Mathematical image processing meeting

Organizers : A. Cohen, M. Nikolova and F. Malgouyres

03-07/09/2007

1 Time table

1.1 Monday 3

- **Lunch break**
- **Afternoon session**
  - 14h-14h50 : N. Kingsbury
  - 14h50-15h40 : S. Durand
  - 15h40-16h : *Coffee breack*
  - 16h-16h50 : S. Dekel

1.2 Tuesday 4

- **Morning session**
  - 9h-9h50 : S. Boltz
  - 9h50-10h40 : F. Dibos
  - 10h40-11h : *Coffee break*
  - 11h-11h30 : Pong Chi Yuen
  - 11h30-12h20 : J.-F. Aujol
- **Lunch Break**
- **Afternoon session**
  - 14h-14h40 : G. Steidl
  - 14h40-15h20 : P. Vandergheynst
  - 15h20-15h40 : *Coffee breack*
  - 15h40-16h20 : J. Froment
  - 16h20-17h00 : A. Almansa

1.3 Wednesday 5

- **Morning session**
  - 9h-9h50 : M. Unser
  - 9h50-10h30 : G. Peyré
  - 10h30-10h50 : *Coffee break*
  - 10h50-11h30 : E. Le Pennec
  - 11h30-12h20 : L. Perrinet
- **Lunch Break**
- **Afternoon session**
  - 14h-14h50 : P. Aràndiga
  - 14h50-15h30 : P. L. Dragotti
  - 15h30-15h50 : *Coffee breack*
  - 15h50-16h30 : M. Farge and R. Nguyen van yen
  - 16h30-17h00 : V. Perrier

1.4 Thursday 6

- **Morning session**
  - 9h-9h40 : A. Cohen
  - 9h40-10h20 : R. Gribonval
  - 10h20-10h40 : *Coffee break*
  - 10h40-11h30 : P.L. Combettes
  - 11h30-12h10 : F. Malgouyres
- **Lunch Break**
- **Afternoon session**
  - 14h-14h40 : C. De Mol
  - 14h40-15h20 : J.-L. Starck
  - 15h20-15h40 : *Coffee breack*
  - 15h40-16h20 : J. Fadili
  - 16h20-17h10 : L. Moisan

1.5 Friday 7

- **Morning session**
  - 9h50-10h40 : J. Weikert
  - 10h40-11h : *Coffee break*
  - 11h-11h50 : M. Nikolova
  - 11h50-12h40 : O. Scherzer
- **Lunch Break**

2 Titles and abstracts

1. **A. Almansa**, CNRS researcher, CMLA, École normale supérieure de Cachan.
   - **Non-linear regularization of irregular sampling problems in digital imaging** (Joint work with V. Caselles and G. Facciolo)
   - We propose several algorithms to solve a problem in image restoration which considers several different aspects of the image acquisition system, namely: irregular sampling, denoising, deconvolution, and zooming.

     The first algorithm is based on an extension of a previous image denoising algorithm proposed by A. Chambolle using total variation, combined with irregular to regular sampling algorithms proposed by H.G. Feichtinger, K. Gröchenig, M. Rauth and T. Strohmer, and local constraints ideas from V. Caselles et. al.

     Then a few variants of total variation regularization, antialiasing, local constraints, convex optimization and discretization techniques are considered in order to further reduce the computational cost of the algorithm, while at the same time better controlling artifacts in coarsely sampled areas. Finally we present some experimental results and we compare them with those obtained with the algorithm proposed by K. Gröchenig et al.

2. **J.-F. Aujol**, CNRS researcher, CMLA, École normale supérieure de Cachan.
   - **A nonconvex model for multiplicative noise removal**
   - In this work, we focus on the problem of multiplicative noise removal. We draw our inspiration from the modeling of speckle noise. By using a MAP estimator, we can derive a functional whose minimizer corresponds to the denoised image we want to recover. Although the functional is not convex, we prove the existence of a minimizer and a comparison principle. We study the associated evolution problem, for which we derive existence and uniqueness results for the solution. We prove the convergence of an implicit scheme to compute the solution. We conclude with some numerical results.

