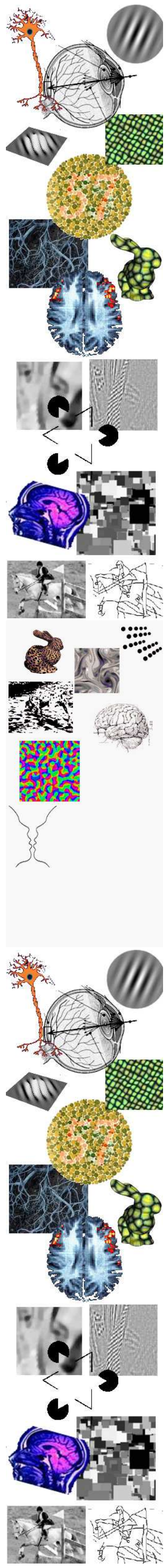
Workshop

An interdisciplinary approach to Textures and Natural Images Processing

8 & 9 January 2007
Institut Henri Poincaré (Paris, France)



This workshop is intended to give an overview of cutting edge research in textures and natural images processing. Talks given by top scientists in their field will bridge the gap between several communitees including mathematics, computer vision/graphics, neurosciences and experimental psychology. All the presentations will be in english. The workshop is supported by the GDR "Mathématiques des Systèmes Perceptifs et Cognitifs" and the GDR ISIS.

Themes

- Mathematics – functional spaces for natural images and oscillating pattern modelling.
- Image processing – sparse representation of natural images and textures.
- Computer graphics – texture acquisition, modeling and synthesis.
- Computer vision and psychophysics – natural image perception and recognition.
- Neurosciences – neurogeometry and visual perception of textures and natural images.

Scientific commitee

Laurent Cohen (Ceremade Université Paris Dauphine)
Yves Frégnac (UNIC-CNRS Gif-sur-Yvette)
Yves Meyer (ENS Cachan)
Jean-Luc Starck (CEA Saclay)

Organizing commitee

Jean François Aujol (CMLA, ENS Cachan)
Jalal Fadili (GREYC-ENSICAEN)
Gabriel Peyré (Ceremade Université Paris Dauphine)

Sponsors

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Program

Monday 8 January

9h00–9h45	Breakfast
	Welcome
Session 1 Chair: Gabriel Peyré	
10h00–11h00	Stéphane Mallat (*École Polytechnique*)
11h00–11h30	Yann Gousseau (*ENST*)
11h30–12h30	Agnès Desolneux (*Université Paris 5*)
	Lunch break
Session 2 Chair: Pascal Mamassian	
13h45–14h45	Yves Frégnac (UNIC-CNRS Gif-sur-Yvette)
14h45–15h45	Guy Orban (Col. de France, Fac. Leuwen)
	Coffee break
Session 3 Chair: Jalal Fadili	
16h00–17h00	Yves Meyer (*CMLA, ENS Cachan*)
17h00–17h30	Jean François Aujol (*CMLA, ENS Cachan*)
17h30–18h00	Laure Blanc-Féraud (*I3S*)

Tuesday 9 January

Session 4 Chair: Yves Meyer	
9h00-10h00	Song-Chun Zhu (*UCLA*)
10h00-10h30	Simon Masnou (*Université Paris 6*)
	Coffee break
Session 5 Chair: Jean-Luc Starck	
10h45-11h15	Xavier Descombes (*Ariana - INRIA*)
11h15-12h15	Jean-Michel Morel (*CMLA, ENS Cachan*)
	Lunch break
Session 6 Chair: Guy Orban	
13h30-14h00	Pascal Mamassian (*Université Paris 5*)
14h15-15h00	Denis Pelli (*NYU*)
15h00-15h45	Michael Landy (*NYU*)
	Coffee break
Session 7 Chair: Jean-François Aujol	
16h00-16h30	Jean Luc Starck (*CEA Saclay*)
16h30-17h00	Jalal Fadili (*GREYC-ENSICAEN*)
17h00-17h30	Gabriel Peyré (*Ceremade*)

Abstracts

Jean-François Aujol – *A TV-Hilbert model for image denoising and decomposition.*
Abstract: In this talk, we present a general TV-Hilbert framework for image restoration and image decomposition. We minimize a functional of the type $\inf_u(|u|_{TV} + |f - u|_H)$ We propose an automatic algorithm to get an optimal restored image (in the SNR sens) from a noisy image. We also explain how to design a Hilbert norm to extract specific types of textures. We illustrate this approach with some numerical examples.

