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13. ABSTRACT *(Maximum 200 words)*

This is a report on the IMA summer programs: Radar/Sonar (June 18 - June 29, 1990) and New Directions in Time Series Analysis (July 2 - July 27, 1990). At least four proceedings volumes are being prepared by participants of these very successful research programs and will be sent to the ARO as soon as they have been published by Springer-Verlag.

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RADAR/SONAR AND TIME SERIES ANALYSIS
FINAL REPORT

WILLARD MILLER, JR.

April 8, 1991

U.S. ARMY RESEARCH OFFICE

DA/DAAL03-90-G-0136

INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS
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PROGRAMMATIC ITEMS

VIII. SCIENTIFIC DESCRIPTION OF SUMMER 1990 RADAR AND SONAR PROGRAM.

The organizing committee for the program "Radar and Sonar" consisted of: Alberto Grunbaum (chairman), Marvin Bernfeld, Richard E. Blahut, and Richard Tolimieri.

LIST OF ACTIVITIES

The IMA program on Radar and Sonar was a follow-up on a portion of the 1988 IMA summer program on Signal Processing; it included ideas which were suggested by the participants of that program. Our goal was to increase the interaction between mathematicians and electrical engineers in universities and mathematical scientists in industry working on significant problems in radar or sonar.

The first week of the program was tutorial. The second week was devoted to presentations of problems by scientists from industry or universities. The problems we were looking for were those of significance to the field of radar or sonar as well as containing mathematical issues.

Week 1, June 18–June 22, 1990

TUTORIAL

Lecturers: Richard E. Blahut, Willard Miller, Jr. and C.H. Wilcox

The first week was run as a summer school. There were three minicourses, each consisting of five-hours of lectures. Lecture notes prepared by the lecturers were distributed to students and participants they arrived. With the idea of an audience consisting mainly of mathematicians and engineers, the tutorial topics were one on mathematics, one on the physical aspects of scattering, and one on the engineering modelling and processing of the phenomena under consideration.

A great effort was be made to insure that this week was devoted to help people cover two out of the three short courses in detail: a mathematician needed to spend more time and effort in the engineering and physics components, and a corresponding distribution of effort was encouraged for engineers and physicists.

Minicourse 1
lecturer: Willard Miller,Jr.

TOPICS IN HARMONIC ANALYSIS
WITH APPLICATIONS TO RADAR AND SONAR

Minicourse 2
lecturer: C.H. Wilcox

SONAR AND RADAR ECHO STRUCTURE

Minicourse 3
lecturer: Richard E. Blahut

THEORY OF REMOTE SURVEILLANCE ALGORITHMS

Week 2, June 25–June 29, 1990

RESEARCH PROBLEMS

Scientists from industry and government agencies who were working on problems in Radar or Sonar presented research problems. During this week, in addition to the audience of the first week, there were other invited participants (mostly from universities) whose research is connected to Radar and Sonar.

RESEARCH AND TUTORIAL ASSESSMENT

Assessment of the program by Alberto Grunbaum:

From my point of view I consider this effort a complete success. The format consisting of one week of EXTREMELY WELL PREPARED LECTURES, followed by a week of fairly informal talks on (most of the time) open problems is very close to ideal.

I was very impressed by the three lecturers of the first week: they were supposed to deliver to the participants complete lecture notes weeks before the Workshop, and this is exactly what they did. Not only that but the material was completely polished and ready to use as a very good book. The style of lecturing of all three kept the audience tuned in all the time on the three topics: people kept coming back to all of them and there was a nice spirit established that allowed people to ask, interrupt, try to really follow, etc..

I think that everyone got the idea that the most challenging part of the interaction among math people and engineers is one of learning a bit of each others language, so that the trees will not cover the forest.

I did not count very systematically the audience , but I think that we had a core of somewhere between 25 and 35 people coming to all the lectures. This included a present and a former Director of IMA for a good part of the time. And they were among the ones asking questions.

The second week was very different in character. I managed to exercise my dictatorial powers in keeping every speaker to 30 minutes. Next time I would go for 25 and 5 minutes of questions. We did not have a huge number of talks and this really gave people a chance to go back to their offices and try to digest the material. This was particularly true the first week: I spent many nights till 12 pm in my office doing just that, and ran into many other participants working their tails off to understand the material of the day.

I think that the material that we tried to present the first week: 1) some of the basic physics that gives therelation between the "object" and the measured scattered pattern, 2) some of the harmonic analyisis that allows you to understand this "transform" in a mathematical framework, and 3) some of the signal processing issues connected with handling truly discretized and noisy samples of the "ideal" echo, are at the core of the problem .

Personally, I managed to establish contacts with "real people" who will I hope be willing to carry out some experiments in which I am very interested. In fact the lack of a "central place" for more continued interaction of this kind is a troubling point in my mind; I hope that we have made a start, and this crowd can be assembled back sometime soon.

I think we all really worked very hard (in my case only for the two weeks that I was there) and IMA did a splendid job.

RADAR/SONAR, PART I

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RADAR/SONAR, PART II

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EDITORS: M. BERNFELD, R. BLAHUT AND A. GRUNBAUM

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*Papers received to date.

IX. SCIENTIFIC DESCRIPTION OF SUMMER TIME SERIES PROGRAM.

The organizing committee for the program "New Directions in Time Series Analysis" consisted of: Emanuel Parzen (chairman), David Brillinger, Murray Rosenblatt, Murad Taqqu, John Geweke and Peter E. Caines.

The theory and methods of time series analysis lie at the intersection of the mathematical, statistical, computational, and system sciences, and provide an elegant interplay among these disciplines. They provide the means of applying advanced mathematical ideas and theorems to contribute towards the solutions of very practical problems. Time series analysis is truly an *interdisciplinary* field, because development of its theory and methods requires *interaction* between the diverse disciplines in which it is being applied. To harness its great potential there must develop a community of statistical and other scientists who are educated and motivated to have a background in theory and methods of time series analysis adequate to handle the problems of time series analysis in *all* the fields in which they occur.

The reasons as to why it was important and timely to conduct an Interdisciplinary Workshop on New Directions in Time Series Analysis in 1990 are:

(1) major advances are occurring in the theory and applications of time series, and they need to be more widely disseminated among time series researchers;

(2) there are many new directions of research, including nonlinear problems, non-Gaussian models, higher order spectra, long-range dependence, random fields;

(3) the methods of time series analysis are of great interest for their potential and actual application in many applied fields;

(4) communication among the community of researchers will be enhanced by bringing theoretical and applied researchers together in the time and space setting provided by the IMA workshop;

(5) the published Proceedings can be expected to be an important stimulus to applications of, and research in, newly developed methods of time series analysis;

(6) there had not been for many years an interdisciplinary workshop in time series analysis; the IMA 1989 Summer Program on Statistics intersected the Time Series Workshop only briefly in our Week III on Statistics.

LIST OF ACTIVITIES

The organizational plan of the workshop was to have theme weeks organized as follows:

Week 1, July 2–6, 1990

NON-LINEAR AND NON-GAUSSIAN MODELS AND PROCESSES

Organizers: David Brillinger and Murray Rosenblatt

Topics included higher-order moments and spectra, bilinear systems, nonlinear processes, applications to astronomy, geophysics, engineering, simulation.

Week 2, July 9–13, 1990

SELF-SIMILAR PROCESSES AND LONG-RANGE DEPENDENCE

Organizer: Murad Taqqu

Topics included time series with long memory self-similar processes, fractals, 1/f noise, stable noise.

Week 3, July 16–20, 1990

INTERACTIONS OF TIME SERIES AND STATISTICS

Organizer: Emanuel Parzen

Topics included time series model identification, analysis of categorical valued time series, nonparametric and semiparametric methods for time series.

Week 4, July 23–27, 1990

TIME SERIES RESEARCH COMMON TO ENGINEERS AND ECONOMISTS

Organizers: John Geweke and Peter Caines

Topics included modeling of multivariate (possibly non-stationary) time series, especially by state space and adaptive methods.

The talks on July 16 were dedicated in honor of John Tukey's contributions in Time Series Analysis.

RESEARCH ASSESSMENT

Assessment by D.R. Brillinger and M. Rosenblatt of Week 1 "Non-linear and non-Gaussian models and processes":

The first week of the Summer Program brought together statisticians, probabilists, engineers and dynamic systems researchers from different countries. The topics dealt with in the first week were broad and yet there was a great deal of interplay between the ideas presented by the operators. There were distinctions between deterministic and stochastic models, between applications and theory, and between various nonlinear models and techniques. The material was current and it seems clear that the proceedings should be of great interest. The spirit was informal with two morning talks and one afternoon each day. This allowed much ad hoc discussion to take place between the participants.

Individuals spoke of how important it had been for them to interact in this way with the experts on the different topics.

It is hard to imagine how the environment and facilities provided by the IMA could be improved upon. Particularly important to the applied participants were the office-based computer facilities allowing both in-house computation and direct connection to home facilities.

Assessment by Murad Taqqu of Week 2 of the Time Series Workshop:

The second week was devoted to 'Self-similar processes and long-range dependence." There were many participants from abroad including Canada, Japan, Europe and even the USSR. The week was very successful. It brought together mathematicians, statisticians and engineers, people who do not usually have the opportunity to meet together. Through formal talks and informal discussions, the participants became aware that long-range dependence can arise in diverse settings, that it has its own intrinsic mathematical interest in connection with self-similarity and fractals and tnat statistical techniques that can detect its presence and estimate its intensity are still inadequate.

Although there had been specialized meetings in the past, this is the first time that such a workshop has taken place. The diversity of the participants' background gave rise to lively discussions, and there were many opportunities for informal discussions.

The talks reflected the diversity of points of view. Some focused on the presence of self-similarity in dynamical systems, on multifractals, scaling in networks and on 1/f noise. Several talks concerned limit theorems under long-range dependence. A number of presentations were devoted to statistical problems for detection and estimation. Benoit Mandelbrot, in addition to a technical presentation of multifractals presented a very interesting video "New York Notes," a show of fractals with accompanying music by Charles Wuorinen.

The IMA environment was particularly suitable for this kind of meeting. The facilities were great and the staff extremely helpful and efficient.

Assessment by Emanuel Parzen of Week III:

As many as 100 people attended many sessions. There were 10 one hour talks, 15 half hour talks, 1 hour of tribute to John Tukey, and 1.5 hours of open forum. The 20 hours of formal meetings provided, and stimulated, ample time for informal discussions. Morning sessions started at 8:30 a.m., afternoon sessions at 1:30 p.m., Coffee breaks at 9:30 a.m. and 2:30 p.m. There was a workshop dinner Thursday evening.

Participants reported that the meeting was the best, most productive, and most enjoyable ("fun") of any meeting that they had ever attended "They never knew they could learn so much so fast".

The proceedings are expected to provide a major reference work, providing a broad survey of past and future research accomplishments in the statistical theory of time series analysis.

Speakers represented almost all senior faculty members in U.S. Statistics Departments who are active in Time Series research. Personal reasons forced the following invited speakers not to attend: Peter Bloomfield, H.L. Gray, Johannes Ledolter, Adrian Raftery, George Tiao, and Robert Kohn from Australia. Ruey Tsay spoke in week IV.

A highlight of week III was the participation of John Tukey, to whose pioneering and fundamental contributions the week was dedicated. Another historic figure whose presence enriched week III was Akiva Yaglom from Moscow.

The success of the workshop was made possible by the support provided by the IMA Director (Avner Friedman), Associate Director (Willard Miller), staff, facilities, and arrangements. All participants expressed their deep appreciation of the outstanding work of the IMA, and of the support of sponsoring agencies.

Assessment by John Geweke of Week IV:

The participants and topics in this portion of the program were representative of problems in time series currently being studied by econometricians. Specific topics addressed, all by more than one participant, included the following.

(1) Inference for possibly nonstationary time series. There was particular focus on testing the unit root hypothesis, with comparisons of Bayesian and frequentist procedures.

(2) Alternatives to unit root models as descriptions of nonstationarity and forecasting devices. In particular, the use of long-memory models was discussed. The focus here was on the substantial technical problems that arise in using likelihood-based methods, and several lacunae in the asymptotic distribution theory.

(3) Nonlinear time series models. There is a wide variety of alternatives to the standard linear model. Two discussed in these sessions were (a) semi-parametric extensions of the widely used autoregressive conditional heteroscedasticity (ARCH) model and (b) chaotic models.

(4) Model based inference using a multitude of time series. While much of econometric time series work is similar to what is done in statistics or engineering, much of it is also distinguished by the available of well-specified models grounded in economic theory. This poses special problems for inference, in that likelihood functions are typically highly nonlinear in the parameters. When longitudinal data bases are employed, data base management becomes an additional feature of the problem.

Much of the informal discussion, among the econometricians and together with the engineers, focussed on the validity and usefulness of classical stochastic model specification; and conditional on the validity and usefulness of this approach, the relative merits of Bayesian and frequentist methods, both in principal and in practice. Needless to say these issues were not resolved with any finality in one week. However, all participants gained insights, at the technical level, into approaches different than the ones conventional in their discipline. The key interactions here occurred between the systems theorists in engineering and econmetricians grounded in statistics; and between the Bayesians and frequentists among those with a statistical background.

Assessment by P. E .Caines of Week IV:

The overall purpose of the engineering section of the IMA Time Series Meeting was to present current directions of research in stochastic systems for the purposes of modeling, prediction and control. The engineering sessions were alternated with the econometric sessions in order to maximize the probability of cross-fertilization between the fields. In particular, at the suggestion of Manfred Deistler, an open forum on common issues in engineering and econometrics was held during the lunch period on the Thursday.

A summary of the activities in the engineering section is as follows (co-authors of papers are given in the complete listing of the programme and in the proceedings): The Monday afternoon session was focussed on the questions of structural issues in the construction of dynamical mathematical models for observed processes. The speakers here were: Cornelis Los (A Scientific View of Economic Data Analysis), Ben Hanzon (Parameter-Independent Characterizations of the Structure of a Linear Dynamical Model), Anders Lindquist (Stochastic Realization Theory) and Andrea Gombani (Approximate Stochastic Realizations).

