radon transforms on circular arcs (CART), for which inverse formulas have been only recently obtained. We have *succeeded in establishing the working of two new modalities. Combining Compton scatter emission tomography to transmission Compton scatter tomography appears as a natural idea for constructing a scattered radiation bimodal imaging system. Work to show that they all do lead to viable imaging systems is underway because preliminary results are most encouraging.*

Johan Nuyts - *Katholieke Universiteit Leuven (Belgium)*

Iterative reconstruction for metal artifact reduction in CT

CT imaging suffers from so-called metal artifacts. Due to their high density, metal implants absorb almost all of the X-ray energy, and as a result, the X-ray projections contain only very limited information along lines going through metals. Most analytical image reconstruction methods do not cope well with this lacking information, and the reconstructed images contain disturbing streak artifacts.

Most methods for metal artefact reduction in CT assume that the acquired information along rays intersecting the metal is totally unreliable. They erase that information and replace it with synthetic data. This is called "projection completion". There are many papers, proposing different ways to synthesize these artificial values. These methods are very effective in removing the streak artifacts. However, the method involves discarding some of the available data, and as a result, a significant loss of image contrast in the vicinity of the metals is usually observed. This can affect the diagnostic value of the images (in particular if the CT scan is done to evaluate the success of an implant placement).

Analytical reconstruction relies on mathematical inversion of the acquisition model. For very realistic models, mathematical inversion may become intractable. Iterative reconstruction applies numerical inversion, it only needs an acquisition model, not its inverse. Because of that, more complex models can be used. We study the use of iterative reconstruction with a more detailed acquisition model, aiming at metal artefact suppression using all available data. Instead of discarding the data as unreliable, we attempt to model the physics in a more accurate way, such that the (limited) information present in the metal projections can contribute to the reconstruction.

In this presentation, the iterative reconstruction will be explained, and its performance compared to that of projection completion methods.

Session 4.4: Microwave Imaging

June 4th, 15:30-17:00, room 314. Chair: B. Duchêne and N. Joachimowicz

Christian Pichot - *LEAT, CNRS, Univ. Nice Sophia-Antipolis (France)*

Microwave imaging and sensors for biomedical applications

In the electromagnetic spectrum, microwaves cover a frequency domain extending from 300 MHz to 300 GHz. Nowadays microwaves are mainly used for terrestrial and spatial telecommunications and radar. Microwave imaging is an imaging technique such as X-ray tomography that allows a perception of the matter through the complex permittivity of the objects while X-ray imaging is related to density of tissues. The complex permittivity is an electromagnetic quantity sensitive to many physical and chemical parameters. Microwave imaging encompasses a wide range of applications, especially in the field of non-destructive testing (NDT) and medical applications. The first to show such an interest for biological applications were Larsen and Jacobi in 1979; they showed the internal structure of a canine kidney using transmission imaging with two antennas moving in parallel. From these results, microwave imaging has gained more and more interest for medical applications. The initial focus covered mainly remote measurements of internal temperature for hyperthermia treatments, the dielectric properties of biological tissues are highly temperature dependent, has been extended to many other areas. Here we will discuss about research activities of the latest applications, detection of breast tumors, detection and monitoring of some heart diseases (ischemia and infarction), stroke (ischemic and hemorrhagic) and other applications envisaged and the different systems and sensors under investigation.

Magnus Otterskog - ***Univ. Mälardalen (Sweden)***

Building and validation of a flexible two antenna microwave mammography system

Microwave imaging of biological tissue is an imaging method that has been a research topic for quite a while now. The number of suggested clinical applications is increasing however mammography remains the most popular one. The increase in computational power has made it possible to build complex 3D electromagnetic models of parts of the human body and to solve the inverse scattering problem to obtain an image with a reasonably good resolution for finding tumours. However the published images produced from real measurement data is so far not completely satisfactory in terms of precision and suppression of artefacts. Most of the available systems are based on static arrays of more or less complex antenna elements. If the antenna elements are less complex the modelling will be easier but on the other hand the coupling of energy into the body might be less efficient loosing measurement dynamics and in the same time information about small structures inside the imaging object. At Mälardalen University we are building a data acquisition system that gives us many degrees of freedom in terms of antenna type used and number of measurement positions. It is based on a two-arm manipulator (robot) that will place the antennas in any position directly on, or in close proximity of the object. There is one transmitting antenna and one receiving. The use of only two antennas will decrease the problem with mutual coupling between antenna elements and the modelling of the system will be less complex. The system uses no coupling medium that completely covers the system volume; instead we have put a lot of effort into construction of a good antenna with a very controlled near field and a small portion of surface waves that propagate along the object's surface. Our conference contribution will deal with pros and cons of our system and show data from system validation.

Ian Craddock and T. Henriksson - ***Univ. Bristol (United Kingdom)*:**

Time-domain microwave imaging for medical applications

Microwave imaging is recognized as a potential candidate for many biomedical applications, such as breast tumour detection. Many different approaches is found in literature based on radar techniques and microwave tomography, solving the inverse scattering problem in frequency- or time-domain. The electromagnetic group at University of Bristol has been devoted to the imaging problem in time-domain, using Delay-And-Sum (DAS) radar algorithm and full 3D time-domain inverse scattering. The two techniques deliver very different output, the radar approach gives the locations of the main scatterers (the tumour), while inverse scattering reconstruct the dielectric properties of the whole breast. Both reconstructions can potentially be used in the patient diagnose, individually or in combination.

A state of the art clinical radar breast imaging prototype has been developed, which is able to make a patient scan with 1770 measurements from a 60 slot antenna array in less than 10 seconds. The slot antennas are designed for a frequency band between 4-10 GHz. The system automatically detecting air gaps and bad fit between the patient and the antenna array, which is crucial to obtain good results. The microwave tomography algorithm has been developed from an in-house developed FDTD solver to solve the 3D time-domain inverse scattering problem using a conjugate gradient scheme, with a realistic slot antenna model and MRI based breast phantoms. As well known, the full 3D inverse scattering problem is extremely computational heavy, thus, efforts have been made to reduce the computational burden while solving the full 3D problem.

This presentation covers the ongoing microwave imaging activity at University of Bristol, with achievements in both clinical trials with the radar equipment and the time-domain microwave tomography algorithm development. The difference of the two approaches will be explained as well as the different nature of the outcomes and how they can be combined.