3. **P. Aràndiga**, Professor, Departament de Matemàtica Aplicada, Facultat de Matemàtiques, Valencia.

    - **Compression of images using Learning multiresolution schemes.** (Joint work with A. Cohen and D. Yañez)
    - Learning theory plays a key role in several scientific fields such as statistics, data mining, artificial intelligence,as well as in some engineering areas.

      Multiscale decompositions are a well established tool that aims at a rearrangement of the information contents of a set of discrete data. Multiresolution transform are based on transfer operators connecting consecutive resolution levels. In this work we apply learning techniques in order to construct one of the key operators of multiscale decompositions within Harten's multiresolution framework: the prediction operator. When applied to the compression of images, 'Learning' can be used to obtain nearly-optimal filters for the prediction process for images. We perform several numerical experiments with these newly designed "learning-multiresolution" transforms and compare our results with the results obtained with other more classical methods.

4. **M. Barlaud**, Professor, Laboratoire I3S, Université de Nice-Sophia Antipolis.

    - **High-dimensional statistical distance for region-of-interest tracking: Application to combining a soft geometric constraint with radiometry** (Joint work with S. Boltz and E. Debreuve)
    - This paper deals with region-of-interest (ROI) segmentation in video sequences. The goal is to determine in one frame the region which best matches, in terms of a similarity measure, a ROI defined in a reference frame. A measure can combine color histograms and geometry information into a single PDF. Geometric informations are basically interior region coordinates. We propose a system of shape coordinates constant under regions deformations. High-dimensional color-geometry PDF estimation being a difficult problem, measures based on these PDF distances may lead to an incorrect match. Instead, we use an estimator for Kullback-Leibler divergence efficient for high dimensional PDFs. The distance is expressed from the samples using the kth-nearest neighbor framework (kNN). We plugged this distance into active contour framework using shape derivative. Segmentation results on both rigid and articulated sequences showed promising results.

5. **A. Cohen**, Professor, Laboratoire J.L. Lions, Université Paris 6.

- **Near optimal recovery of arbitrary signals and images from uncomplete measurements**
- Compressed sensing is a recent concept in signal and image processing where one seeks to minimize the number of measurements to be taken from signals or images while still retaining the information necessary to approximate them well. The ideas have their origins in certain abstract results from functional analysis and approximation theory but were recently brought into the forefront by the work of Candes-Romberg-Tao, and Donoho who constructed concrete algorithms and showed their promise in application. There remain several fundamental questions on both the theoretical and practical side of compressed sensing. This talk is primarily concerned about one of these issues revolving around just how well compressed sensing can approximate a given signal from a given budget of fixed linear measurements, as compared to adaptive linear measurements. More precisely, we consider discrete N-dimensional signals x with $N >> 1$, allocate $n << N$ linear measurements of x, and we describe the range of k for which these measurements encode enough information to recover x to the accuracy of best k-term approximation. We also consider the problem of having such accuracy only with high probability.

6. **P.L. Combettes**, Professor, Laboratoire J.L. Lions, Université Paris 6.

    - **Sparsities and iterative threshholding**
    - The notion of soft thresholding plays a central role in problems from various areas of applied mathematics, in which the ideal solution is known to possess a sparse decomposition in some orthonormal basis. Using convex-analytical tools, we extend this notion to that of proximal thresholding and investigate its properties, providing in particular several characterizations of such thresholders. We then propose a versatile convex variational formulation for optimization over orthonormal bases that covers a wide range of problems, and establish the strong convergence of a proximal thresholding algorithm to solve it. Numerical applications to signal recovery are demonstrated. Finally, we investigate notions of sparsity in terms of more general linear and nonlinear signal representation schemes and discuss pertinent algorithms.

