CeLyA Centre Lyonnais d'Acoustique — Université de Lyon

Program

Statistical Approach In Time And Frequency Analysis of Cyclostationary Signals
J. Leskow

This lecture will be devoted to three major tasks. The first will be in explaining the need for time and frequency analysis in cyclostationary and almost periodically correlated signals. The second task of the lecture will be in addressing the main inferential problems that are encountered in statistical analysis of signals, that is: estimation, testing and identification. Finally, the third task will be showing that modern resampling methods like bootstrap, subsampling or other algorithms have a critical advantage over the classical methods. The statistical results will be then applied to vibromechanic and acoustic data. The lecturer will present also some Matlab routines that might be useful for time and frequency statistical analysis of cyclostationary and almost periodically correlated signals.

Cyclostationary Processes and their Generalizations -Spectral Analysis and Applications
A. Napolitano

In these talks, two recently introduced classes of nonstationary processes are reviewed and the problem of their statistical function estimation is addressed. The considered classes are the generalized almost-cyclostationary (GACS) processes and the spectrally correlated (SC) processes. GACS processes exhibit multivariate statistical functions that are almost-periodic functions of time whose Fourier series expansions have coefficients and frequencies that can depend on the lag shifts of the processes. SC processes exhibit spectral components with different frequencies that are correlated. Both GACS and SC processes include as special case the almost-cyclostationary (ACS) processes. The estimation of statistical functions of continuous-time GACS and SC processes is considered starting from continuous- and discrete-time observations.

Applications of Demodulation and Cepstrum Analysis in Machine diagnostics
B. Randall

Demodulation has many applications in machine diagnostics, and can be applied very simply using Hilbert transform theory. Amplitude demodulation has been used for many years for envelope analysis in bearing diagnostics, but only recently has the connection with spectral correlation analysis of cyclostationary signals been recognised. Phase/frequency demodulation has direct application in torsional vibration analysis, which when expressed in terms of angular displacement is a phase modulation and in terms of rotational speed is a frequency modulation. There is no modulation term for torsional vibration expressed as angular acceleration. Quite recently, phase demodulation has been used for order tracking (angular resampling) including "autonomous" order tracking, where the information on instantaneous speed is extracted from the signal itself. This can correct for speed variations as large as ±30%, but then other problems arise, and these will be discussed. Both amplitude and phase demodulation of the gearmesh signal have been used for detection of local faults on gears, and this has been shown to give the earliest indications of tooth root cracks.
Cepstrum analysis is the inverse Fourier transform of the log spectrum and has two main application areas in mechanics. One has to do with the detection and classification of harmonic and sideband families which result from periodic impulsive signals, and also the periodic structure of log spectra given by echoes (allowing echo removal). The other is based on the fact that for SIMO systems, the cepstrum of the response is the sum of the cepstra of the forcing and transfer functions, and often allows them to be separated. This can be combined with blind source separation methods (which can extract SIMO from MIMO responses) to separate the source and transmission path components in the response to a particular source.

Correlation and Spectral Analysis Methods of Periodically Correlated Random Processes and Their Generalizations for Vibration Diagnostics
I. Kravets

Mathematical model of vibration signals for mechanical system fault identification and classification purposes on the base of periodically correlated random process will be investigated. The properties of these models will be described. Coherent, component, least squares, harmonic series representation and forecasting methods for probability characteristics estimation will be showed. The asymptotic behavior of component and coherent period estimators for periodically correlated random processes will be investigated using small parameter method. Examples of given approaches application to the analysis of simulated and real time series will be discussed. The methodology of vibration diagnostics on the base of developed methods will be presented.

Overview of Identification of Vibration Sources by the Force Analysis Technique
C. Pezerat

The Force Analysis Technique (also known as the RIFF Technique) is an experimental approach allowing the identification of the vibration excitation from the measurement of displacement or velocity fields. It is an inverse method based on a local verification of the motion equation of the vibrating structure. The advantages of this technique are: its simplicity, the fact to be a local method and the fact to require little information. The Force Analysis Technique was developed during the last decade and several developments exist today, depending of the kind of excitation and/or structures studied. The aim of the lecture is to give the basis of the Force Analysis Technique, expose all its variants and show industrial applications.