The following morning the talks centered on the problem of estimating exact and approximate structures of linear systems. In this session issues of stochastic complexity, and the geometric and topological properties of realizations of linear systems were addressed. These ideas were then considered in the analysis of the properties of estimators for such important quantities as the order(s) of a system in ARMAX form. Specifically the talks were: Laszlo Gerencser (Stochastic Complexity and Modelling), C Z Wei (Recursive Estimators and Oder Estimation Criteria) and Jan Maciejowski (Balanced Realizations, Linear Systems and Identification).

The next topic on the engineering agenda was stochastic adaptive control. This may be viewed as the application of recursive identification to the problem of the stabilization and performance enhancement of a system whose dynamics –in particular parameters – are a priori unknown and which must be learned in "real time". One of the main outstanding problem areas is the adaptive control of systems whose dynamics are changing in time. The speakers in the session on the adaptive control of time varying systems were: Sean Meyn (Estimation and Control of Time Varying Systems: A Markov Chain Analysis of Stability and Performance), Peter Caines (Controllability and Ergodicity of Jump Parameter Adaptive Control Systems), Ren Wei (The Convergence of Parallel Model Adaptation Schemes in the Presence of Colored Noise), Han-Fu Chen (Convergence of the Astrom-Witternmark Self-Tuning Regulator and Related Topics) and Lei Guo (Identification and Adaptive Control for Time-Varying Stochastic Systems).

The talks the following morning returned to the themes of structural properties of linear system models and the fundamental issues of constructing models for data.In this view the set of possible trajectories of the data is the system to be estimated. This talk was given by Jan Willems (Continuity of Latent Variable Models).

The subsequent talk presented an approach to the time varying system model problem which connected to the previous talks on system oder estimation, maximum likelihood techniques and complexity measures for system models. The term "smoothness" in the title refers to dynamical properties of the hypothesized models for the evolution of the signal or the dynamical model itself: Will Gersch (Smoothness Priors).

The subsequent talk addressed the errors in variables problem introduced earlier by Cornelis Los and presented results concerning the identifiability of dynamic models of this type: Manfred Deistler (Identification of Dynamic Systems from Noisy Data).

Following the talk of Manfred Deistler the topic of recursive estimation and control of linear systems was treated by T. Z. Lai (Properties of Recursive Estimators in Adaptive Estimation and Control).

T.Z. Lai presented a survey of the properties of the main recursive estimation methods and presented results on the achievment of efficiency by modifications of the algorithms in certain systematic ways. Finally, the engineering section concluded with a survey of the principle results in bilinear modeling, prediction and estimation together with a set of new results: Dominique Guegan (Identification and Forecasting in Non-linear Stochastic Processes).

NEW DIRECTIONS IN TIME SERIES ANALYSIS

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EDITORS: DAVID BRILLINGER, PETER CAINES, JOHN GEWEKE, EMANUEL PARZEN,
MURRAY ROSENBLATT, MURAD TAQQU

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*Papers received to date.

APPENDIX A: PROGRAM FOR RADAR/SONAR.

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IMA NEWSLETTER #163

June 11 - June 30, 1990

Workshop on CHAOTIC PROCESSES IN THE GEOLOGICAL SCIENCES

June 11–15, 1990

(jointly with the Minnesota Supercomputer Institute)

Organizers: S.-N. Chow, M. Golubitsky, R McGehee,
G. R. Sell and D. A. Yuen

The goal of the geological sciences is to understand the earth well enough to construct detailed quantitative models of physical and chemical processes within the earth. Recently, concepts from dynamical systems and chaos have been used to derive a better understanding of the behavior of complex geological systems. The purpose of this workshop is to be arena for scientific exchanges between earth scientists and mathematical researchers, especially with experts in dynamical systems.

IMA Summer Program

RADAR AND SONAR

June 18 - June 29, 1990

Organizing Committee: Alberto Grunbaum (chairman), Marvin Bernfeld
Richard E. Blahut, Richard Tolimieri

The program goal is to increase the interaction between mathematicians and electrical engineers in universities and mathematical scientists in industry working on significant problems in radar or sonar. The first week of the program is tutorial. The second week will be devoted to presentations of problems by scientists from industry or universities. The problems we are looking for should be of significance to the field of radar or sonar as well as containing mathematical issues.

PARTICIPATING INSTITUTIONS.Georgia Institute of Technology, Indiana University, Iowa State University, Michigan State University, Northern Illinois University, Northwestern University, Ohio State University, Purdue University, University of Chicago, University of Cincinnati, University of Houston, University of Illinois (Chicago), University of Illinois (Urbana), University of Iowa, University of Michigan, University of Minnesota, University of Notre Dame, University of Pittsburgh, Wayne State University

SCHEDULE FOR JUNE 11 - 30

Workshop on
CHAOTIC PROCESSES IN THE GEOLOGICAL SCIENCES

June 11–15, 1990
(jointly with the Minnesota Supercomputer Institute)
Organizers: S.-N. Chow, M. Golubitsky, R McGehee,
G. R. Sell and D. A. Yuen

Most of the workshop talks will be held in Conference Hall 3-180 on the entry floor of the new Electrical Engineering/Computer Science Building. This building is located on the corner of Washington Avenue and Union Street, a block from the IMA Main Office. The conference hall is on the Ethernet and has a projection system for display of computer output.

In addition to the scheduled lectures, there will be opportunities during the workshop for a number of informal, impromptu presentations. Participants are encouraged to bring along material they might want to present.

Also, on June 12 a video session will be held at the Minnesota Supercomputer Institute. Participants with interesting visuals, in the form of 16 mm. movies, videotapes or online SUN workstation, IRIS or MacintoshII movies, are encouraged to bring them. (An IRIS or SUN can read cartridge tapes in standard UNIX tar format. It is also possible to read magnetic reel tapes in UNIX tar format on the IMA APOLLO network, and then transfer the files to an IRIS or SUN over the campus network.) If you wish to contribute to the video session, please let our staff know in advance, so that we can have the right equipment available.

For those who want to send data along electronically for online movies, we offer anonymous ftp access on a Sun SparcStation. Type

```
ftp 128.101.152.11
```

to connect. Log in as "anonymous" and give your e-mail address as the password. You should now be logged in. Type

```
cd pub
```

to get into the public directory. At this point, you can use the "cd" command to get into a subdirectory. To transfer <file> back to your home machine, type

```
get <file>
```

Similarly, you can use the "put" to transfer a file to the IMA. For more information, type

```
man ftp
```

from a UNIX shell, or use the "help" command while in ftp.

Monday, June 11

Introduction and Mantle Convection, Mantle Rheology

The talks today are in Conference Hall EE/CS 3-180

9:00 am	Registration and coffee	Reception Room EE/CS 3-176
9:30 am	David A. Yuen University of Minnesota	Nonlinearities and chaotic processes in the geological sciences

Abstract: An introduction will be given on the various types of nonlinearities which arise in geological phenomena and how these give rise to interesting time-dependent phenomena, ranging from chaotic to turbulent regime. The different phenomena and equations will be described to give a common background for the workshop. We will also discuss the influences of geological material properties on generating interesting nonlinear time-dependent processes, which may or may not have counterparts in other physical disciplines.

10:30 am Coffee Break Reception Room EE/CS 3-176

11:00 am W.R. Peltier Mantle rheology and mantle convection
University of Toronto

Abstract: The Earth is a radially stratified viscoelastic object which cools on a timescale determined by the efficiency of convective heat transport through its "solid" mantle. The Rayleigh number of this circulation depends upon mantle viscosity which is itself a strong function of temperature because of the thermally activated nature of the solid state creep process that governs mantle "flow". Mantle viscosity may be inferred on the basis of a number of different geophysical observations, most but not all connected to the response of the planet to the 10^5 yr cycle of glaciation and deglaciation that has been a durable characteristic of hte geological record throughout the past 900,000 yrs of Earth history. The formal problem of inferring mantle viscosity from such data is a classical problem in geophysical inverse theory, although one that is somewhat exotic because of the nature of the data that must be inverted. Considerable progress in the development of suitable theory has recently been achieved that completes the partial analysis presented previously in Peltier (1976). This theory has now been applied to both synthetic and "real" data, allowing for the first time a detailed quantitative analysis of the inherent resolving power of the viscoelastic relaxation data of postglacial rebound and a detailed assessment of the extent to which the radial variation of mantle viscosity is constrained by these data. A Bayesian formulation of this inverse problem has proven to be especially advantageous. The results of these recent analyses will be discussed in detail and their implications with respect to the style of convection in the earth's mantle will be discussed.

2:00 pm U. R. Christensen Three-dimensional mantle convection with variable viscosity: Mantle plumes and toroidal excitation
Max-Planck Inst.

Abstract: We report numerical calculations for three-dimensional convection with variable viscosity. A hybrid spectral and finite difference method is used. The coupling of modes in the equation of motion, which is caused by lateral viscosity variations, is treated iteratively. solutions for bimodal, hexagonal, square, triangular and spoke patterns are reported for bottom heated convection at infinite Prandtl number. The Rayleigh number is between critical and 10^5 and temperature-induced viscosity contrasts up to 100 are considered. In agreement with results from laboratory experiments we find that temperature-dependent viscosity favours at low Rayleigh number flow patterns like squares or hexagons, where a columnar rising current is surrounded by sheet like descending flow. The dichotomy in geometry between upwelling and sinking flow becomes more pronounced with increasing viscosity contrast. The temperature-dependence of viscosity gives rise to a toroidal velocity component. However, it amounts only to a few percent of the total velocity. In contrast, at the earth's surface an approximate equipartitioning of poloidal and toroidal energy is found. We show that with non-Newtonian and depth-dependent rheology the toroidal component at the free surface can become significant, and a pattern reminiscent of plate motion can arise in a free convection model. Although these results are obtained in a parameter range which is not directly applicable to the earth, they support the conclusions that (i) upwelling flow in the mantle is unlikely to be sheet-like and will probably be in the form of columnar plumes, and that (ii) the toroidal motion found at the earth's surface is due to the highly non-linear rheology which leads to the existence of mobile surface plates and is not caused by viscosity variations related to lateral temperature contrasts deeper in the mantle.

3:00 pm Michael Gurnis Large-scale mantle convection and dynamic interaction with plates
University of Michigan

Abstract. The dynamic coupling of tectonic plates (including non subducting continental lithosphere and subducting oceanic lithosphere) with thermal convection is being investigated with finite element models. In a range of cases, the plates are viscous entities (like the background fluid) and are introduced into the system with various rheologies and boundary conditions. The models are meant to explore rather specific parts of the over-all coupling between tectonic plates and convection and to help us understand the relationship between various quantities measured on the Earth's surface and the dynamic processes in the interior.

Particular attention will be given to the interaction between large non-subducting continental lithosphere and the deep mantle and how these interactions effect seismic structure, dynamic topography, the geoid, and sea-level (measured as continental flooding). I will demonstrate that such interactions have a first order influence on the spatial and temporal pattern of continental flooding; I will suggest how the pattern of observed marine deposits on continental platforms can be used to constrain aspects of mantle rheology and mantle flow.

4:00 pm	Vincent Hall 502 (The IMA Lounge)	IMA Tea (and more!)

Tuesday, June 12 (at Minnesota Supercomputer Institute)

Earthquakes & Turbulence in Thermal Convection, Visualization

The talks today will be held in Room 3125 (and 3155) of the Minnesota Supercomputer Center, 1200 Washington Avenue South, Minneapolis. The IMA will provide a Transit Coach to pick people up on Union Street (along side the EE/CS Building). The bus will start boarding at 8:30 am, depart for MSI at 8:45 am, and arrive at MSI by 9:00 am.

Also, the (free) University Campus Bus #13A can be used to reach MSI. It leaves Fraser Hall at 8:35 am (and 9:35, 10:35, etc.), and arrives at MSI at 8:39 am. The last return #13A bus to leave MSI is at 4:40 pm. (Buses leave from MSI at 40 after the hour from 8:40 am to 4:40 pm.)

You can also walk from the IMA to MSI. The distance is approximately one mile.

9:00 am	J.B. Rundle Livermore National Lab.	Lattice automata models for earthquakes and frictional sliding

Abstract: A variety of phenomena associated with earthquakes and laboratory friction experiments suggest fundamental similarities to nonlinear dynamical systems operating near a critical point. These phenomena include a large scaling regime for number of earthquakes as a function of area, and the observation of hysteresis loops in frictional sliding experiments, suggesting the existence of a long lived metastable state. Important basic questions about friction remain unanswered, including the origin of rate dependence in laboratory studies of friction between clean, dry surfaces.

The physical processes associated with frictional sliding and earthquakes can be illuminated by the use of a simple lattice automaton recently proposed in the literature (JBR, J. Geophys. Res., 93, 6237, 1988). In this model, interactions between lattice points x_i and x_j are specified by means of an operator T_{ij}, also called the stress Green's function. The independent field variable ϕ_i (order parameter) is the reduced slip, or slip deficit $\phi_i = s_i - Vt$, where s_i is the shear slip at x_i, V is the time averaged rate of sliding, and t is time. The force, or shear stress σ_i at each lattice point is given by $\sigma_i = p_i + \Sigma_j T_{ij} \phi_j$, where p_i is the background, or bias stress, at x_i. Dynamical evolution of the system occurs when the stress σ_i increases, through increases in p_i, or as t increases by constant (independent of V) decay time increments δt. When σ_i equals or exceeds a failure level σ_i^F, the slip s_i is increased according to a specified rule. On each time step, s_i is adjusted at all failed lattice points, prior to again incrementing t by δt. The stress at each lattice point decays from the unrelaxed value to its relaxed value over a lifetime Γ, which may be greater or less than δt, the time interval between loadings.

The nature of the model is sufficiently general that it incorporates both the quasistatic Burridge-Knopoff model of a shear fault, as well as the recently proposed Self Organized Criticality model of Bak and colleagues. Numerical results for a specific model simulating laboratory friction experiments will be described (JBR and SR Brown, Phys. Rev. Lett., submitted, 1990). A scaling regime can be seen which grows as V increases, indicating increasing proximity to the dynamical critical point where a spanning cluster of failed points appears. The size of the scaling region can be used to estimate the failure correlation length ξ_d, which diverges at the critical point. The most interesting result is the appearance of rate dependence, similar in magnitude and sign to the rate and state dependence seen in laboratory sliding friction experiments. Joint work with S.R. Brown.