7. **C. De Mol**, Professor, Dept Math. and ECARES, Université Libre de Bruxelles

    - **Sparsity-enforcing inversion methods**
    - We recall how to define and compute sparse solutions of inverse imaging problems, in connection with different applications. The problem is formulated as the minimization of a least-squares discrepancy with a sparsity- or block-sparsity enforcing penalty. We state regularization theorems which allow to cope with errors both in the data and

in the operator. Finally, we analyze and compare several iterative algorithms which can be used to compute such sparse solutions.

8. **S. Dekel**, Chief Scientist, ISIITS, GE Healthcare, Tel-Aviv.

    - **Curvelets: A low-level framework for computer vision.** (Joint work with A. Sherman)
    - Curvelets[1] are a recent construction of a tight frame that provides a stable representation of L2 functions with the property of excellent time-frequency-orientation localization. In [2], the authors show similarities between Curvelets and new models of the human vision system developed by researchers working in Natural Scene Statistics. In this work, we employ Curvelets as a computational low-level framework for computer vision and present experimental results. We believe that the mathematical properties of Curvelets make them a more suitable framework for computer vision than their predecessors: local Fourier transforms, Wavelet transforms or steerable filters.

      1. E. Candes, L. Demanet, D. Donoho, and L. Ying, Fast Discrete Curvelet Transforms, Multiscale Modeling and Simulation 5 (2006), 861-899.

      2. D. Donoho and A. Flesia, Can recent innovations in harmonic analysis ?explain? key findings in natural image statistics?, Network: Computation in Neural Systems 12 (2001), 371-393. (Received May 14, 2007)

9. **F. Dibos**, Professor, LAGA/L2TI, Université Paris 13

    - **Camera motion and depths estimations in a video sequence**
    - In a first step we propose a new model for camera motion estimation with the only knowledge of the images in a video sequence. Thanks to the registration group, a bijective link is done between the camera motion and the deformations of the images. The approxiamted quadratic model obtained for the deformations is then used as a starting point for the determination of depths. This is achieved by the way of a Belief Propagation algorithm.

10. **P.L. Dragotti**, Lecturer, Dept of electrical and electronic engineering, Imperial College.

    - **Signal reconstruction from sparse measurements with applications to image super-resolution and distributed compression**
    - Consider the problem of sampling signals which are not bandlimited, but still have a finite number of degrees of freedom per unit of time, such as, for example, piecewise polynomial or piecewise sinusoidal signals, and call the number of degrees of freedom per unit of time the rate of innovation. Classical sampling theory does not

enable a perfect reconstruction of such signals since they are not bandlimited. In this talk, we show that many signals with finite rate of innovation can be sampled and perfectly reconstructed using kernels of compact support and a local reconstruction algorithm. The class of kernels that we can use is very rich and includes functions satisfying Strang-Fix conditions, wavelets, Exponential Splines and functions with rational Fourier transform. Extension of such results to the 2-dimensional case are also discussed and applications to image super-resolution, accurate feature extraction and distributed image compression are presented.

11. **S. Durand**, Associate Professor, LAMFA, Faculté de Math-Info, Université de Picardie-Jules Verne.

    - **On the construction of discrete directional wavelets: space-frequency localization and redundancy factor**
    - We address the issue of constructing directional wavelet bases. After considering orthonormal directional wavelets whose Fourier transforms are indicator functions, we propose approximations of these wavelets by basis functions with compact support or fast decay. These transformations are implemented by non uniform filter bank trees. Some numerical results are given.

      In the second part of this talk, we discuss the frequency localization of directional wavelet bases. We analyze the incompatibility between an accurate space-frequency localization and the non redundancy constraint. Then we show that there exist directional wavelet tight frames that are well localized and have a redundancy factor arbitrary close to 1.

12. **J. Fadili**, Associate Professor, GREYC, École Nationale Supérieure d'Ingénieurs de Caen.