Xavier Descombes – *Urban analysis from texture.*
Abstract: We will first show that a simple texture model allows to discrimate urban areas on middle resolution images. Some exemple will be presented on SPOT panchormatic images (10m resolution) and ERS images. We then will adapt the model in case of higher spatial resolution and higher spectral resolution. When spatial resolution increases, as for SPOT V images, we will show that an anisotropic generalization of the previous model is required to avoid some false alarms. Finnaly, we will consider hyperspectral data. In this case, we will address the problem oif dimension reduction to reduce the complexity of the extracton problem. Some result on AVIRIS data (mmore than 100 spectral cahnnels) will be presented.

Agnès Desolneux – *A contrario methods for image analysis.*
Abstract: According to Helmholtz principle, perceptual objects in an image can be defined as events which have a very low probability to appear in pure noise. We will see how this principle can be used for the detection of geometric structures in an image or for denoising.

Jalal Fadili – *Morphological diversity, sparse overcomplete representations and some inverse problems.*
Abstract: Sparse overcomplete representations are attracting interest in image processing theory, particularly due to their potential to generate sparse representations of data based on their morphological diversity. In this work, we consider a scenario of linear inverse problems where the image ro be recovered can be sparsely represented in an overcomplete dictionary of sparse linear transforms. These transforms are chosen to offer a wider range of generating atoms; allowing more flexibility in image representation and adaptativity to its morphological content (texture, natural parts, etc). The linear inverse problem is formulated as the minimization of an energy functional with a sparsity-promoting regularization (e.g. ℓ_1 norm of the image representation coefficients). We will discuss theoretical aspects related to the optimization problem, and propose some fast iterative algorithms for its solution for which we establish convergence properties. A wide variety of examples ranging from deconvolution to component separation and inpainting are given to illustrate teh potential applicability of the approach in image processing.

Laure Blanc-Féraud – *Some applications of the ℓ^∞ norm in image processing.*
Abstract: Our goal in this work is to give algorithms for minimizing generic regularizing functionals under a ℓ^∞-constraint. We show that many classical models using total variation can be stated under this formalism. Among others are the Rudin-Osher-Fatemi model, the $BV - \ell^1$ model, the $BV - \ell^\infty$ model and Y. Meyer's cartoon+texture decomposition model. All the models we study are difficult to handle both theoretically and numerically because of the non differentiability of the functionals and of the domains. We propose to use, as convergent minimization algorithm, the projected subgradient algorithm. We give some numerical results that show the qualities and limits of the algorithm, and we tackle the question of the use of the total variation to treat noises of bounded amplitude.

Yves Frégnac – *Efficient coding and spike timing precision in V1 neurons during visual processing of natural scenes.*
Abstract: The efficient coding hypothesis posits that our visual system is optimized for the spatiotemporal statistical properties of our everyday environment. It is assumed that the early visual processing carried out by the retino-thalamo-cortical pathway is to produce an efficient

representation of the incoming visual signal. Barlow and Attneave recognized the importance of information theory in this context, and hypothesized that sensory information should be encoded in the most compact way, in order for our brain to most effectively utilize all available computing resources. This principle of redundancy reduction has been shown to be equivalent to the maximization of mutual information between the visual input and neural responses. To a certain degree, this view is consistent with a decomposition of the visual scene into statistically independent components.

I will review electrophysiological attempts made in my lab to reveal optimization of the neural code for the processing of natural scenes. Cells were recorded intracellularly in the mammalian primary visual cortex (V1). Subthreshold and spiking response patterns were compared, in the same cell, for 4 classes of stimuli presenting spatio-temporal statistics of increasing information content. Full field stimuli consisted of: 1) optimal drifting grating (Fourier input), 2) the same grating animated through virtual eye-movement sequences (simulating fixation drift, microsaccade and tremor), 3) a natural scene animated by the same eye-movement sequence and 4) binary dense noise. Our results show that the spike-based code, in term of noise, entropy, efficiency and the apparent recruitment of non-linear mechanisms depend greatly on the stimulus context and dimensionality. Noise and entropy of the spike discharge decrease with stimulus complexity, whereas efficiency and temporal precision increase. At the lower boundary of the complexity scale, drifting gratings evoke highly variable visual responses, the code is based on rate and a lack of sparseness is apparent in the cortical representation. Using animated sequences of natural images, cortical network dynamics become much more constrained, the spike timing precision reaches the ms range and neurons carry almost independent information, with a high efficiency at all temporal scales. At the higher boundary of the complexity scale, i.e. white noise, the cortical network dynamics are so constrained that most neurons are kept silent. We conclude that the cortical code is optimized for processing natural scenes and that the visual cortex operates by removing high-order redundancies.