9:50 am	Lou Howard Florida State University	On turbulent thermal convection
10:40 am	Coffee Break	
11:00 am	A.C. Fowler Oxford University	Convection and Chaos

Abstract: This rather discursive talk will discuss two types of chaotic behaviour exhibited by high Prandtl number convection, that is, "phase chaos" and plumes. In mantle convection, these differing aspects of the motion find their expression in the migration of subduction zones and hotspots, respectively. The analysis of plumes in a single convection cell can be undertaken in the framework of Howard's "bubble" model of convection, using an asymptotic analysis based on a similar method applied to the Lorenz equations. This leads to an approximate Poincaré map, wherein chaotic behaviour arises through the near attainment of trajectories which form homoclinic connections between states of conductive thermal equilibrium. Alternatively, "cellular chaos" at large Rayleigh number can be modelled using a set of ordinary differential equations for variables which describe the size and location of slowly varying convection cells. The differential equations are parametrised using quasi-stationary boundary layer theory. The same method can in principle be extended to three dimensions, and represents a paradigm for the study of time-dependent motions of the earth's lithospheric plates.

11:50 am	Lunch Break	Lunch in the MSI Reception Area provided for registrants
1:30 pm	S. Balachandar University of Illinois, Urbana	Direct numerical simulation of turbulent thermal convection

Abstract: A direct numerical simulation of thermal convection between horizontal plane boundaries has been performed, at $Ra = 9800 Ra_c$, where Ra_c is the critical Rayleigh number for the onset of convection. The flow is found to be fully turbulent, and an analysis of the probability distributions for temperature fluctuations indicates that this is within the "hard turbulence" regime, as defined by the Chicago group. Plots of temperature vertical velocity correlation along with flow visualizations indicate the presence of turbulent thermal plumes and these coherent structures are found to make significant contribution to the overall heat transfer. The effect of finite domain on the classical scaling properties, which are based on a semi-infinite domain, is explored. The highly intermittent nature of vorticity and temperature distributions is revealed by their non-Gaussian probability distributions. Under proper scaling a universal probabilistic description exists over the entire convection cell, except for the very narrow sub-layer near the top and bottom boundaries.

2:20 pm	U. Hansen U. zu Köln	Chaotic thermal convection at infinite Prandtl number

Abstract. Numerical simulations of $2-d$ high Rayleigh (Ra) number, base heated convection in large aspect ratio boxes are presented for infinite Prandtl number fluids as applied to the earth's mantle. Typically, flows at $Ra > 10^6$ consist of large-scale cells with intermittent boundary layer instabilities. Due to the instabilities the flow displays strong temporal variations while the existence of the large scale flow leads to spatial coherent structures. Changes in the large-scale component (appearance or disappearance of convection cells) are found to operate on a time scale much longer than the one associated with the boundary layer instabilities. For Ra exceeding 10^7 we find the heat transfer mechanism changing from one, characterized by mushroom-like plumes to one consisting of disconnected instabilities. The evolution and the fate of the boundary-layer instabilities is determined by the kind of interaction between those instabilites and a 'wind', generated and maintained by the large scale circulation. Collisions of instabilities within the thermal boundary layers lead to pronounced plumes having the tendency to develop 'pulse-like behavior'. Tilting of the instabilites, resulting from the shear which is exerted by the wind is another typical feature of the multiscale flow. The richness of the dynamical phenomena resulting from the interaction of the different scales is potentially interesting with respect to the observed variety of geodynamical features.

3:10 pm	Coffee Break	
3:30 pm	Video session	Participant-supplied visuals, in the form of videotapes or online IRIS, MacintoshII or SUN movies, will be shown.

Presentations by Gurnis, Hansen, Jaupart, Spera, Peltier, Yuen, Balachandar, Glatzmaier and others.

MSI Chaos Workshop talk

4:30 pm	Yongmin Kim University of Washington	The University of Washington graphics system processor
6:00 pm	Reception	Grandma's Saloon , near Holiday Inn on West Bank

Reception from 6:00 to 8:00 PM on the ground-floor of Grandma's Saloon. Cash bar; hors d'oeuvres will be served .

Wednesday, June 13

Magma Physics, Soliton Dynamics, Volcanic Transitions

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:00 am	George W. Bergantz University of Washington	Conjugate solidification and melting in open and closed multi-component systems

Abstract: Underplating and intrusion of continental crust by basaltic magma has repeatedly been invoked as a mechanism to provide the needed heat and mass transfer to initiate and sustain magmatism in a variety of tectonic settings. This superposition yields a strongly time dependent and non-linear feedback system with both conductive and convective components. Theoretical and experimental studies have been undertaken which focus on the manner in which transport properties and thermal history are buffered by enthalpy changes associated with simultaneous solidification and melting as a function of the change of melt fraction for naturally ocurring compositions. This is particularly important as the crystallization of basalts and the melting interval for common crustal rocks overlap; this yields strong changes in material properties which govern the heat transfer systematics at the solidification-melting interface.

Experiments: The underplating process was modeled by superposing mixtures of fluid and solid paraffins representing "basalt" and "country rock" in a variety of geometries. The paraffins have similar Stefan numbers, and relationships between density, viscosity, enthalpy, and most importantly, melting interval, as magmas. These paraffins exhibit no nucleation delay. Turbulent convection in the underplated material was not observed. the system exhibited a dynamical and thermal history largely consistent with models based on a coupled conductive solidification of the "basalt" and partial melting of the "country rock".

Numerical modeling: of this conjugate system in the presence of both forced and fully coupled free convection yields a variety of time dependent interactions from melting back of the wall in the case of turbulent forced flow to a short-lived period of natural convection associated with the fully coupled and more geologically realistic case. The governing dynamical quantities are the slope of the solid fraction distribution, the degree of superheat relative to the temperature where the viscosity changes by a factor of approximately $1/e$, and the background temperatures of the country rock. The Peclet number associated with interdendritic flow is demonstrably small, and can be neglected. The formulation of the problem in terms of a general dependent variable, the chemical potential, will be discussed.

9:50 am	Claude Jaupart Université Paris 7	Transitions of eruption regimes in silicic volcanoes

Abstract: In silicic volcanoes, eruptions commonly begin with violent explosive phases and evolve towards a regime of dome formation. Dome growth is initially not a stable process and usually leads to an explosive phase. Thus, the volcano may alternate between phases of explosive activity and dome growth. These transitions are characterized by a decrease of gas volume fraction which has usually been attributed to chemical gradients in the volcano chamber. Petrological and geochemical studies suggest that this interpretation may be oversimplified. a critical observation is that the eruption rate decreases as an eruption proceeds and is markedly smaller during dome growth than during explosive activity. We suggest that the transition from explosive activity to dome formation is due to gas loss through permeable conduit walls and is a direct consequence of the observed decrease in eruption rate. We derive the equations for the dynamics of a lava/gas mixture rising towards the surface. In the volcanic conduit, the gas content of lava is determined by two processes which act in opposite directions: pressure release leading to gas exsolution and expansion, and gas loss to the country rocks. The eruption rate depends on the pressure which obtains in the volcano chamber. This pressure steadily decreases with time as the chamber empties, implying a decrease of eruption rate. In turn, this decrease acts to increase the amount of gas lost to the country rocks and hence to reduce the gas content of the erupted material. This model therefore predicts that, with time, the eruption should in general undergo transitions from Plinian to Peleean conditions and then to dome formation. These transitions occur as bifurcations in the evolution of gas volume fraction with height in the conduit. We find that very small pressure fluctuations of the order of one bar lead to large changes of gas content at the vent. This sensitivity to tiny pressure changes provides an explanation for observed alternations between Plinian and Peleean phases, as well as between explosive phases and dome formation.
Joint work with Claude J. Allegrè.

10:40 am	Coffee Break	Reception Room EE/CS 3-176

11:10 am	Herbert E. Huppert University of Cambridge	Solidification and multicomponent convection within the earth

Abstract: Solidification processes occur principally in three different areas within the earth: as the liquid outer core cools it forms a solid inner core; the magma in a magma chamber crystallizes and may form plutons; magma flowing up a dyke may solidify against the dyke walls and the associated volcanic eruption may cease. the seminar will discuss some of the fundamental processes involved in all these areas. A major driving mechanism, which will be analysed in detail, is that upon solidification almost all multicomponent fluids release fluid of a different composition and density. This density difference can drive strong convective motions which can alter the form and rate of the solidification.

1:30 pm	Frank J. Spera UC Santa Barbara	Nonlinear interactions in magmatic and hydrothermal flow driven by two sources of buoyancy

Abstract. In the natural convective flow of both magma and hydrothermal fluids in the crust of the Earth, two sources of buoyancy are generally present (thermal and chemical buoyancy). Because chemical diffusion is generally much slower than the conductive transport of heat, these systems are classic examples of multiply-diffusive convection. Furthermore, due to phase change and the constraints implied by local thermodynamic equilibrium, buoyancy sources may be local and complex in both time and space.

The dynamics of mixing of an initially chemically stratified system (brine-fresh water) or (rhyolitic-basaltic melt) has been studied as a function of Ra, R_ρ and Le for viscous fluids and for porous media flows. Video animations illustrating these sometimes chaotic flows will be presented in an effort to clarify underlying physical mechanisms. Finally, some results from a recent multiphase model (i.e. convection plus solidification) relevant to a simple binary eutectic system will be shown. The latter model is a continuum one with specific accounting for the relative motion between viscous fluid and crystalline solid in the two-phase mushy region, for latent heat effects, for chemical diffusion in the melt phase and for inertial effects (finite Pr). Complex C-field sometimes develop in these flows, this suggests that geologic flows may be intrinsically unsteady.
Joint work with Curtis Oldenburg and Nina Rosenberg.

2:20 pm	David J. Stevenson Caltech	Aspects of the dynamics in two-phase media

Abstract: A large fraction of the Earth is either solid nor liquid but a combination of these phases. I will concentrate on partial melts, the precursor to all igneous activity. After a brief introduction to the underlying theory and a summary of the properties of magmons (non-linear solitary waves) I will shift to recent work concerning the possible instability of partial melts under shear, especially the fascinating and non-linear phenomenon of the possible development of a dendritic drainage network as the origin of macrosegregation.

3:10 pm	Coffee Break	Reception Room EE/CS 3-176
3:30 pm	Grae Worster Northwestern University	Solidification of magma chambers
4:20 pm	Reception	A reception for workshop participants, and sponsored by the University of Minnesota Geology and Geophysics Department, will be held in Pillsbury Hall ·

Thursday, June 14

Chaotic Convection in Spherical Systems and Geodynamo

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176
9:30 am	Pascale Chossat U. of Nice	Bifurcation and dynamics in spherically invariant systems

Abstract: Substantial progress in the study of spherically symmetric systems has recently been made in a joint work of Lauterbach, Melbourne and myself, thanks to the development of symmetry-breaking bifurcation theory. Initiated by Busse in the early 70's and developed by several contributors since then, the bifurcation analysis, when the critical spherical modes span a $2\ell+1$ dimensional irreducible representation space with $\ell < 5$, is "almost" fully understood. The case $\ell = 5$, i.e., dimension 11, is also understood to a great extent. In this case several new solutions have been found, including time-periodic solutions (rotating waves with low frequency) which bifurcate from the trivial equilibrium and can be asymptotically stable. When a mode interaction between spherical harmonics is assumed, more complicated and quite fascinating dynamics have been observed and studied by Armbruster and myself. The mode interaction $\ell = 1, 2$ already shows a remarkable behavior, characterized by the successive exploration of various types of equilibria (or limit cycles) and following an intermittent-like dynamics. Such a behavior was already noticed in 1986 by Friedrich and Haken in a numerical investigation of the system resulting from a center manifold reduction applied to the Bénard problem in a self-gravitating spherical shell, when the spherical modes with $\ell = 1$ and 2 are both excited at the onset of convection. This dynamics is related to the presence of heteroclinic cycles connecting equilibria belonging or not to the same group orbit of solutions. These invariant sets share the property of being "robust" under small perturbations which keep the system spherically invariant. The dynamics driven by some of these objects is very reminiscent of the Earth's magnetic field behavior in geological time (pole reversals). I will present an overview of these results and of the group-theoretic methods which have been employed. My hope is to show that geophysical problems can be very stimulating for the mathematicians, whose partial answers may lead in return to interesting questions for the geophysicists...

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Phillippe Machetel French Space Agency of Toulouse	Influences of chaotic mantle convection on thermal anomalies
2:00 pm	Gary A. Glatzmaier Los Alamos National Lab.	Three-dimensional numerical simulations of chaotic convection in the Earth's mantle

Abstract: Three-dimensional numerical simulations of highly viscous thermal convection in a spherical fluid shell are used to try to understand the basic properties of convection in the Earth's mantle. The anelastic approximation filters out sound waves while accounting for a density stratification. All dependent variables are expanded in spherical harmonics to describe their latitudinal and longitudinal structures and in Chebyshev polynomials to describe their radial structures. A semi-implicit time integration scheme that uses a spectral transform method to compute the nonlinear terms evolves the time-dependent solution. Two cases are presented. One is totally heated from within the model mantle and has a Rayleigh number of 120,000 It initially has a tetrahedral spatial pattern that is periodic in time. After several periods this spatial and temporal pattern evolves into a chaotic time-dependent structure. The second case is 80% heated from within the mantle and 20% heated from below and has a Rayleigh number of 1,600,000. This case, which is more representative of the Earth's mantle, is strongly chaotic and characterized by long narrow downflows near the outer boundary and cylindrical upflows near the inner boundary. 16 mm. movies of both cases are shown.

3:00 pm	F.H. Busse University of Bayreuth	Theory of the geodynamo and the problem of core-mantle coupling

Abstract: The possibilities for numerical investigations of the dynamo process in rotating spherical shells will be discussed with emphasis on physically feasible self-consistent models. The recent progress of Zhang and Busse (1987, 1988, 1989, 1990) will be reviewed and new developments will be described. Attention will be focussed on the problem of core-mantle coupling in connection with the dynamo process in the presence of lateral variations of the conductivity in the lowermost mantle. Provided the spatially varying component of the conductivity is sufficient large, standing and drifting components of the non-axisymmetric part of the magnetic field can be separated. Possible relationships to observations of secular variation and to decade changes in the length of the day will be discussed.