    - **Wavelets, Ridgelets and Curvelets for Poisson Noise Removal** (joint work with B. Zhang and J.-L. Starck)
    - In order to denoise Poisson count data, we have introduced a new Variance Stabilizing Transform (VST) to stabilize the variance of a low-pass filtered discrete Poisson process, yielding a near Gaussian process. This transform is fast for any dimensional data, and is more efficient than existing VSTs in low and very low-count situations. We then combine the VST with the wavelet, the ridgelet and the curvelet transforms, leading to multiscale VSTs (MS-VSTs) and nonlinear decomposition schemes. By doing so, the noise-contaminated coefficients of these MS-VST-modified transforms are asymptotically normally distributed with known variances. A classical hypothesis-testing framework is adopted to detect the significant coefficients. To improve the final estimate, we propose to solve sparsity-promoting minimization porblem.

We show that this MS-VST approach provides an astounding denoiser capable of recovering important structures of various morphology in (very) low-count images. A range of examples illustrate the efficiency of this approach.

13. **M. Farge**, CNRS researcher, LMD, École Normale Supérieure Ulm.

    - **Extraction of coherent structures out of two-dimensional turbulent flows: comparison between real-valued orthogonal wavelet bases and complex-valued wavelet frames** (Joint work with and Romain Nguyen van Yen and Kai Schneider)
    - We will present a wavelet-based algorithm we have proposed to extract coherent structures out of one realization of a two-dimensional vorticity field, which corresponds to one instant of a turbulent flow evolution.

      We will thus consider an image (i.e., a two-dimensional vorticity field) and assume that the coherent structures are what remains after denoising. This apophetic method presents the advantage not to require hypotheses on the structures themselves, but only on the noise, which is supposed to be additive and Gaussian. Since we do not know a priori the variance of the noise we estimate it from the variance of the weaker wavelet coefficients, using an iterative procedure [ACHA, 18(2), 2005.

      We will compare the results thus obtained using, either a real-valued orthogonal wavelet basis (Coifman 12), or a complex-valued wavelet frame.

14. **J. Froment**, Professor, LMAM, Université de Bretagne Sud.

    - **Restoration of motion-blurred images : parameters estimation and image recovery** (joint work with Quansheng Liu, Feng Xue, Xiaoqun Zhang)
    - In this talk, we consider the ill-posed inverse problem of restoring a motion-blurred image, resulting from a uniform linear camera motion. Firstly, we adapt a general probabilistic method to estimate the motion parameters. Thanks to the uniform linear assumption, the estimation of the parameters reduces to the detection of the direction and of the gap between oscillations of the Fourier spectrum. Using the Helmholtz principle, the maximum meaningful parallel alignments are detected in the frequency domain, and the direction and the extent of the blur are identified by an adapted K-means cluster algorithm. Secondly, we restore the image using a constrained total variation approach. Among all solutions generating the same observed blurred image, the method chooses one with small total variation. We conclude the talk by some experiments. On simulated motion-blurred images, the restoration is simply perfect. On natural images, the quality of the process depends whether or not the

uniform linear motion blur assumption is satisfied. This suggests to generalize the approach so that this assumption may be relaxed.

15. **R. Gribonval**, INRIA researcher, METISS Project, IRISA, Campus de Beaulieu, Rennes.

    - **Average case analysis of multi-channel sparse recovery using greedy algorithms** (joint work with with H. Rauhut, K. Schnass, P. Vandergheynst)
    - We analyze two greedy algorithms for simultaneous sparse approximation of multichannel signals over redundant dictionaries. The first one, p-thresholding, selects the atoms that have the largest p-correlation while the second one, p-simultaneous matching pursuit (p-SOMP), generalises an algorithm studied by Tropp. We first provide exact recovery conditions as well as worst case analyses of all algorithms. The results, expressed using the standard cumulative coherence, are reminiscent of the single channel case and impose stringent restrictions on the dictionary.

      We unlock the situation by an average case analysis of both algorithms. We set up a probabilistic signal model where the coefficients of the atoms are drawn from a Gaussian distribution. Under this model, and with mild conditions on the coherence, we show that the probability that p-thresholding and p-SOMP fail to recover the correct components gets overwhelmingly small as the number of channels increases.