Support Contributed by CNRS, ANR (Natstats), ACI-NIM and the European Community (FET- Bio-I3: 015879 (Facets)) to Y.F. Joint work with Y. Frégnac, P. Baudot, O. Marre and M. Levy.

Yann Gousseau – *Occlusion and scaling in natural images (joint work with Francois Roueff)*
Abstract: In this talk we address the problem of the simultaneous modeling of both the occlusion phenomenon and scaling laws, two fundamental ingredients of the structure of natural images. Previous works (by Ruderman, Alvarez et al., Mumford et al.) have shown that the dead leaves model from Mathematical Morphology (a superimposition of random objects), when combined with scaling laws, is to a large extend coherent with the statistics of natural images. However, such a framework imposes minimum sizes for objects, which prevent the modeling of images regularity (or clutter) at any scale. We show that, under some hypotheses, it is possible to consider limits at small scales of such models. We give some regularity properties of the resulting "scaling dead leaves" model in the context of Besov spaces. We then show how to use these models to estimate the regularity of natural images by proposing a statistical estimator for its parameters. Eventually, we conclude by showing the implications of such a modeling in a Bayesian image denoising framework.
Reference :
"Modeling occlusion and scaling in natural images", with F. Roueff, SIAM Journal of Multiscale Modeling and Simulation, to appear. http://www.tsi.enst.fr/ gousseau/gr06.pdf

Michael Landy – *Visual Texture: Discrimination, Pattern Identification and Cortical Coding.*
Abstract: Visual texture has been studied psychophysically as a means of elucidating the initial coding of spatial, visual patterns. I will review several recent studies on texture perception and coding. In the first, we looked at how texture may be used visually to define identifiable objects. For texture-defined letters, we found that the channels used to identify letters are scale-invariant, unlike the case of luminance-defined letters. In an fMRI study, we found orientation-selective responses to texture-defined edges in multiple cortical areas using an adaptation paradigm. The

amount of orientation-selective adaptation increased in higher-tier areas (e.g., V3A, LOC), unlike the case of luminance-defined edges for which the amount of adaptation in V1 was as great as any other cortical areas studied. I will also review studies of the visual estimation of surface roughness in 3-d textures. We found that, despite the availability of strong 3-d cues such as binocular disparity, visual estimates of surface roughness were strongly influenced by viewing conditions (the illuminant and viewing positions relative to the surface). Finally, I will review our current efforts at understanding visual coding of texture by comparing discimination judgments to the wavelet statistics of texture images.

Stéphane Mallat – *Geometrical Grouplets.*
Abstract: The perception of geometrical structures in images is the result of a complex grouping process, studied in the 1920's by the Gestalt school, on which electro-physiology of the the visual brain brings information. The geometry of textures and contours provides essential parameters for the recognition of shapes and is still not well understood. For video sequences, geometry is the heart of movement perception. Some geometrical perception is also present when listening to sounds and their harmonic "movements". Behind these multiple forms of geometries, is there some common mathematical and algorithmic approach that could provide efficient representations ? We will review some physiological models of simple cells in the visual cortex in V1 and their horizontal connections. Grouplet orthogonal bases and tight frames are constructed with multiscale association fields between wavelet image coefficients, that have similarites with horizontal connections between simple cells. Applications to image super-resolution, noise removal and texture synthesis will be shown.

Pascal Mamassian – *Three-dimensional perception from texture and shading.*
Abstract: There are multiple cues that the human visual system is using to infer the three-dimensional (3D) structure of objects. Among these cues, texture is traditionally taken to be informative about local surface orientation and shading to be informative about local surface curvature. I will present a short overview of the literature on the perception of 3D shape from texture and shading to draw the main similarities and differences between these cues.

Simon Masnou – *A two-step method for texture/geometry inpainting.*
Abstract: A large variety of approaches, some of them very efficient, have been proposed in recent years for the inpainting problem, i.e. the problem of recovering missing parts in a digital image. Yet the large-scale, unstationary geometric structures are often poorly reconstructed. In a joint work with Frédéric Cao and Yann Gousseau, we propose a two-step method for the restauration of both texture and geometric information that has also the ability of recovering non local geometric structures. I will discuss numerical and theoretical issues.