4:00 pm	Paul H. Roberts UCLA	Magnetoconvection patterns in rotating convection zones

Abstract: In addition to the well-known granulation and supergranulation observed on the solar photosphere, a third scale of motion has been postulated in the solar convection zone (="SCZ"): that of the so-called "giant cells". It is usually supposed that these span the entire thickness of the SCZ, and stretch from pole to pole in a sequence of elongated cells, forming a "cartridge-belt" or "banana cell" pattern round the Sun. Despite observational efforts, conclusive verification of the existence of giant cells is still lacking. Ribes and others have been led, from an analysis of sunspot motion, to believe that convective motions near the solar surface form a pattern that is the antithesis of the cartridge belt: a system of "toroidal" or "doughnut" cells, with edges parallel to the lines of solar latitude. Jones, Galloway and Roberts have recently tried to meet the resulting theoretical challenge.

A significant parameter of rotating magnetoconvection is the Elsasser number, $\Lambda = \sigma B^2/2\Omega\rho$, where B is the (predominantly zonal) magnetic field, Ω is the angular velocity, ρ is the density and σ is the (turbulent) conductivity. Intuitively, one expects that, when $\Lambda \ll 1$, Coriolis forces dominate Lorentz forces and, because of the Proudman-Taylor theorem, cells will be elongated along the axis of rotation in cartridge-belt style; when $\Lambda \gg 1$, the magnetic field is decisive and the convective cells align themselves with B in toroidal style. Because of the large variation of ρ across the SCZ, Λ is plausibly small at depth, but large near the solar surface.

Jones, Galloway and Roberts have initially aimed at determining the preferred pattern of convection in an apparently simple system intended to mimic regions near the solar equator. a plane horizontal layer of compressible conducting fluid is rotating abour a horizontal axis perpendicular to an ambient uniform horizontal magnetic field. Jones, Roberts and Galloway (1990) analysed the linear stability problem for the onset of convection, and demonstrated that the convection was necessarily time-dependent, a result that held for all Λ, even the non-magnetic case $\Lambda = 0$. Apart from this interesting difference, the model behaved much the same as the corresponding incompressible (Boussinesq) model, for which convection at onset is direct (i.e. time independent). In particular, even for large variations in the local value of Λ across the SCZ, the convection pattern is the same at all depths, and shows no sign of becoming toroidal. To simulate the large superadiabatic gradient in the upper convection zone, we also examined a two-zone model in which the

Rayleigh number, R, in the upper zone is ten times that in the lower zone. Two kinds of convective modes were discovered, one highly concentrated in the upper zone, and one predominant in the lower zone. The latter tends toward the banana cells; the former to the doughnuts.

Jones and Roberts (1991) studied the one-zone model (modified by vertical side walls parallel to the applied B) at finite amplitudes, and showed that the Lorentz force created a large "geostrophic" flow parallel to B and a function of height only. In certain circumstances (stress-free side walls) increase of R leads to symmetry-breaking. One mode is concentrated near the surface and moves in one direction; the other is concentrated near the base of the convection zone and moves in the opposite direction. The unfolding of this symmetry breaking through the action of compressibility has been investigated. Some conjectures about the relationship of these modes to the Ribes observations will be made.

6:00 pm	Workshop Dinner	Peking Garden

Dinner is arranged for the Peking Garden located at 2324 University Ave. S.E. (across the street from the Days Inn Hotel). Phone 623-3989. A variety of Chinese food types will be served. A set price of $10.50 per person includes appetizer, fried rice, entrees and tea. More details will be supplied during the Workshop.

Friday, June 15

The talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176
9:30 am	Donald Turcotte Cornell University	On the route to chaos in the crust and mantle
10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Stephen Morris UC Berkeley	Rheological control of solid-state transformations occurring by nucleation and growth

Abstract: A solid transforming by nucleation and growth consists of grains of new phase growing in a matrix of parent phase. The grain radius is seen to increase by four or five orders of magnitude as neighbouring grains grow and merge. It is argued here that growth therefore involves flow in the matrix unless the two phases have very nearly the same density. What follows is a theoretical study of the coupling of flow and growth-rate when the parent and product phases have the same composition. The standard metallurgical treatments of this problem assume growth is controlled completely by interfacial kinetics. The object of the present work is to show why the coupling of flow and growth-rate is important and to show how it can be observed in experiments.

The coupling of flow and growth-rate is studied initially for an isolated spherical grain by taking the interfacial kinetics to be infinitely fast. The timescale for growth is then determined by the rheology of the matrix and by the amount ($P - P'$) by which the applied pressure P exceeds the equilibrium pressure P', i.e., the pressure P' at which the two phases are in equilibrium across a plane interface. Detailed analysis shows that rheologically-controlled growth has a characteristic signature: when the excess pressure ($P - P'$) is independent of time, the volume of an isolated spherical grain grows exponentially with time. This result is general and holds for any matrix in which the deviatoric stress depends on the strain-history and not simply on the instantaneous strain.(For example, it applies when the deviatoric stress is proportional to the strain–rate.)

By contrast, previous studies of kinetic control have shown the volume of an isolated spherical grain to grow algebraically with time. It should therefore be possible to distinguish the two types of control in high-pressure experiments. An unambiguous test is possible by experiments involving single grains, so that the nucleation-rate is not a factor in interpreting measurements of the volume fraction.

Recent experiments by Rubie et al(1990) are compatible with the existence of rheological control, but the results are slightly ambiguous: the authors inferred that only a single grain was present, but were not sure. This work is motivated by a problem in geophysics. The pressure in the earth is nearly hydrostatic, and phase transitions therefore occur on level surfaces if the temperature is horizontally-uniform and the transition is in thermodynamic equilibrium. However the conditions for thermodynamic equilibrium are poorly understood. The essential problem is one of scaling: for application to the mantle, measurements taken in the laboratory must be extrapolated to dilatation-rates 10-12 orders of magnitude slower. If kinetics alone control the growth, this extrapolation leads to the well-known conclusion that significant vertical deflexions of the transition-layer are unlikely at the high temperatures typical of the deep mantle.

By contrast, it is shown here that the existence of rheological control means that laboratory experiments are compatible with significant vertical deflexions of the transition-layer if the strain-rate in the matrix depends strongly on the deviatoric stress. The problem is analysed for two particular choices of matrix. The first example is a power-law matrix in which the strain-rate varies as the n-th power of the deviatoric stress. It is shown that if the matrix is a linear solid(i.e. $n = 1$), rheological control will cause no major deflexion of the transition-layer. In contrast, major deflexions are possible if the strain-rate depends strongly on the deviatoric stress(i.e., $n >> 1$). This behaviour is clarified by the second example which studies the limiting case of an elastic, perfectly-plastic solid with yield stress $2m$ and elastic rigidity G. This example allows us to find the additional dissipation produced if mantle convection occurs through the transition-layer. The volume-integrated caused by phase changes is found to exceed that caused by deformation outside the transition-layer if the yield stress of the matrix satisfies $2m > G/3000$. (The corresponding excess pressure is about 0.2 GPa.)

The additional dissipation may have two effects on the large-scale flow. First, it reduces the turnover speed of the cell and is therefore likely to destabilise the horizontal boundary-layers, and enhance mixing. Secondly, layering may result if sufficient dissipation is added.

2:00 pm Alain Vincent — The spatial structure and statistical properties of homogeneous turbulence
C.E.R.F.A.C.S., Toulouse

This talk is cosponsored by the Army High Performance Computing Research Center (AHPCRC).

Abstract: A direct numerical simulation is used to obtain a statistically stationary three-dimensional homogeneous and isotropic turbulent field at a Reynolds number around 1000 (R_λ around 150). The energy spectrum displays an inertial subrange. The velocity derivative distribution, found to be strongly non-Gaussian, is found to be close to but not exponential. The n-th order moments of this distribution, as well as the velocity structure functions, do not scale with n, as predicted by intermittency models. Visualization of the flow structures confirms directly the previous finding that the vorticity is organized in very elongated thin tubes. the width of these tubes is of the order of a few dissipation scales, while their overall length can assume the global scale of the flow.

3:00 pm Akerman Hall 130D — Tour of Dan Joseph's laboratory

We will show experiments on water lubricated pipelining with bamboo waves and corkscrew waves, two dimensional cusped interfaces which violate Laplace's law, rollers, drafting, kissing and tumbling of fluidized particles, non linear stabilization of fingering instabilities in porous media, drag reduction using riblets. The tour probably will last 30 or 40 minutes.

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3:30 pm A. Vanderbauwhede — Periodic solutions in reversible systems
University of Ghent

Abstract. Reversible systems are systems of ode's such that if $x(t)$ is a solution, then also $R\,x(-t)$ is a solution, where R is a linear involution ($R^2 = I$). Assuming that the eigenvalues $+1$ and -1 of R have the same multiplicity symmetric periodic orbits will generically appear in one parameter families. We show how such families originate from equilibria and disappear in homoclinic orbits. Moreover, in certain regions of phase space the set of symmetric periodic orbits can show a cascade of branchings, with solutions along or

branching family being subharmonic to the solution along the primary branch. We describe these branchings and give a method to study them.

This SPECIAL LECTURE will be held in Vincent Hall 570

IMA Summer Program

RADAR AND SONAR

June 18 - June 29, 1990

Organizing Committee: Alberto Grunbaum (chairman), Marvin Bernfeld
Richard E. Blahut, Richard Tolimieri

Most of the program talks will be held in Conference Hall 3-180 on the entry floor of the new Electrical Engineering/Computer Science Building. This building is located on the corner of Washington Avenue and Union Street, a block from the IMA Main Office. The conference hall is on the Ethernet and has a projection system for display of computer output.

Week 1, June 18–June 22, 1990

TUTORIAL

Lecturers: Richard E. Blahut, Willard Miller, Jr. and C.H. Wilcox

The first week will be run as a summer school. There will be three minicourses, each consisting of five-hours lectures. Lecture notes prepared by the lecturers will be distributed to students and participants. With the idea of an audience consisting mainly of mathematicians and engineers, the tutorial topics will be one on mathematics, one on the physical aspects of scattering, and one on the engineering modelling and processing of the phenomena under consideration.

A great effort will be made to insure that this week will be devoted to help people cover two out of the three short courses in detail: we anticipate that a mathematician will need to spend more time and effort in the engineering and physics components, and a corresponding distribution of effort will be encouraged for engineers and physicists. We will make sure that time is allowed for private study. We will also arrange for discussion sessions where people with different backgrounds will hopefully help each other, and learn in the process a bit about each others language. We consider this last point one of the main goals of this effort.

Minicourse 1
lecturer: Willard Miller,Jr.

TOPICS IN HARMONIC ANALYSIS WITH APPLICATIONS TO RADAR AND SONAR

Abstract: This minicourse is an introduction to basic concepts and tools in group representation theory, both commutative and noncommutative, that are fundamental for the analysis of radar and sonar imaging. Several symmetry groups of physical interest will be studied (circle, line, rotation, $ax+b$, Heisenberg, etc.) together with their associated transforms and representation theories (DFT, Fourier transform, expansions in spherical harmonics, wavelets, etc.). Through the unifying concepts of group representation theory, familiar tools for commutative groups, such as the Fourier transform on the line, extend to transforms for the noncommutative groups which arise in radar-sonar.

The insight and results obtained will be related directly to objects of interest in radar-sonar, such as the ambiguity function. The material will be presented with many examples and should be easily comprehensible by engineers and physicists, as well as mathematicians.

Minicourse 2
lecturer: C.H. Wilcox

SONAR AND RADAR ECHO STRUCTURE

Abstract: The structure of pulse mode sonar and radar echoes is derived from the underlying field equations of fluid dynamics and electromagnetics, respectively. The scattering object Γ is assumed to lie in the far field of both the transmitter and the receiver. In this approximation, the sonar or radar pulse mode signals are shown to be represented by plane waves $s(x \cdot \theta_0 - t)$ at all points x near Γ and times $t \in R$. In the derivation of this result the signal speed is normalized to unity and θ_0 denotes a unit vector which is directed from the transmitter toward Γ. For a stationary scatterer Γ the echoes are also represented by plane waves $e(x \cdot \theta - t, \theta, \theta_0)$ at all points x near the receiver, where θ is a unit vector which is directed from Γ toward the receiver. The principal result of these lectures is the relation

$$e(\tau,\theta,\theta_0) = Re\left\{\int_0^\infty e^{i\tau\omega} T(\omega\theta,\omega\theta_0)\hat{s}(\omega)d\omega\right\}$$

where $\hat{s}(\omega)$ is the Fourier transform of $s(\tau)$ and $T(\omega\theta,\omega\theta_0)$ is the scattering amplitude for Γ. Thus $T(\omega\theta,\omega\theta_0)$ is the amplitude of the scattered field in the direction θ due to the scattering by Γ of a plane wave $e^{i\omega\theta_0 \cdot x}$ with frequency ω and propagation direction θ_0. For scatterers Γ that move with velocity v such that $|v| < 1$ it is shown that the echo waveform is given by

$$e(\tau,\theta,\theta_0) \doteq \frac{\gamma}{\gamma_0} Re\left\{\int_0^\infty e^{i\tau\omega} T(\omega\gamma\theta',\omega\gamma\theta_0')\hat{s}(\frac{\gamma}{\gamma_0}\omega)d\omega\right\},$$

where

$$\gamma = \frac{1 - v \cdot \theta}{\sqrt{1 - v^2}}, \quad \gamma_0 = \frac{1 - v \cdot \theta_0}{\sqrt{1 - v^2}}$$

and θ', θ_0' are related to θ, θ_0 by a Lorentz transformation based on v. Finally, it is known that the high frequency limit

$$\lim_{\omega \to \infty} T(\omega\theta,\omega\theta_0) = T^\infty(\theta,\theta_0)$$

exists. Hence if $\hat{s}(\omega)$ is concentrated in a high frequency band where $T(\omega\theta,\omega\theta_0)$ is essentially constant then one has the approximation

$$e(\tau,\theta,\theta_0) = T^\infty(\theta',\theta_0')s(\frac{\gamma_0}{\gamma}\tau).$$

Minicourse 3
lecturer: Richard E. Blahut

THEORY OF REMOTE SURVEILLANCE ALGORITHMS

Abstract. Algorithms for remote surveillance imaging have been developed independently in many fields including radar, sonar, medical imaging, and radio astronomy. Recently, it has become apparent that an underlying theory of remote surveillance could be developed. This emerging unified theory may suggest new directions for future developments.