Imaging the Sound Using Microphone Arrays
J.-H. Thomas

The lecture deals with imaging techniques allowing the representation of the sound field radiated by a system. It focuses in particular on Nearfield Acoustic Holography which solves an inverse problem to reconstruct the sound field near the sources from space-time signal processing.

Damage Characterization of Materials from Acoustic Emission Signal processing
J-H. Thomas

With the aim to recognize the damage mechanisms which occur in a material under load, the presentation shows how pattern recognition, time-scale analyses, multidimensional analyses can work together from Acoustic Emission signals to succeed in the task.

Applications of cyclostationarity to acoustics and vibrations
J. Antoni

During the last decades signal processing has experienced considerable developments and now offers a lot of new and sometimes unexpected possibilities. The object of this presentation is to provide an overview of some of these advances related to cyclostationary modeling of vibration and acoustic signals and their impact in several fields of application. Cyclostationary analysis – a special case of time-frequency analysis – is ideally suited to capture the cyclic behaviour of signals in rotating and reciprocating machines, synchronously with their kinematics. It offers new solutions to otherwise difficult or intractable inverse problems. This is the case for diagnostics, the task of inferring a fault from the external observation of its symptoms, for system identification, source reconstruction, and (blind) signal separation and extraction -- the task of intercepting one specific mechanical signature among a superposition of many others – a promising field of research which will be discussed in detail. The lecture will be supported by several examples of application in vibration monitoring and acoustic imaging of rotating machines.

Practical aspects of cyclostationarity
F. Guillet, M. El Badaoui

There are many researches on the way cyclostationarity can be used, and the fields it can be applied to are numerous: mechanics, health (biomechanics, biomedical), telecommunications, meteorology, etc ... This course aims at presenting a hands-on approach of cyclostationarity and will be mainly based on experiments conducted on reciprocating machines and test benches for studying bearing faults.

Invited lecturers

Jacek Leskow • Jacek Leskow is professor at The Polish-American Graduate School of Business, Nowy Sącz, Poland. He has spent many visiting periods at the University of California, USA, and CIMAT, Mexico. His research area comprises statistical signal processing, bootstrap and resampling methods, nonparametric inference. He is recipient of three research awards from NATO Collaborative Linkage, grants for research on statistical models for telecommunication signals, and first prize for the best paper on statistical signal analysis, European Signal Processing Society, 2007.

Antonio Napolitano • Antonio Napolitano received Ph.D. in Electronic Engineering and Computer Science in 1994 from the University of Napoli Federico II. Since 2005 is Professor of Telecommunications at the University of Napoli "Parthenope", Napoli, Italy. He is IEEE Senior Member. Since 2006 to 2009 and since 2011 to present he has been Associate Editor of the IEEE Transactions on Signal Processing, since 2008 is in the Editorial Board of Signal Processing (Elsevier). Since 2008 he is Member of the Signal Processing Theory and Method Technical Committee (SPTM-TC) of the IEEE Signal Processing Society. He received from the European Association for Signal Processing (EURASIP) in 1995 the Best Paper Award for an article on higher order cyclostationarity and in 2006 the Best Paper Award for an article on the functional approach for signal analysis. In 2008 he received form Elsevier the Most Cited Paper Award for a review article on cyclostationarity.

Bob Randall • Bob Randall is a visiting Emeritus Professor in the School of Mechanical and Manufacturing Engineering at the University of New South Wales (UNSW), Sydney, Australia, which he joined as a Senior Lecturer in 1988. Prior to that, he worked for the Danish company Bruel & Kjaer for 17 years, after ten years experience in the chemical and rubber industries in Australia, Canada and Sweden. He authored the book "Frequency Analysis". At UNSW he was promoted to Associate Professor in 1996 and to Professor in 2001. He is the invited author of chapters on vibration measurement and analysis in a number of handbooks and encyclopedias, and a member of the editorial boards of four journals including Mechanical Systems and Signal Processing and Trans. IMechE Part C. He is the author of more than 190 papers in the fields of vibration analysis and machine diagnostics, and has successfully supervised fourteen PhD and three Masters projects in those areas. Since 1996, he has been Director of the DSTO (Defence Science and Technology Organisation) Centre of Expertise in Helicopter Structures and Diagnostics at UNSW.