      We further show that, if the dictionary satisfies a uniform uncertainty principle, the probability that simultaneous OMP fails to recover any sufficiently sparse set of atoms gets increasingly smaller as the number of channels increases.

16. **N. Kingsbury**, Reader in Signal Processing, Dept. of Engineering, University of Cambridge.

    - **Rotation-Invariant Matching of Local Features using Dual-Tree Complex Wavelets**
    - We describe a technique for using dual-tree complex wavelets to obtain rich feature descriptors of keypoints in images. The main aim has been to develop a method for retaining the full phase and amplitude information from the complex wavelet coefficients at each scale, while presenting the feature descriptors in a form that allows for arbitrary rotations between the candidate and reference image patches. In addition we have modified our previouly proposed approach so that it can be more resilient to errors in keypoint location and scale. Our feature descriptors are potentially very useful for object detection and recognition in images.

17. **E. Le Pennec**, Associate Professor, Laboratoire de Probabilités et Modèles Aléatoires, Université Paris 7.

    - **Bandelets and Model Selection in Image Estimation**
    - In this talk, I will recall how the statistical model selection theory is hidden in the thresholding in an orthogonal basis. I will then explains how this general framework can be applied to a lot of others image estimation scheme in order to reobtain their performance. I will present a resulting bandelet estimator that is proved to be quasi optimally minimax for the class of geometrical images. Eventually, its numerical performance will also be shown.

18. **F. Malgouyres**, Associate Professor, LAGA and L2TI, University Paris 13.

    - **On Basis Pursuit**(Part of this work was made with Tieyong Zeng)
    - After introducing a theoretical property, saying that the projection onto a polytope simplifies a data distribution, we will propose a Proximal Point Algorithm to solve the Basis Pursuit.

19. **L. Moisan**, Professor, MAP5, University Paris 5.

    - **An a-contrario model for sharpness detection based on total variation** (Joint work with Gwendoline Blanchet and Bernard Rougé)
    - We propose to measure the sharpness of an image by the phase coherence of its Fourier coefficients. By computing the probability of random phases to produce an image whose total variation is not greater than the one of the observed image, we obtain a paramater-free measurement which is stongly related to our intuition of sharpness and our ability to locate details in an image at a sub-pixel scale.

      We propose solutions for issues like periodization, quantization and aliasing, and show several experiments and possible applications of this sharpness measurement.

20. **M. Nikolova**, CNRS researcher, CMLA, École normale supérieure de Cachan.

    - **Bounds on the minimizers of (nonconvex) regularized least-squares**
    - This is a theoretical study on the minimizers of cost-functions composed of an L2 data-fidelity term and a possibly nonsmooth or nonconvex regularization term acting on the differences or the discrete gradients of the image or the signal to restore. More precisely, we derive general nonasymptotic analytical bounds characterizing the local and the global minimizers of these cost-functions. We provide several bounds relevant to the observation model. For edge-preserving

regularization, we exhibit a tight bound on the L-infinite norm of the residual (the error) that is independent of the data, even if its L2 norm is being minimized. Then we focus on the smoothing incurred by the (local) minimizers in terms of the differences or the discrete gradient of the restored image (or signal).

21. **V. Perrier** Professor, LJK, Institut Polytechnique de Grenoble.

    - **Orthogonal Helmholtz decomposition using divergence-free and curl-free wavelets. Application to the simulation of 2D turbulent flows.** (Joint work with Erwan Deriaz)
    - In many physical problems, like the study of incompressible fluids or in electromagnetism, the quantities have to fulfill a divergence-free condition. The Helmholtz decomposition consists in decomposing a vector field, into the (orthogonal) sum of its divergence-free component and its curl-free component.This decomposition is straightforward in the whole space thanks to the Leray projector which can be explicitly described in Fourier domain.

      The objective of the present talk is to propose an orthogonal Helmholtz decomposition in wavelet domain of any vector field. This decomposition will be based on divergence-free and curl-free wavelets originally designed by P.-G. Lemarié (1992) and K. Urban (2000). Since divergence-free and curl-free wavelets are biorthogonal bases, we will proposed an iterative algorithm to provide such decomposition, of which we will prove the convergence in arbitrary dimension, using Shannon wavelets.