This course will develop, from the engineer's point of view the two-dimensional Fourier transform, the ambiguity function, the Radon transform, and the projection-slice theorem. The course will explain how these topics deal with the imaging problem by discussing how they relate to doppler frequency shifts, synthetic aperture radar, and tomographic reconstruction of images. The course will be organized in a way to integrate the vocabulary and methods of the fields of radar, sonar, tomography, radio astronomy, and related fields.

Monday, June 18

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:00 am	Registration and coffee	Reception Room EE/CS 3-176

9:30 am **Willard Miller,Jr.** Harmonic analysis with applications to radar, I
IMA

Abstract: The Doppler effect: wideband and narrow-band ambiguity functions. A group theory primer: orthogonality relations for finite group representations. Linear Lie groups.

10:30 am **Coffee Break** Reception Room EE/CS 3-176

11:00 am **Calvin H. Wilcox** Sonar and radar echo structure, I
University of Utah

Abstract: Physical principles of acoustics. Sonar pulses with prescribed sources. Sonar pulses with prescribed radiaiton patters. the structure of CW (=Continuous Wave) mode sonar echoes. The CW mode scattering amplitude.

2:00 pm **Richard E. Blahut** Theory of remote surveillance algorithms, I
IBM

Abstract: Signals in One and Two Dimensions. Pulse Trains. Dirichlet Functions. Pulse Shape Parameters. Fourier Transforms. Rectangular and Hexagonal Sampling. Projection-Slice Theorem. Radon Transform. X-ray Transform. Inverse Radon Transform.

4:00 pm **Vincent Hall 502** IMA Tea (and more!)
(The IMA Lounge)

Tuesday, June 19

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am **Coffee break** Reception Room EE/CS 3-176

9:30 am **Willard Miller,Jr.** Harmonic analysis with applications to radar, II
IMA

Abstract: Representation theory for infinite groups: orthogonality relations for compact Lie groups, the rotation group and spherical harmonics, Fourier transforms and their relation to Fourier series. Representations of the Heisenberg group: the Schrödinger representation, orthogonality of radar cross ambiguity functions, the Heisenberg commutation relations and the Bargmann-Segal Hilbert space.

10:30 am **Coffee Break** Reception Room EE/CS 3-176

11:00 am **Calvin H. Wilcox** Sonar and radar echo structure, II
University of Utah

Abstract: The structure of pulse mode sonar echoes from stationary scatterers. Sonar echoes in the far field. Role of the scattering amplitude. Echoes of high frequency pulses.

2:00 pm **Richard E. Blahut** Theory of remote surveillance algorithms, II
IBM

Abstract: Ambiguity Functions. Properties. Shape, Resolution and Ambiguity. Ambiguity Function of Pulse Trains. Chirp Pulses. Uncertainty Ellipse. Cross-Ambiguity Function. Computation of Ambiguity Functions.

Wednesday, June 20

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am **Coffee Break** Reception Room EE/CS 3-176

9:30 am	**Willard Miller,Jr.** IMA	Harmonic analysis with applications to radar, III

Abstract: More representations of the Heisenberg group: the lattice representation, functions of positive type. Representations of the affine group: the wideband cross ambiguity functions, decomposition of the regular representation.

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Calvin H. Wilcox University of Utah	Sonar and radar echo structure, III

Abstract: Sonar pulse scattering from moving objects. Use of the Lorentz transformation. Structure of the sonar echo wave form. Doppler shift and pulse distortion. Echoes of high frequency pulses.

2:00 pm	Richard E. Blahut IBM	Theory of remote surveillance algorithms, III

Abstract: Antenna Systems. Antenna Aperture and Pattern. Antenna Gain. Rectangular and Hexagonal arrays. Phased arrays. Interferometry. The Radar Range Equation, Crystallography. Indirect and Direct Methods.

Thursday, June 21

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176
9:30 am	Willard Miller,Jr. IMA	Harmonic analysis with applications to radar, IV

Abstract: Weyl-Heisenberg frames: the Weil-Brezin-Zak transform, windowed transforms and ambiguity functions, frames. Affine frames and wavelets.

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Calvin H. Wilcox University of Utah	Sonar and radar echo structure, IV

Abstract: Physical principles of electromagnetic theory. Radar pulses with prescribed sources. Radar pulses with prescribed radiation patterns. The structure of CW mode radar echoes. The CW mode matrix scattering amplitude.

2:00 pm	Richard E. Blahut IBM	Theory of remote surveillance algorithms, IV

Abstract: Radar Systems. Doppler and Delay. Radar Cross Section, Radar Imaging Systems, The Imaging Equation, Synthetic Aperture Imaging, swath and Spotlight. Bistatic Radar. Radar Astronomy. Interferometry. Detection Threshold. Probability of Detection and False Alarm. Clutter. Moving Target Detection. Cramer-Rao Bounds.

Friday, June 22

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

9:30 am **Willard Miller,Jr.** Harmonic analysis with applications to radar, V
IMA

Abstract: The Schrödinger group: automorphisms of the Heisenberg group, Theta functions and the lattice Hilbert space.

10:30 am **Coffee Break** Reception Room EE/CS 3-176

11:00 am **Calvin H. Wilcox** Sonar and radar echo structure, V
University of Utah

Abstract: The structure of pulse mode radar echoes from stationary scatterers. Radar echoes in the far field. Role of the scattering amplitude. Radar pulse scattering from moving objects. Use of the Lorentz transformation. Structure of the radar echo wave form.

2:00 pm **Richard E. Blahut** Theory of remote surveillance algorithms, V
IBM

Abstract: **Image Reconstruction and Passive Systems.** Tomography. The Radon Transform. Radar Tomography. Phase Contrast Imaging. Radio Astronomy. Passive Detection.

Week 2, June 25–June 29, 1990

RESEARCH PROBLEMS

Scientists from industry, government agencies and universities who are working on problems in Radar or Sonar will present research problems. We expect that a number of new problems and solutions will be generated during the program, and the schedule will remain flexible to allow for last minute changes. During this week, in addition to the audience of the first week, there will be other invited participants (mostly from universities) whose research is connected to Radar and Sonar.

Monday, June 25

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:00 am **Registration and coffee** Reception Room EE/CS 3-176

9:30 am **Marvin Bernfeld** On the alternatives for imaging rotational targets
Raytheon

Abstract: The point-to-point variations in microwave reflectivity (or point reflectivity) of rigid targets normally renders topographical discriminants that are useful in recognizing the different classes. The task of constructing a point reflectivity image, based on backscatter radar measurements, is a problem in inverse electromagnetic scattering and the subject of this paper. When an apparent rotation is introduced into the radar-target model, the reconstruction procedure that is usually specified involves a synthetic aperture radar (SAR) to enhance the resolution of crossrange target features.

In classical SAR systems, the backscattered signals are stored in memory on a rectangular grid and then processed to provide a representation of the desired image over range and Doppler coordinates. This rectangular processing format, however, imposes a severe restriction on the signal processing aperture since the time span that the backscatter can be effectively integrated is limited because of range migration and continuously diminishing Doppler coherence. As a result, the crossrange resolution and the processing gain are often less than desired when classical SAR systems are employed for imaging rotational targets.

The limitation of the classical SAR systems has led to the invention of two additional SAR solutions. One of these has been called CHIRP Doppler Radar and it is currently being evaluated. By employing parallel tomographic measurements involving multiple ridge-like ambiguity functions, which are characteristic of different linear FM slopes, faster measurements are theoretically possible. Therefore, the migration of scatterers through resolution cells, which limits the effective coherent integration of backscatter in the classical SAR systems, can be alleviated. Theoretically, when it is developed, this radar will provide enhanced range-Doppler images compared to the classical SAR systems.

In the second of these solutions, the backscattered signals returned from individual linear FM pulses are stored in polar format after appropriately being processed in a way that yields the radial profiles on the Fourier transform of the point reflectivity. The images are derived, subsequently, by computing the inverse Fourier transform.

The latter solution has already been described by several authors, drawing on an anology, in some cases, to tomographic mathematical methods. This paper also offers a description. The purpose is to provide the background for - it is believed - a new observation concerning the nature of the backscattered signals. Specifically, evidence of the CHIRP-Z transform is observed in the description of the backscattered signals. This is an important observation since it reveals a procedure for reconstructing point reflectivity without resorting to an approximation of backscattered signals that has previously been proposed.

10:00 am	Walter Schempp Universitat Siegeu, West Germany	Quantum holography

Abstract: The development of more powerful computers in recent years has been driven by a seemingly unending thirst for automation, control issues, information availability, and a yearning for new understanding of the self-organization principles of ourselves and our environment. The challenges of the future force us to create and study new concepts of adaptive information processing and to implement novel computer architecture based on synergetic principles.

Until now, the increased power has been driven largely by advancements in microelectronics, such as electronic switches (transistors) with higher switching speeds and integrated circuits (ICs) with increased levels of integration. Although the advancements in the IC hardwiring and packaging functions have been significant, their prospect for continuing at the same steady rate are being dimmed by physical limitations associated with further miniaturization.

As a result, computer architects are turning to the design of parallel processors to continue the drive toward more powerful computers. The system of interconnects by which the processing elements can share information among themselves is one of the most important characteristics of any parallel computer. The massively parallel organization principles which distinguish analog neural networks from the small scale interconnection architectures of standard digital computer hardware are some of the main reasons for the largely emerging interest in neurocomputers.

Until recently optical computing was looked upon as an alternative technology for performing an old task. Now, a paradigm shift is coming about as a result of the realization that optical computers are fundamentally different from, and in many senses superior to, any electronic computer. Certain optical neurocomputer architectures which are based on the holographic image encoding and decoding procedures are the only available ones that are intrinsically quantum mechanical processors.

The survey lecture presents an introduction to optical and optoelectronic implementations of analog and digital neurocomputer architectures. It deals with the mathematical modelling by the Kirillov quantization procedure of quantum parallelism, according to which different alternative at the quantum level are allowed to coexist in quantum linear superposition. Since quantum effects can occur over distances of kilometers or even light years, the Kirillov quantization allows to study, as a particularly important example, the optical processing of synthetic aperture radar (SAR) data. The quantum mechanical computer approach gives also rise to amacronic structures with applications in imaging systems with processing right at the focal plane similar to the amacrine clustered processing layers in front of the retina.

References

W. Schempp: Harmonic analysis on the Heisenberg nilpotent Lie group, with applications to signal theory. Pitman Research Notes in Math., Vol. 147, Longman Scientific and Technical, Harlow, Essex, and J. Wiley & Sons, New York 1986

W. Schempp: Neurocomputer architectures. Results in Math. 16, 345-382 (1989)

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	P. Moulin Washington University	A sieve-constrained maximum-likelihood method for target imaging

Abstract: We consider rotating targets having a diffuse reflectance-process. The image to be formed is the two-dimensional power spectrum, called the scattering function, of the reflectance process. Additive receiver-noise is incorporated in the model as well. Statistical estimation theory is used to form the image.

Under this model, the estimation approach is derived by application of fundamental principles of statistical inference. The solution to the stochastic inverse-problem is obtained by application of the principle of maximum likelihood. A fundamental problem that arises is that the parameter space is infinite-dimensional whereas the dataset is finite, so the inverse problem is ill-posed, and regularization of the estimates is needed. We investigate Grenander's method of sieves to address this issue and present two main results. The first is a criterion for selecting the mesh size of the sieve, which determines the rate of convergence of the estimates. This criterion is based on information concepts for measuring convergence in the parameter set and is applicable to a wide class of estimation problems.

In the second part of our study, we recommend a method of sieves based upon a spline representation for the image. Images can be produced at different resolution levels consistent with the dataset and the statistical model. They offer a potential for significant improvements over images obtained via conventional radar techniques. Finally, we propose tractable estimation algorithms for practical applications.
Joint work with J. A. O'Sullivan, and D. L. Snyder.

11:30 am Robert Shore — Some problems in obtaining and using
Hanscom Air Force Base — incremental diffraction coefficients

Abstract: Incremental difraction coefficients provide an important technique for enhancing the accuracy of the physical optics (PO) approximation. The PO approximation, widely used for calculating scattering from perfectly electrically conducting bodies, consists of approximating the actual currents at a surface point, by those induced on an infinite perfectly conducting plane tangent to the body at the point. The PO approximation works well away from shadow boundaries provided that the radii of curvature of the reflecting surface are large compared with the wavelength, and that there are no surface discontinuties. When surface discontinuties or shadow boundaries are present, the accuracy of the scattered fields obtained via the PO approximation can be significantly improved if the fields radiated by the nonuniform currents (the difference between the actual and PO currents) can be closely approximated and included in the scattering calculations. The far-field contribution from the nonuniform current of a differential element of an edge or shadow boundary – the incremental diffraction coefficient (IDC) – can be obtained by regarding the edge or shadow boundary locally as the edge or shadow boundary of a canonical scatterer (e.g., wedge, half-plane, cylinder) provided that an expression is available for the IDC of the canonical scatterer. The IDC can then be integrated along the edges or shadow boundaries to obtain the far field of the nonuniform currents. When IDC's can be found they provide a powerful technique for augmenting the accuracy of the fields calculated using the PO approximation. In contrast to other techniques commonly employed to account for scattering from edge discontinuties of perfectly conducting surfaces (e.g., GTD, PTD), the integration of IDC's along edge discontinuities yields corrections to PO fields that are valid in virtually all ranges of pattern angles, and so avoids having to employ several distinct formulations, each valid in a particular range.

In this paper after a brief introduction to IDC's we first describe a recent and highly useful method for obtaining IDC's for an important class of canonical scatterers. If a closed form expression can be supplied for the scattered far field of a two-dimensional planar scatterer, the IDC's at arbitrary angles of incidence and scattering can be found immediately through direct substitution in general expressions. No integration, differentiation, or specific knowledge of the currents is required. The direct substitution method for determining IDC's is, however, limited to perfectly conducting scatterers that consist of planar surfaces, such as the wedge, the slit in an infinite plane, the strip, parallel or skewed planes, polygonal cylinders, or any combination therof; and requires a closed-form expression (whether exact or approximate) for the two-dimensional scattered far field produced by the current on each different plane of the canonical scatterer.