Igor Kravets • As a senior researcher, Dr. Kravets is a signal processing team leader in the Physico-Mechanical Institute of the National Academy of Sciences of Ukraine. In 2003 Kravets Igor received the M.S. degree in Radio Physics and Electronics at Lviv Franko National University (Ukraine) in the field of Wave Theory and Automatic Control. In 2008 Kravets Igor received the Ph.D. degree in Lviv Polytechnic National University (Ukraine) in Mathematical Modelling and Numerical Methods. He is the author of more than 63 papers in the fields of signal processing and machine diagnostics. He has over eight years of experience of being involved in science projects of various scales. They have included theoretical and experimental investigations in statistical signal processing, development of methodology and new technical means for vibro-acoustic gears and bearing diagnostics, creation of complex scientific computational software and cooperation in signal detection, analysis and modelling with both Western world and Former Soviet Union scientific schools.

Charles Pezerat • Charles Pezerat is Professor of Acoustics and Vibration at the Laboratory of Acoustics of the University of Maine (LAUM) in France from 2009. He is Head of the VAGuE team (Vibrations, guided acoustics and flows) and teaches at the engineering school ENSIM. He is also in charge of the vibroacoustics Group (GVB) of the French Society of Acoustics SFA. After a training in general engineering at the school ECAM in 1990, Charles Pezerat has chosen to study Acoustics and obtained a Master degree at the University of Maine in 1991 and a PhD thesis at the Vibrations and Acoustics Laboratory (LVA) of INSA of Lyon in 1996. He became research engineer between 1997 and 1999 and Assistant Professor at the LVA between 1999 and 2009. The research of Charles Pezerat is in the vibroacoustics domain for industrial applications where his main topic is on inverse problems.

Jean-Hugh Thomas • Jean-Hugh Thomas received in 1996 the Ph.D degree in diagnosis and pattern recognition from the University Of Technology of Compiègne (UTC). He is assistant professor at ENSIM (Ecole Nationale Supérieure d'Ingénieurs du Mans), Le Mans, France from 1998. His research activities in the Laboratoire d'Acoustique de l'Université du Maine (LAUM UMR-CNRS 6613) deal with acoustic imaging techniques based on microphone arrays and signal processing methods to extract relevant features for diagnosis applications.

François Guillet • François Guillet received the M.Sc. and Ph.D. degrees in signal processing from the National Polytechnic Institute of Grenoble, Grenoble, France, in 1987 and 1990, respectively. From 1991 to 1994, he was the Director of the Department of Industrial Engineering and Maintenance, Academic Institute of Technology of Roanne, Université Jean Monnet de Saint-Etienne, Roanne, France. In 1995, he contributed in the creation of the Laboratoire d'Analyse des Signaux et des Processus Industriels (LASPI). Since 2003, he has been a Professor with Université Jean Monnet de Saint-Etienne and the Head of LASPI. His research interests include signal processing applied to the diagnosis of rotating machines by vibratory, electric, and instantaneous speed analysis, including cyclostationary process studies, blind system identification, and deconvolution.

Mohamed El Badaoui • Mohamed El Badaoui received the Dipl. Eng. and the M.Sc. degrees in electronics engineering in 1996 and the Ph.D. degree in signal processing in 1999 from the Université Jean Monnet de Saint-Etienne, Roanne, France. He is currently an Associate Professor with the Laboratoire d'Analyse des Signaux et des Processus Industriels, Academic Institute of Technology of Roanne, Université Jean Monnet de Saint-Etienne. His research interests include signal processing applied to vibratory analysis, biomechanics analysis, system identification, cyclostationary analysis, and blind sources separation.