      An important application of the Helmholtz decomposition is the Direct Numerical Simulation of turbulence. We will propose a new numerical scheme for solving the incompressible Navier-Stokes equations, based on divergence-free wavelets, and which only requires Fast Wavelet Transforms for the computation of the velocity and the pressure. Finally we show numerical results on the simulation of 2D homogeneous turbulent flows.

22. **L. Perrinet**, CNRS researcher, INCM, Marseille.

    - **Neural Codes for Adaptive Sparse Representation of Natural Images**
    - I will illustrate in this talk how computational neuroscience may inspire and be inspired by mathematical image processing. Focusing on efficiently representing natural images in the primary visual cortex, we derive an event-based adaptive algorithm inspired by statistical inference, Matching Pursuit and Hebbian learning. This algorithm allows to learn efficient "edge-like" receptive fields similarly to Independent Components Analysis. The correlation-based inhibition has been shown to be a necessary condition for the fomation of this type

of receptive fields and shows the putative functional role of lateral propagation of information in cortical layers.

I'll first present state-of-the-art neural algorithms for this task, the results of a detailed analysis of this Sparse Hebbian Learning algorithm and finally draw a comparison with similar strategies.

23. **G. Peyré**, CNRS researcher, CEREMADE, Université Paris Dauphine.

    - **Adaptive Sparse Representation of Geometric Textures**
    - In this talk, I will show how adapted dictionaries can be trained to approximate and generate geometric texture patterns. I will restrict myself to two different approaches, namely bandlets dictionaries and dictionaries learned from data.

      Bandlets dictionaries are well suited to approximate locally parallel textures that exhibit a strong anisotropy. Each basis is parameterized by a geometric flow that follows closely the texture patterns. The resulting basis vectors generate a tight frame of elongated atoms that can sparsify turbulent textures. A sparse modeling over a well chosen bandlet dictionary can be used for various tasks such as texture synthesis, compressed sensing decoding or morphological component separation.

      Rather that using had-oc geometrical constraints for textures, one can try to infer the model from a set of exemplar input textures. A way to perform this modeling is to impose a sparsity assumption on the set of patches extracted from the texture. This sparsity can be optimized by learning a dictionary to optimally represent the input patches. The resulting model can smoothly interpolate between aggressive compression routinely used in computational harmonic analysis and realistic texture synthesis required by computer graphics applications. This texture model also finds applications in problems such as structure+texture decomposition or image inpainting.

24. **O. Scherzer**, Professor, Dept of computer science, University Innsbruck.

    - **Non-Convex Variational Problems in Imaging**
    - We study non-convex variational methods appearing in image processing. The term non-convex is understood in the sense of the calculus of variations. Such models have to be relaxed in order to be able to solve them in a stable way numerically. We give a few examples and highlight the relation to morphological partial differential equations.

25. **J.-L. Starck**, CEA researcher, Service d'Astrophysique, CEA Saclay.

    - **Generalized Morphological Component Analysis: From Images to Hyperspectral Data**

- The Morphological Component Analysis (MCA) is a a method which allows us to separate features contained in an image when these features present different morphological aspects. We show that MCA can be extended to multichannel data (GMCA) and that GMCA is a very interesting alternative to standard blind source separation techniques. GMCA is then used for different applications such inpainting, denoising and sources extraction.

26. **G. Steidl**, Professor, Dept of Applied Mathematics and Computer Science , University of Mannheim.

    - **Variational methods for denoising matrix fields** (joint work with S. Setzer and B. Burgeth)
    - The restoration of scalar-valued images via minimization of an energy functional is a well-established technique in image processing.

      Recently also higher-order methods have proved their advantages in edge preserving image denoising. In this paper, we transfer successful techniques to matrix fields, where our functionals couple the different matrix channels.