We then demonstrate the utility of IDC's by presenting a few applications to scattering problems, showing the importance of the nonuniform current contribution to the scattered fields. Examples are shown for the calculation of reflector antenna patterns, and for the calculation of the field scattered by a perfectly conducting circular disk illuminated by a plane wave.

Finally, as an invitation to further work in this area, we draw attention to the importance of removing the restriction of the substitution method for obtaining IDC's to planar, perfectly conducting scatterers. It would

be of much utility if a simple method not involving current integration could be found for obtaining IDC's for a circular cylinder or a rounded wedge (parabolic cylinder), or for non-perfectly conducting scatterers. In addition, the attractiveness of using IDC's for calculating scattering from perfectly conducting scatterers with discontinuities that can be locally modeled by planar canonical scatterers would be considerably enhanced if a general purpose computer program could be developed for such scatterers that would circumvent the currently rather laborious procedure of transforming from the local coordinate system of the IDC's to the global coordinate system of the scatterer in order to integrate the IDC's.
Joint work with Arthur D. Yaghjian.

2:00 pm	Mireille F. Levy Rutherford Appleton Lab.	Parabolic equation models for assessment of propagation effects on radar performance

Abstract: Strong refractive index gradients in the troposphere are not uncommon, and have a noticeable effect on radar performance for propagation close to the horizontal. In anomalous propagation conditions, coverage diagrams are distorted, with regions of enhanced propagation and radar "holes". We review these effects, and describe an efficient numerical method based on the parabolic approximation of the wave equation, which allows the computation of the electromagnetic field for propagation in an inhomogeneous atmosphere over irregular terrain.

2:30 pm	F. Alberto Grunbaum UC Berkeley	Concentrating a scatterer and its scattering amplitude (or trying to beat Heisenberg)

Abstract: The scattering of a plane wave either by an object or by a potential leads to the notion of the "scattering amplitude". This is a function of the incoming direction, the outgoing direction and the wave number k..There is a complicated nonlinear relation between the shape of the object, or the potential, and this scattering amplitude.

This "scattering transform" enjoys many of the properties of the Fourier transform and in certain limiting cases (like very high frequency,or very weak scatterer) it reduces to it.

The plan is to discuss some carefully crafted exmaples that show that Heisenberg's injunction about simultaneous concentration in the physical and the frequency domain do not hold (universally) for this transform: for instance, one can design highly "concentrated" radial potentials whose backscattering amplitude is a concentrated function of the wave number k.

This is very much an open area. I plan to introduce the problem, show some pictures for the one and three dimensional problem, and suggest an experiment that hopefully someone will be willing to carry out.

The original motivation for this "unnatural question" comes from medical imaging using Magnetic Resonance. In that case the scattering problem is a one dimensional Zakharov-Shabat two component system, and one wants to design "ultrashort" radio frequency pulses that would give very high spatial resolution.

The construction of fairly concentrated objects whose scattering amplitude has some concentration properties has potential importance in several areas of imaging.

3:30 pm	Vincent Hall 502 (The IMA Lounge)	IMA Tea (and more!)

Tuesday, June 26

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee break	Reception Room EE/CS 3-176
9:30 am	Louis Auslander CUNY	Wavelets and Gabor bases, and their role in radar and sonar
10:00 am	Brett Borden NWC, China Lake, CA	Phase monopulse tracking and its relation to noncooperative target recognition

Abstract. We review the method of phase monopulse tracking and its associated "glint" problem. This problem was first examined more than 30 years ago but has yet to be successfully resolved. Nor shall WE attempt to solve it. Rather, we demonstrate how the very same data used for tracking can be used for target classification and recognition.

10:30 am	Coffee Break	Reception Room EE/CS 3-176

11:00 am	Daniel Goodfellow Honeywell, Everett, WA	Detection probabilities for partially correlated signal fluctuations

Abstract: This presentation develops a model for representing partially correlated signal fluctuations. Swerling's pioneering paper [1] observed the need for modelling this situation and noted that his "fully-correlated" and "uncorrelated" models merely bound this more realistic case. To date, however, virtually all significant papers in this area, with the exception of reference [4], have limited themselves to Swerling's original correlation models (zero or one). Furthermore, most of these papers have dealt only with signal fluctuation distributions which are members of the chi-square family which we have found too restrictive to fit recent empirical sonar measurement data.

The proposed model allows the calculation of partially correlated signal fluctuation statistics for a broad class of fluctuation distributions. This class includes all finite-variance SNR distributions with a probability density function which can be represented as the convolution of two densities or for which a monotonic invertible function of the SNR can be represented as the convolution of two densities. It contains all of the classical fluctuating and non-fluctuating signal results listed in references [1-3] as special cases. In particular, it provides a a convenient form for modelling partially-correlated Log-Normal signal fluctuations which was the primary motivation for this work. The principal discussion topic of interest centers around efficient numerical computation of the model equations.

References:

1) Marcum, J.I., and P. Swerling, "Studies of Target Detection of Pulsed Radar", IRE Transactions on Information Theory, Vol IT-6, April 1960.

2) Heidbreder, G.R., and R.L. Mitchell, "Detection Probabilities for Log-normally Distributed Signals", IEEE Transactions, Vol AES-3, No. 1, January 1967, pp 5-13.

3) Robertson, G.H., "Operating Characteristics for a Linear Detector of CW Signals in Narrow-Band Gaussian Noise", Bell System Technical Journal, April 1967, pp. 755-775.

4) Nutall, A.H., and E.S. Eby, "Signal-to-noise Ratio Requirements for Detection of Multiple Pulses Subject to Partially Correlated Fading with Chi-Squared Statistics of Various Degrees of Freedom", NUSC TR 7707, 2 June 1986.

11:30 am	Howard Resnikoff Aware Inc., Cambridge, MA	Relationships between Fourier analysis and compactly supported wavelet expansions
2:00 pm	José M. F. Moura Carnegie Mellon University	Performance evaluation in sonar multipath problems

Abstract: Positioning systems (active or passive) localize targets by maximizing in parameter space a generalized cross-ambiguity function. When the propagation medium is inhomogeneous, the received signal is actually a noisy superposition of filtered correlated versions of the transmitted signal (multipath). Traditionally, multipath is dealt with as a nuisance that degrades the receiver performance. However, by taking into account the propagation effects (so called matched field processing), one processes coherently the available replicas achieving performance enhancement. The talk explores what the (local) performance limits are when multipath is present and derives performance, bounds for localization that exhibit the tradeoff between temporal processing techniques (multiple paths) and spatial processing methods (multiple sensor arrays).

2:30 pm	Mos Kaveh University of Minnesota	Rethinking the formulation of signal-subspace direction-of-arrival estimators

Abstract. Certain functionals of two vectors are proposed as models for the formulation of signal subspace estimators of the directions of arrival of signals by an array of sensors. The two vectors are the projections of the array steering vector onto i) the subspace spanned by the noise and the least significant signal eigenvector and ii) the least significant signal eigenvector. It is shown that the now "classical" MUSIC and Minimum-Norm estimators are based on special cases of these functionals. It is further shown that the choice of the functional significantly affects estimator performance, with some providing resolution and mean-squared error thresholds similar to rooting techniques which are only applicable to linear uniform array models.

Wednesday, June 27

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176
9:30 am	Izador Gertner CUNY	The finite Zak transform
10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Harold Naparst Fidelity Management Co., Boston	The connection between wavelets and dense target radar imaging

Abstract: The method of "wavelets" refers to a decomposition of a function $e(t)$ into shifted and translated versions of an "analyzing wavelet" $s(t)$. If we regard $s(t)$ as the radar signal and $e(t)$ as the echo from a dense target environment D, then I have previously given a way to choose a set of signals so as to be able to reconstruct D from the echoes corresponding to those signals.

Now it seems that the "wavelet theory" is moving closer to the same goal, although the dense target application has not been discussed as such in wavelet literature. So far, however, the structure of the solutions are quite different. This is somewhat surprising, since at bottom is the same idea: Fourier Analysis on the Affine Group.

We discuss this problem and hope to stimulate a solution.

2:00 pm	Jorge P. Zubelli UC Berkeley	Image reconstruction of the interior of bodies that diffuse radiation

Abstract. We shall describe a nonintrusive procedure to reconstruct certain internal characteristics of objects that diffuse as well as attenuate radiation. Our method is based on a model where diffusion and scattering of the radiation particles play an important role. The paths of such particles are therefore convoluted, in contradistinction with the linear paths of X-ray tomography. The reconstruction problem under consideration is much harder than the traditional one and requires a substantially larger computational power. On the other hand, it has potential applications to a number of areas where X-ray tomography would not be suitable. We shall present a few reconstructions that were obtained via computer simulations and point out some interesting problems arising from the above mentioned approach. Some of these results are reported in a recent paper in Science by Singer, Grunbaum, Kohn and Zubelli.

2:30 pm	Gunter Meyer Georgia Tech.	The parabolic Fock theory for a convex dielectric scatterer

Abstract. This talk deals with a high frequency asymptotic method for representing surface fields near the shadow boundary of a convex dielectric scatterer. It will be shown that the parabolic approximation of Fock to the scaler Helmholtz equation follows from elementary singular perturbation expansions. Together with similar consideration for the Leontovich (impedance) boundary conditions this approach provides a closed form solution of the approximating boundary value problem in terms of the Fock-van der-Pol- Bremmer integral. The correct asymptotic limit of this integral will be established by standard residue and growth estimates.

Thursday, June 28

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am **Coffee Break** Reception Room EE/CS 3-176

9:30 am **Jeffrey C. Allen** Fast matrix-vector multiplication for image restoration
Naval Ocean System Center, San Diego

Abstract: The regularized pseudoinverse of the m by n point-spread matrix A is

$$\hat{A} = (A^H A + \beta^2 I)^{-1} A^H.$$

It is assumed that $m \geq n$. The expansion of the displaced difference of this regularized pseudoinverse in an SVD is

$$\hat{A} - Z_m \hat{A} Z_n^H = \sum_{k=1}^{\alpha_+} d_k p_k q_k^H$$

where Z_m and Z_n correspond to m by m and n by n downshift operators. This permits the representation of the regularized pseudoinverse as a sum of products of lower triangular m by n Toeplitz matrices times n by n upper triangular Toeplitz matrices determined by the factors in the SVD:

$$\hat{A} = \sum_{k=1}^{\alpha_+} L(d_k p_k) U(q_k^H)$$

The multiplication of a vector by a Toeplitz matrix can be performed quickly as a convolution via any of several fast transforms:
(a) The FFT
(b) The Winograd Prime Factor DFT
(c) The Fast Hartley Transform
(d) Number theoretic Transforms (Mersenne, etc.)
The lower triangular Toeplitz matrix has the form

$$L(x) = \begin{bmatrix} x_1 & 0 & 0 & 0 & \cdots & 0 \\ x_2 & x_1 & 0 & 0 & \cdots & 0 \\ x_3 & x_2 & x_1 & 0 & \cdots & 0 \\ x_4 & x_3 & x_2 & x_1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & 0 \\ x_n & x_{n-1} & x_{n-2} & x_{n-3} & \cdots & x_1 \\ \vdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ x_m & x_{m-1} & x_{m-2} & x_{m-3} & \cdots & x_{m-n+1} \end{bmatrix}.$$

We have shown that when the point spread matrix A is Toeplitz, the displacement rank $\alpha_+(\hat{A})$ is four or less. This permits the rapid successive application of the regularized pseudoinverse to many different vectors for
(1) Restoration when the point spread function is separable.
(2) Restoration of tomographic projections when the point spread function has rotational invariance.

Joint work with J.M Speiser and H.J. Whitehouse.

10:00 am Luise Schuetz Prediction of acousto elastic scattering and radiation
Naval Res. Lab., Washington, D.C.

Abstract. We consider the problem of predicting the scattering and radiation of acoustic fields by elastic structures in a parameter regime where the elastic behavior of the structure and the loading of the fluid must be considered as coupled effects. Such predictions have been made by a number of researchers using collocation-based approaches; however, these solutions have been limited to very low frequencies. Since high frequency approximations are not valid down to this frequency range, there is considerable interest in extending the integral equation based appraoches to higher frequencies. We describe the obstacles to such a development as well as recent advances.

10:30 am Coffee Break Reception Room EE/CS 3-176

11:00 am Craig Poling Sonar detection
Honeywell (USD)

Abstract: A detection problem arising in adaptive focused beam forming is presented. Partial progress toward the solution is discussed. Ideas and comments are solicited.

2:00 pm Richard Marino Laser radar imaging: Systems and techniques. I
Lincoln Laboratory, MIT

Abstract: This talk describes both system and data processing issues associated with laser radar in general and the FIREPOND laser radar in particular. After highlighting the major components of the FIREPOND facility, detailed predictions of laser radar signatures are described. These predictions include the effects of target speckle, LO shot noise, and the net system point spread response. We then describe the results of applying tomographic techniques to both predicted and experimentally obtained range resolved, Doppler resolved, and range-Doppler resolved signatures. The relative merits of these imaging techniques, along with waveform design issues, are discussed.

2:30 pm Kenneth Schultz Laser radar imaging: Systems and techniques. II
Lincoln Laboratory, MIT

Abstract: See the previous abstract.

3:00 pm Round Table Vincent Hall 502

There will be two parts to this (approximately) one hour informal discussion:

1) A roud table on present problems in industry.

2) Planning for possible future radar-sonar meetings.

Light refreshments will be served.

6:30 pm Radar-Sonar Dinner Details about the dinner will be announced
Grandma's Restaurant during the workshop

Friday, June 29

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am Coffee Break Reception Room EE/CS 3-176

9:30 am Peter Maass Wideband approximation and wavelet transform
Technische Universität Berlin

Abstract. Consider a signal ψ which is reflected by a (continuous or discrete) distribution of objects D. The echo e is given in the wideband approximation by

$$e(t) = \int\int D(x,y)\sqrt{y}\psi(y(t-x))dxdy \quad (1).$$

This equation can be expressed in terms of the wavelet transform L_ψ associated with the signal ψ, namely

$$e = cL_\psi^* D \quad (2).$$

Under certain restrictions on ψ the transform L_ψ^* is unitary and (2) is inverted - on $\overline{range(L_\psi)}$ - by L_ψ itself. Unfortunately the required properties for ψ are not met by any practical signal. In order to allow a large class of signals, e.g., $\psi \in \{\phi \mid \phi, \phi' \in L_2(\mathrm{R})\}$, the inversion formula has to be modified; $\tilde{D}$ denotes the projection of D onto $range(L_\psi)$:

$$\tilde{D} = \frac{d}{dx} L_{d\psi e}.$$

Incorporating the echos from a set of signals allows the reconstruction in $\cup_{i=1}^{n} range(L_{\psi_i})$. Fast algorithms are known for the computation of the wavelet transform.