Jérôme Antoni • Jerome Antoni received the M.S. degree in Mechanical and Electrical Engineering in 1995 and 1996, from the University of Technology of Compiegne (UTC), and Ph.D. degree in Signal Processing, 2001, from the Grenoble Institute of Technology, France. He was appointed full time Professor in 2008 at UTC. He is now with the Laboratory of Acoustics and Vibration, INSA, France. The main direction of his research activity is concerned with the diagnostics of mechanical systems from vibration and acoustical measurements. He is the co-author of more than 60 journal papers and 130 conference papers in these fields. He is with the Editorial Boards of Mechanical System and Signal Processing, International Journal of Condition Monitoring, and Diagnostyka.

Recommended readings

- A. Napolitano, Generalizations of Cyclostationary Signal Processing -- Spectral Analysis and Applications, John Wiley & Sons Ltd. To appear. 2012.
- R.B. Randall, Vibration-based Condition Monitoring: Industrial, Aerospace and Automotive Applications, John Wiley & Sons Ltd, 2011.
- H.L. Hurd and A. Miamee, Periodically Correlated Random Sequences: Spectral Theory and Practice, John Wiley & Sons Ltd, 2007.
- W. A. Gardner, Cyclostationarity in Communications and Signal Processing, IEEE press, 1994.

Registration form

(to be sent to lva@insa-lyon.fr or faxed to +33(0)4-72-43-87-12 before April 30, 2012)

First Name:	**Last Name:**
Title:	**Birth Date:**
Organization, University, Company:	**Address (Street Address,City, State, ZIP, Country):**
Phone:	**E-mail Address:**

Do you need to have a room booked at Valpré (summer school site http://www.valpre.com): **• single room: 78€/night** ☐ **• shared room (2 beds): 50€/night** ☐ **(recommended if you apply for free accommodation)**	**Sunday 24th June** ☐ **Monday 25th June** ☐ **Tuesday 26th June** ☐ **Wednesday 27th June** ☐ **Thursday 28th June** ☐
Are you applying for free accommodation (only a limited number of participants will be selected, with priority given to young international academics):	**yes** ☐ **no** ☐
Date and signature:	

Admission

Applicants are asked to send an application form to lva@insa-lyon.fr **before the 30th of April**; it should comprise

- the attached registration coupon,
- a motivation letter,
- a short CV,
- a letter of recommendation signed by the head of department or supervisor for PhD students.

There are no registration costs. Lunches and coffee breaks will be offered to all participants during the duration of the summer school.

The total number of participants is limited to 40.

Accommodation

We recommend all participants stay at the Valpré conference site (http://www.valpre.com) where the summer school will take place. Rooms will be automatically booked when registering, unless specifically stated otherwise by the applicant.

A limited number of participants will be offered free accommodation (including the nights of Sunday 24th to Thursday 28th) – priority is given to young international academics.

Information about travel and access to the summer school site is available at http://www.valpre.com/rubriques/haut/acces-contact/acces http://www.valpre.com/rubriques/haut/acces-contact/plan-dacces-valpre-v.-english-.pdf

Coordinators

- **Jerome Antoni (INSA of Lyon, Lyon, France)**
- **François Guillet, Mohamed Elbadaoui (University of Saint-Etienne, Roanne, France)**
- **Jacek Leskow (The Polish-American Graduate School of Business, Nowy Sącz, Poland)**

Contact

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June 25 - 28, 2012

Non-stationary signal processing and inverse problems in acoustics and vibrations

Summer school

Researches in acoustics and vibrations and in signal processing have for long been interconnected. Early developments of signal processing owe a lot to formal results historically established in the theory of sound. Inversely, latest advances in signal theory have often found exemplary – and sometimes unexpected - applications in acoustics and vibrations.

The aim of this summer school is to teach the state-of-the-art on some recent advances in non-stationary signal processing (cyclostationary processes) and signal processing approaches to inverse problems (spatio-temporal signal processing) found in acoustics and vibrations. Fields of application include vibration-based condition monitoring of rotating machines, structural-health-monitoring, acoustic imaging, but not only. Lectures are given by worldwide and internationally acknowledged specialists in these domains. The school is open to anyone interested in collecting information from a vibration or acoustical signal, with priority given to young academic researchers.