Yves Meyer – *Geometry+texture+noise decompositions.*
Abstract: A series of spectacular discoveries by David Hubel and Torsten Wiesel in neurophysiology are paving the way to a collection of models in image processing. In these models an image is viewed as a sum f=u+v (or f=u+v+w) between two or three components. The first component is aimed at describing the geometry of the image and the two other components are taking care of the texture and of the noise. Some variational approaches are discussed.

Jean-Michel Morel – *Texture synthesis and the technique of abstract art.*
Abstract: In this prospective talk I'll discuss, on the technical side, the abstract art programme developed in theory or in practice at the begining of the past century by Cézanne, Matisse, Kandinsky, Klee and other painters. I'll point out in examples the strong technical limitations that painters faced when they gave up figuration and attempted to create abstract shapes and compositions. These difficulties led to a strong stylistic convergence, which can be interpreted in merely technical terms. This question has taken a new aspect thanks to the existence of computers, which permit to realize quickly any technical idea about random shape, color and painting technique. I'll show some examples of abstract textures made by the very same principles at work in abstract painting. This will revive the technical problems linked to the synthesis of abstract images. (joint work with Luis Alvarez, Bruno Galerne and Yann Gousseau)

Guy Orban – *Texture as a cue for 3D shape and material properties.*
Abstract: We have investigated texture processing in human and monkey using fMRI and single cell recordings. Neurons in area TEs (Janssen et al Science 2000) are selective for the direction of tilt specified by texture and disparity (Liu et al J Neurosci 2004). In human extraction of 3D shape from texture involves caudal ITG, LOS/V7 and parietal regions. Similar fMRI tests in monkeys activate AIP, V4 and TEO. In human texture judgments activate ventral cortical regions surrounding fusiform cortex (Peuskens et al J Cogn NS 2004). Infero-temporal neurons exhibit selectivity for materials, which in a number of cases disappears with scrambling.

Gabriel Peyré – *Sparse Modeling of Textures.*
Abstract: In this talk I will present a statistical model for textures that uses a sparse decomposition on a set of local atoms learned from an exemplar. This model is described by the variances and kurtosis of the marginals of the decomposition of patches in the learned dictionary. A fast sampling algorithm allows to draw a typical image from this model. The resulting texture synthesis captures the geometric features of the original exemplar. To speed up synthesis and generate structures of various sizes, a multi-scale process is used. Applications to texture synthesis, image inpainting and texture segmentation are presented.

Denis Pelli – *Crowding: Perhaps texture is what we see when object recognition fails.*
Abstract: "Crowding" is a failure of object recognition in visual perception. When a letter presented in the peripheral visual field is surrounded by other letters, the visual system cannot isolate it and we are unable to identify the original letter. We see a jumble. Crowding was discovered, clinically, more than fifty years ago, but is now taking off as a research topic, as a way to study object recognition. I propose that it would be very useful to define "texture" as what we see when object recognition fails. Crowding manipulations make it easy to turn object recognition on and off. I will show that crowding limits reading and face recognition. I will also show examples of situations (art & science) that explore perception without recognized objects.

Jean-Luc Starck – *Texture, Edges and Sparsity: The MCA approach.*
Abstract: 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 very useful for decomposing images into texture and piecewise smooth (cartoon) parts and for inpainting applications. This method is extended to multichannel data, which leads to a new approach for blind source separation, based on the morphological diversity concept instead of the statistical independence of the source.

Song-Chun Zhu – *A Mathematical Model for Texture, Texton and Primal Sketch – Visual Learning with Implicit and Explicit Manifolds.*
Abstract: In this talk, I will first review two representation schemes for modeling textures and textons respectively. The first is the Markov random fields (MRF) for stochastic texture. Originated from statistical physics, an MRF (or Gibbs, FRAME) represents a texture category as a micro-canonical ensemble of images that satisfy certain global statistics property. A texture is then an equivalence class that satisfies some implicit constraint equations and is called an implicit manifold. The second is the texton model for atomic image structures. This model, steamed from harmonic analysis and sparse coding, represents a texton as a set spanned by some explicit functions with a small number of hidden variables. Thus it is called an explicit manifold. Then I will show that the two models lie in two extreme regimes of the Image space. The texture is at high entropy regime and the textons are at low entropy regime. The two types of manifolds are the pure-atomic spaces which are composed to create complex image patterns. As a result of this analysis, we achieve two interesting models. (i) A math model for the primal sketch concept, proposed by David Marr for early vision representation, which integrates the texture and texton models. (ii) A perceptual scale space theory for studying the information scaling and thus the perceptual transitions between the two types of spaces.