      For the numerical computation we use second-order cone programming. Moreover, taking the operator structure of matrices into account, we consider a new operator-based regularization term. Using matrix differential calculus, we deduce the corresponding Euler-Lagrange equation and apply it for the numerical solution by a steepest descent method.

27. **M. Unser**, Professor, École Polytechnique Fédérale de Lausanne.

    - **Affine invariance, splines, wavelets and fractional Brownian fields** (Joint work with Pouya Dehghani Tafti and Dimitri Van De Ville)
    - Invariance is an attractive principle for specifying image processing algorithms. In this work, we concentrate on affine – more precisely, shift, scale and rotation – invariance and identify the corresponding class of operators, which are fractional Laplacians. We then specify some corresponding differential equation and show that the solution (in the distributional sense) is either a fractional Brownian field (Mandelbrot and Van Ness, 1968) or a polyharmonic spline (Duchon, 1976), depending on the nature of the system input (driving term): stochastic (white noise) or deterministic (stream of Dirac impulses). The affine invariance of the operator has two remarkable consequences: (1) the statistical self-similarity of the fractional Brownian field, and (2) the fact that the polyharmonic splines specify a multiresolution analysis of $L_2(R^d)$ and lend themselves to the construction of wavelet bases. We prove that these wavelets essentially behave like the operator from which they are derived, and that they

are ideally suited for the analysis of multidimensional signals with fractal characteristics (isotopic differentiation, and whitening property).

28. **P. Vandergheynst**, Assistant Professor, École Polytechnique Fédérale de Lausanne.

    - **Processing images on surfaces and applications**
    - Signals come nowadays in increasingly different flavours. In particular it is more and more often the case that we collect data on surfaces, due to either the characteristics of the observed phenomenon or because we use complex sensors. There is no mathematical weapon of choice when tackling such problems, but one easily acknowledges the importance of geometry.

      In this talk I will review two approaches for dealing with signals on surfaces in a multiresolution way. The first method is based on classical harmonic analysis and leads to the construction of wavelet-like representations on manifolds. The second method is based on extending PDE techniques to surfaces, trying to efficiently cope with geometry.

      I will use two real-world examples to point at the benefits and drawbacks of both approaches: analysing the cosmic microwave background in cosmology and processing omnidirectional (catadioptric) images.

29. **J. Weickert**, Professor, Dept of Mathematics and conputer science, Saarbruecken University.

    - **Wavelets and (Integro-)Differential Equations** (Joint work with Stephan Didas, Gabriele Steidl and Martin Welk)
    - Signal and image denoising is a field where one is typically interested in removing noise without sacrificing important structures such as discontinuities. To this end, a large variety of nonlinear strategies has been proposed in the literature including wavelet shrinkage and PDEs such as nonlinear diffusion filtering. The goal of this talk is to survey connections between these techniques. Specific attention will be paid to anisotropic concepts and interpretations of multiscale wavelet shrinkage in terms of integrodifferential equations.

30. **Pong Chi Yuen**, Professor, Computer science Dept, Hong Kong Baptist University.

    - **Generating Highly Secure Face Biometric Cancelable Template**
    - Biometric is a reliable, robust and convenient way for person authentication. With the success of the biometric research in the last thirty

years, several large biometric systems, such as the ”e-channel” at Hong Kong border control, US-VISIT program in the United States and the automated border control at Kuala Lumpur International Airport have been successfully installed. Additionally, biometric systems are being developed for use in different sectors such as banking (for ATM machine), credit card industry and physical access control. With the growing use of biometrics, there is a rising concern about the security and privacy of the biometric data. Since each person has a unique biometric (e.g. fingerprint, face and iris), if this biometric data is compromised, it is not possible to have a replacement. Therefore, biometric template security is one of the most important issues in developing a practical biometric system (biometric template refers to the extracted biometric features stored in a central database or a smartcard). This talk will first give a brief review on existing methods in protecting biometric template. Our proposed method using random projection and class distribution preserving transform for generating face biometric cancelable template will be reported.