Moreover other Radar features, e.g., matched filter, correlation function, ambiguity, can conveniently be interpretated and investigated in wavelet terminology.

10:00 am	Gary Mohnkern Naval Ocean System Center, San Diego	Problems in stationarity for large acoustic arrays

Abstract: As acoustic receiving arrays become larger, several problems in the minimum variance distortionless response (MVDR) algorithm for frequency domain adaptive beamforming become apparent. As the physical dimensions of arrays become larger, the length of the discrete Fourier Transform (DFT) must become longer to assure coherence for the increased delays encountered between sensors. At the same time, the number of DFTs required to obtain a full rank matrix increases with the number of sensors. For a filled line array, this seems to imply that the amount of data which must be accumulated to obtain an acceptable estimate of the noise field for MVDR increases as the square of the length of the array. The problem is exacerbated because in realistic noise fields adding more sensors increases the range of eigenvalues, decreasing the numerical stability of the cross-spectral density matrix. Furthermore, a longer array has more spatial resolution, so that smaller motions of interferences and targets become significant nonstationarities. All of these make stationarity of the noise field a major problem in designing processing for large arrays. Several potential solutions will be discussed.

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Norman L. Owsley NUSC, New London, CT	Sensor array signal processing: Wavenumber spectrum analysis or beamforming?

Abstract: There is a significant amount of current research activity in the application of modern, high resolution power spectrum estimation techniques to the problem of estimating the wavenumber spectrum for a spatially distributed array of sensors. The theme of this ongoing research equates the ability to resolve discrete sources in wavenumber with the primary measure of performance. Invariantly, the highly regarded high resolution parametric wavenumber estimators are based on a prior knowledge of the total number of sources which are present, i.e. the detection problem has already been solved and the remaining problem is to resolve the soruces. Typically, an algorithm such as the Akaike information criterion (AIC) (see Wax 1985, for example) is referenced as the "detection" procedure for the determination of the number of sources. This ad hoc two step detect-then-resolve procedure has at least two fundamental problems, namely, the treatment of partially correlated noise and the detection of moving sources which may be at the detection threshold. This paper illustrates these issues and suggests that an approach using wideband adaptive beamforming-then-detect is more appropriate than wavenumber parametric spectrum estimation.

11:30 am	Charles L. Weigel Honeywell (USD)	A problem: Estimating phase

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CURRENT IMA PARTICIPANTS

POSTDOCTORAL MEMBERS FOR 1989-90 PROGRAM YEAR

NAME	PREVIOUS/PRESENT INSTITUTION
H. Scott Dumas	SUNY, Albany
Mohamed Elbialy	University of Cincinnati
Michael S. Jolly	Princeton University
Maciej Krupa	University of Houston
Stephane Laederich	Boston University
Debra Lewis	Cornell University
Kening Lu	Georgia Institute of Technology
Mary Silber	UC, Berkeley
Matthew W. Stafford	Loyola University
Mary Lou Zeeman	MIT

LONG-TERM VISITORS IN RESIDENCE

One Month or Longer

Emmanuel Parzen	Texas A&M University	Jun 30 - Jul 28
V.A. Samaranayake	U. of Missouri, Rolla	Jun 30 - Jul 27
Taylan Alankus	SUNY Stonybrook	May 28 - Jun 28
Donald Aronson	University of Minnesota	
Boele L.J. Braaksma	University of Groningen	Dec 28 - Jul 15
Michel Chipot	U. de Metz	Jan 1 - Jun 15
Pascal Chossat	U. of Nice	May 13 - Jun 16
Shui-Nee Chow	Georgia Tech	Sep 15 - Jun 15
Nick Firoozye	Courant Institute	May 15 - Jun 15
Ciprian Foias	Indiana University	Apr 2 - Jun 15
Andrew Fowler	Oxford University	May 15 - Jun 15
Avner Friedman	University of Minnesota	
J. D. Gibbon	Imperial College	May 21 - Jun 21
Tepper Gill	Howard University	May 28 - Jun 30
Christophe Golé	University of Minnesota	Sep 7 - Jun 15
Leon Green	University of Minnesota	
Robert Gulliver	University of Minnesota	
M.A. Herrero	U. Complutense	Jun 25 - Jul 22
Harvey Keynes	University of Minnesota	
David Kinderlehrer	University of Minnesota	
Igor Kukavica	Indiana University	May 15 - Jun 15
Andrzej Lasota	Silesian U., Poland	Apr 2 - Jun 30
John Lorentz	University of Minnesota	
Sjoerd Verduyn Lunel	Georgia Institute of Technology	Mar 19 - Jun 15
Martine Marion	Ecole Centrale de Lyon	Nov 13 - Nov 17, Apr 1 - Jun 15
Larry Markus	University of Minnesota	
Richard McGehee	University of Minnesota	
Willard Miller	University of Minnesota	
G. Minea	Increst, Bucarest	May 25 - Jun 30
Richard Moeckel	University of Minnesota	
Hieu Nguyen	University of Minnesota	
Basil Nicolaenko	Arizona State University	Apr 8 - Jun 15
Peter Olver	University of Minnesota	
Victor Pliss	Leningrad State University	Dec 27 - Jun 30
W. Pritchard	Penn State University	May 20 - Jun 15
George R. Sell	University of Minnesota	

Pat Sethna	University of Minnesota	
Yasutaka Sibuya	University of Minnesota	
Carl Simon	University of Michigan	Dec 27 - Jun 15
Michael Smiley	Iowa State University	Jan 1 - Jun 15
Harlan Stech	University of Minnesota, Duluth	Nov 27 - Jun 15
Peter Szmolyan	Tech. U. Vienna	Sep 5 - Jun 30
Edriss Titi	Cornell/UC, Irvine	Apr 8 - June 15
Arie Vandenberg	Utrecht Stae University	May 4 - Jun 15
Alain Vincent	C.E.R.F.A.C.S., Toulouse	May 25 - Jun 25
David Yuen	University of Minnesota	

SHORT TERM DYNAMICAL SYSTEMS AND WORKSHOP VISITORS IN RESIDENCE

Don Anderson	Caltech	Jun 11 - Jun 15
Bruce Bayly	University of Arizona	May 29 - Jun 15
Roberto Benzi	U. Roma	Jun 4 - Jun 15
George Bergantz	University of Washington	Jun 10 - Jun 15
J. Bloxham	Harvard University	Jun 11 - Jun 15
Andreas G. Boudouvis	University of Minnesota	June 4 - June 15
Jack M. Brownstein	University of Minnesota	June 11 - June 15
F.H. Busse	U. Bayreuth	Jun 11 - Jun 15
Ulrich Christensen	Max-Planck Inst.	Jun 6 - Jun 20
E. Foufoula-Georgiou	University of Minnesota	June 4 - June 15
Susan Friedlander	University of Illinois, Chicago	Jun 3 - Jun 15
Gary Glatzmaier	Los Alamos Nat. Labs.	Jun 10 - Jun 15
David Gubbins	University of Leeds	Jun 10 - Jun 16
Michael Gurnis	University of Michigan	Jun 10 - Jun 15
Aaron Hagen	University of Minnesota	June 11 - June 15
Ulrich Hansen	U. zu Köln	Jun 11 - Jun 15
Xinyu He	U. of New South Wales	Jun 11 - Jun 15
Keith R. Helmlinger	University of Minnesota	June 11 - June 15
Herbert Huppert	University of Cambridge	Jun 11 - Jun 15
Claude Jaupart	U. Paris VII	Jun 11 - Jun 15
William Jones	Ohio State University	Jun 10 - Jun 16
Praveen Kumar	St. Anthony Falls Hydraulic Lab.	Jun 11 - Jun 15
Alison Leitch	University of Minnesota	Jun 11 - Jun 15
Song-sun Lin	National Chiao Tung U.	May 26 - Jun 16
Mian Liu	MSI	Jun 11 - Jun 15
Phillippe Machetel	French Space Center, Toulouse	Jun 11 - Jun 15
Andrei Malesky	Inst. of Physics, Moscow	Jun 11 - Jun 15
Victor P. Maslov	MIEM, USSR	May 29 - Jun 15
Robert P. Meyer	University of Wisconsin	Jun 11 - Jun 15
Robert F. Miller	University of Minnesota	Jun 11 - Jun 15
Steve Morris	UC Berkeley	Jun 11 - Jun 15
Brad Murray	University of Minnesota	Jun 4-8, Jun 11-15
J.O. Oriade	Univ. of Jos	Jun 3 - Jun 17
R. Peltier	University of Toronto	Jun 4 - Jun 15
Alan Pierce	Amoco Production Company	Jun 10 - Jun 16
Henry L. Pollak	UC Santa Barbara	Jun 11 - Jun 15
Y. Pomeau	U. Pierre et Marie Curie	May 29 - Jun 15
Yong-Joo Rhee	University of Minnesota	June 4 - June 15
Paul H. Roberts	UCLA	Jun 3 - Jun 15
John Rundle	Livermore Nat. Lab.	Jun 11 - Jun 15
James Rustad	University of Minnesota	Jun 11 - Jun 15

Jean-Claude Saut	Univ Paris-Sud	Jun 5 - Jun 25
Yan Song	University of Minnesota	June 11 - June 15
E.M. Sparrow	University of Minnesota	June 4 - June 16
Frank J. Spera	UC Santa Barbara	Jun 11 - Jun 15
David Stevenson	Caltech	Jun 12 - Jun 14
John Todoeschuck	Defence Res. Est. Pacific	Jun 9 - Jun 16
Donald Turcotte	Cornell University	Jun 12 - Jun 15
A. Vanderbauwhede	University of Ghent	May 23 - Jun 16
Peter Van Keken	Utrech State University	Jun 4 - Jun 15
Anthony Varghese	University of Minnesota	June 11 - June 15
M.M. Vishik	Inst. Physics of Earth	Jun 3 - Jun 15
Stuart Weinstein	Johns Hopkins University	Jun 11 - Jun 15
Robert Wells	Pennsylvania State University	May 28 - Jun 15
Steve Wiggins	Caltech	Jun 3 - Jun 15
Grae Worster	Northwestern University	Jun 11 - Jun 15
W. Zachary	Howard University	Jun 9-15, Jun 25-Jul 1

SHORT TERM RADAR-SONAR VISITORS IN RESIDENCE

Jeffrey Allen	Naval Ocean Sys. C., San Diego	Jun 28 - Jun 29
Louis Auslander	CUNY	Jun 24 - Jun 28
Marvin Bernfeld	Raytheon	Jun 18 - Jun 29
Richard E. Blahut	IBM	Jun 18 - Jun 22
Martin Blumlinger	Tech. U., Vienna	Jun 17 - Jun 29
Bret Borden	NWC, China Lake, CA	Jun 25 - Jun 26
Mikhail Brodsky	UC Berkeley	Jun 24 - Jun 29
Kevin Buckley	University of Minnesota	Jun 18 - Jun 29
Keith Costella	UNISYS	Jun 18 - Jun 29
Dave Garrett	UNISYS	Jun 18 - Jun 29
Izador Gertner	CUNY	Jun 17 - Jun 29
Daniel Goodfellow	Honeywell, Everett, WA	Jun 24 - Jun 29
Alberto Grunbaum	UC Berkeley	Jun 18 - Jun 29
Lijia Guo	University of Cincinnati	Jun 18 - Jun 25
Doris Hinestroza	University of Cincinnati	Jun 18 - Jun 25
Mostafa Kaveh	University of Minnesota	Jun 18 - Jun 29
Daniel M. Keenan	University of Virginia	Jun 18 - Jun 29
Fritz Keinart	Iowa State University	Jun 17 - Jun 22
Douglas Lake		Jun 18 - Jun 29
M.F. Levy	Rutherford Appleton Labs.	Jun 17 - Jun 29
Brian Loe	Iowa State University	Jun 16 - Jun 23
Charles Lutes	UNYSYS	Jun 18 - Jun 29
Peter Maass	Technische Universität, Berlin	Jun 13 - Jun 29
Richard Marino	Lincoln Laboratory, MIT	Jun 18 - Jun 29
Gunter Meyer	Georgia Institute of Technology	Jun 25 - Jun 29
Ruth Miniowitz	McGill University	Jun 17 - Jun 29
Gary Mohnkern	Naval Ocean System C., San Diego	Jun 23 - Jun 30
Pierre Moulin	Washington University	Jun 23 - Jun 29
Jose Moura	Carnegie Mellon University	Jun 18 - Jun 29
David Munson	University of Illinois, Urbana	Jun 17 - Jun 21
Arje Nachman	AFOSR	Jun 25 - Jun 29
Harold Naparst	Fidelity Management Co., Boston	Jun 22 - Jun 29
Jerry Nelson	UNISYS	Jun 18 - Jun 29
Bob Numerich	Cray Research	Jun 18 - Jun 29
Joseph O'Sullivan	Washington University	Jun 18 - Jun 29

Julia Olkin	SRI International	Jun 17 - Jun 24
Norman Owsley	NUSC, New London, CT	Jun 28 - Jun 29
Rainer Picard	U. of Wisconsin, Milwaukee	Jun 17 - Jun 27
Craig Poling	Honeywell (USD)	Jun 18 - Jun 29
Howard Resnikoff	Aware Inc., Cambridge, MA	Jun 25 - Jun 29
Jung Sik Rno	Raymond Walters College	Jun 18 - Jun 29
D.N. Ghosh Roy		Jun 17 - Jun 25
Walter Schempp	Universitat Siegeu, West Germany	Jun 18 - Jun 29
Luise Schuetz	Naval Res. Lab., Washington, D.C.	Jun 18 - Jun 29
Kenneth Schultz	Lincoln Laboratory, MIT	Jun 25 - Jun 29
Robert Shore	Hanscom Air Force Base	Jun 25 - Jun 29
Donald Snyder	Washington University	Jun 24 - Jun 29
Gerald Sobelman	University of Minnesota	Jun 18 - Jun 29
Mark Stenoien	Honeywell	Jun 18 - Jun 29
Ahmed Tewfik	University of Minnesota	Jun 18 - Jun 29
Charles Weigel	Honeywell (USD)	Jun 18 - Jun 29
Harper J. Whitehouse	Naval Ocean System C., San Diego	Jun 17 - Jun 22
Calvin Wilcox	University of Utah	Jun 17 - Jul 1
Jorge P. Zubelli	UC Berkeley	Jun 18 - Jun 29

APPENDIX B: PROGRAM FOR TIME SERIES.

INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS

University of Minnesota
514 Vincent Hall
206 Church Street S.E.
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IMA NEWSLETTER #164

July 1 - July 29, 1990

IMA Summer Program

NEW DIRECTIONS IN TIME SERIES ANALYSIS

July 2 - July 27, 1990

Organizing committee: Emanuel Parzen (chairman), David Brillinger, Murray Rosenblatt, Murad Taqqu, John Geweke, and Peter E. Caines

The theory and methods of time series analysis lie at the intersection of the mathematical, statistical, computational, and system sciences, and provide an elegant interplay among these disciplines. They provide the means of applying advanced mathematical ideas and theorems to contribute towards the solutions of very practical problems. Time series analysis is truly an *interdisciplinary* field, because development of its theory and methods requires *interaction* between the diverse disciplines in which it is being applied. To harness its great potential there must develop a community of statistical and other scientists who are educated and motivated to have a background in theory and methods of time series analysis adequate to handle the problems of time series analysis in *all* the fields in which they occur.

Most of the summer program talks will be held in Conference Hall 3-180 on the entry floor of the new Electrical Engineering/Computer Science Building. This building is located on the corner of Washington Avenue and Union Street, a block from the IMA Main Office. The conference hall is on the Ethernet and has a projection system for display of computer output. We will also make use of the IMA Seminar room, Vincent Hall 570, for more informal discussions.

In addition to the previously scheduled lectures, there will be many opportunities during the program for informal, impromptu lectures, computer demonstrations, round tables, and so forth. Participants are encouraged to bring along material they might want to present.

PARTICIPATING INSTITUTIONS.Georgia Institute of Technology, Indiana University, Iowa State University, Michigan State University, Northern Illinois University, Northwestern University, Ohio State University, Pennsylvania State University, Purdue University, University of Chicago, University of Cincinnati, University of Houston, University of Illinois (Chicago), University of Illinois (Urbana), University of Iowa, University of Manitoba, University of Michigan, University of Minnesota, University of Notre Dame, University of Pittsburgh, Wayne State University
PARTICIPATING CORPORATIONS.Bellcore, Cray Research, Eastman Kodak, General Motors, Honeywell, IBM, Motorola, 3M, UNISYS

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INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS

University of Minnesota
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PARTICIPATING CORPORATIONS.Bellcore, Cray Research, Eastman Kodak, General Motors, Honeywell, IBM, Motorola, 3M, UNISYS

SCHEDULE FOR JULY 1 - JULY 29

Week 1, July 2–6, 1990

NON-LINEAR AND NON-GAUSSIAN MODELS AND PROCESSES

Organizers: David Brillinger and Murray Rosenblatt

Topics include higher-order moments and spectra, bilinear systems, nonlinear processes, applications to astronomy, geophysics, engineering, simulation.

Monday, July 2

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:00 am	Registration and coffee	Reception Room EE/CS 3-176
9:30 am	Murray Rosenblatt UC San Diego	NonGaussian models
10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	George Papanicolau Courant Institute	Direct and inverse problems for waves in random media
2:00 pm	David Brillinger UC Berkeley	NMR spectroscopy: a comparative test case for spectrum and mle methods

Abstract: This work presents a comparative investigation of two spectral moment-based identification procedures with each other and with the method of maximum likelihood, for the case of a bilinear system having observed input and corresponding output. Inputs considered to the system are pulse, pulse-pair and stochastic. A principal concern of the analysis is the examination of coupled frequencies. Relative advantages and disadvantages of the three identification procedures are mentioned. Advantages of the maximum likelihood approach include the availability of expressions for standard errors and efficiency in an asymptotic sense. It seems that each procedure has a role to play. The work is illustrated by the analysis of some data from NMR spectroscopy collected with stochastic input.

4:00 pm	Vincent Hall 502 (The IMA Lounge)	IMA Tea (and more!)

Tuesday, July 3

The talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Morning Chair: M. Hinich

9:30 am	J. G. Stevens Naval Postgraduate School	Nonlinear modelling of time series using multivariate adaptive splines (MARS)

Abstract: Joint work with P.A.W. Lewis.

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Chrysostomos L. Nikias Northeastern University	Cepstra of higher order spectra: some new problems and applications

Abstract. The purpose of this talk is to present the definitions, properties, computation and applications of cepstra of higher-order spectra (bicepstrum and tricepstrum). In particular, two different computation procedures are described based on singular value decomposition and multidimensional FFT operations. We show that for linear non-Gaussian proesses or deterministic signals, the differences of bicepstrum coefficients contain all the information concerning the phase of the process, whereas their sums contain the magnitude information.

We present methods based on higher-order cepstra for the following problems: (i) signal phase reconstruction from the phase of the bispectrum, (ii) signal reconstruction from only the phase (or magnitude) of higher-order spectra, (iii) time delay estimation from higher-order cross-spectra, and (iv) adaptive blind equalization from fourth-order statistics.

Afternoon Chair: E. Waymire

2:00 pm	Jeffrey D. Scargle NASA-Ames Research Center	Predictive deconvolution of chaotic and random processes

Abstract: This talk will discuss extensions of the classical theory of linear least-squares predictive deconvolution needed to detect, model, and separate chaotic and random processes in time series data.

The nature of chaotic processes will be discussed, and a number of simple examples exhibited and analyzed. The Wold Decomposition for stationary processes applies to all chaotic systems posessing an invariant measure, and shows that time series data produced by any such system can be written in the standard MOVING AVERAGE form $X = R*C$ ($R =$ white chaos and C a constant, not necessarily causal, but invertible filter). This is a very useful model for physical processes.

A deconvolution technique, which allows estimation of R and C from time series data X, will be demonstrated on synthetic data. Some toy processes – such as those connected with the Bernoulli shift, Lozi map, and the Smale horseshoe – have exact deconvolutions, and numerical results will be shown for others – including the Henon, logistic, and continued fraction maps.

An exact deconvolution of the general toral automorphism yields a surprsisingly simple representation for these processes. This and other results suggest that R is connected with symbolic dyanmics. I will suggest a number of unsolved problems in this area.

Wednesday, July 4

4TH OF JULY PICNIC

10:00 am	Picnic at University of Minnesota Landscape Arboretum

A picnic will be set-up at the U of M Arboretum (near Chanhassen, Minnesota). A bus will start loading at the EE/CS building on Union Street at 9:30 am and will leave at 10:00 am. Box lunches will be provided. The bus will leave the Arboretum at about 3:30 pm to return to the EE/CS Building.

Thursday, July 5

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Session Chair: P. A. W. Lewis

9:30 am	Jerry M. Mendel University of Southern California	Harmonic retrieval using higher-order spectra

Abstract. An important problem in signal processing is that of estimating the frequencies and amplitudes of harmonics which are observed in additive colored Gaussian noise. In practice, the observed signals are contaminated with spatially and temporally colored noise of unknown power spectral density. We use a cumulant-based approach to solve this problem. To begin, we define the cumulants of complex processes. We then show that third-order cumulants of harmonic processes are zero, hence, we must use fourth-order cumulants. Our major theoretical result is. specific 1-D slices of the fourth-order cumulant of the noise

measurement for the direction of arrival and retrieval of harmonics in noise problems are identical with the autocorrelation of a related noiseless signal; hence, correlation based high resolution methods (e.g., MUSIC and min norm) may also be used with fourth-order cumulants. Simulation examples will be shown that demonstrate the effectiveness of our method.
Joint work with Ananthram Swami.

10:30 am	Coffee Break	Reception Room EE/CS 3-176

Session Chair: G. Papanicolau

11:00 am	Akiva Yaglom Acad. Sciences, USSR	Random fields and their applications to atmospheric physics
11:30 am	M. Hinich University of Texas	Non-minimum phase deconvolution of speech
11:50 am		Open Discussion

Abstract: Among other matters the discussion will concern questions about George Papanicolau's presentation earlier this week.

Afternoon Chair: J. D. Scargle

2:00 pm	J. Sidorowich UC Santa Cruz	Chaotic time series analysis: applications in prediction and noise reduction

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Friday, July 6

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Session Chair: M. E. Bock

9:30 am	Tohru Ozaki Inst. of Stat. Math., Tokyo	Identification of nonlinearities and non-Gaussianities in time series

Abstract: Many non-Gaussian time series can be regarded as an output of a deterministic nonlinear dynamical system driven by Gaussian white noise. They could also be regarded as an output of a deterministic nonlinear dynamical system. In real time series data analysis, it is not known whether the system noise is zero or not. Also the coefficients of the dynamical system are usually not accurately known. In this talk we give a maximum likelihood estimation method for these unknown parameters using a nonlinear Kalman filtering method. Application of the present method to some real non-Gaussian time series is shown with numerical results.

10:30 am	Coffee Break	Reception Room EE/CS 3-176

Session Chair: E. Parzen

11:00 am	Howell Tong University of Kent	Comments on some contrasting aspects of nonlinear time series

Afternoon Chair: K.-S. Lii

2:00 pm	G. Giannakis University of Virginia	A maximum likelihood viewpoint of cumulants and polyspectral measures for nonGaussian estimation and classification
2:20 pm	P. Rothman NYU	Characterization of the time irreversibility of stationary time series

2:40 pm	Martin Casdagli Los Alamos Nat. Labs.	State space reconstruction

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Week 2, July 9–13, 1990

SELF-SIMILAR PROCESSES AND LONG-RANGE DEPENDENCE

Organizer: Murad Taqqu

Topics include time series with long memory self-similar processes, fractals, 1/f noise, stable noise. Most of the talks for this week will be arranged after the participants arrive at the IMA.

Monday, July 9

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:00 am	Registration and coffee	Reception Room EE/CS 3-176

Morning Chair: B. Mandelbrot

9:30 am	Mourad Taqqu Boston University	Self-similar processes and long-range dependence in time series: An overview

Abstract. We shall give an overview on self-similar processes and long-range dependence. The goal is to introduce and tie together the areas of research that will be discussed in detail during this workshop. We will consider Gaussian and non-Gaussian models, including models related to stable noise that display high variability.

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11-11:30 am	Michael T. Lacey Indiana University	Self-similar processes as limits in dynamical systems

Abstract: Let (X,μ,T) be an (invertible) dynamical system, and for a function $f \in L^1(\mu)$ set $S_n f = f + \ldots + f_0 T^{m-1}$. We show that for a wide variety of H-self-similar, stationary increment processes $Y(t)$ there is an $f \in L^1(\mu)$ so that $m^{-H} S_{[mt]} f \overset{d}{\Rightarrow} Y(t)$. This holds in particular when $Y(t) = B_H(t)$, a fractional Brownian motion of index H. Moreover, for the especially interesting case of irrational rotations, we study the kind of functions f which generate $B_H(t)$ as a limit.

Afternoon Chair: M. Taqqu

2:00 pm	B. Mandelbrot IBM/Yale	Multifractals
3-3:30 pm	Ed Waymire Oregon State University	Network scaling in structure function computations

Abstract. Mathematical problems involving the asymptotic analysis of rooted random tree graphs and branching patterns for large numbers of vertices will be discussed from the point of view of predictions of edge distributions as a function of distance from the root. Predictions are compared to a river network data base and the role of self-similarity and scaling properties is described.

3:30 pm	Vincent Hall 502 (The IMA Lounge)	IMA Tea (and more!)

Tuesday, July 10

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Morning Chair: E. Parzen

9:30 am	Wim Vervaat Catholic University, Nijmegen	Ergodic properties of self-affine processes

Abstract. We call H-self-similar processes with stationary increments *self-affine.* They are invariant in distribution under the transformations $f \mapsto a^{-H} f(a\,\cdot)$ for $a > 0$ and $f \mapsto f(b + \cdot) - f(b)$. We review general properties such as existence of moments, continuity and differentiability of the sample paths and various types of bounded variation, with emphasis on those that can be obtained by application of the Ergodic Theorem. It is crucial that, for the latter, the first moment must exist but need not be finite.

10.30 am	Coffee Break	Reception Room EE/CS 3-176
11-11:30 am	G. O'Brien York University, Ontario	Self-similar processes and point processes

Abstract. We discuss the existence and properties of H self similar processes with stationary increments of the form

$$X(t) = \int_{s=0}^{t} \int_{-\infty}^{\infty} |x|^H (\mathrm{sign} x) \Pi(dx ds)$$

where Π is a point process in $[0, \infty) \times R$.

11:30-Noon	Michael Keane Delft U. of Technology	One-dependent processes

Afternoon Chair: Péter Major

2:00 am	T. C. Sun Wayne State University	Limit theorems for non-linear functions of a stationary Gaussian process
2:30-3 pm	Norma Terrin Carnegie Mellon University	Convergence of quadratic forms with long-range dependence
3:00-3:15 pm	Coffee Break	Reception Room EE/CS 3-176
3:15-3:45 pm	Florin Avram Northeastern University	Convergence to the normal distribution by graph methods

Abstract. When establishing convergence to the nromal distribution by the method of moments, one is often lead to the study of a certain type of sums associated with graphs (when the graph is a cycle, this "graph-sum" is a product of Toeplitz matrices, and the asymptotics in this case was obtained by Szego (1958)).

Two results concerning the asymptotics of these general "graph sums" have been obtained: An inequality which establishes their order of magnitude, as well as an exact limit theorem. The results show dependence on the bond matroid structure of the graph.

The main tool in establishing these results was showing that a Holder type inequality for multiple integrals of functions applied to linearly dependent arguments holds, provided certain rank conditions, known to physicists as the "power counting" conditions, are satisfied.

These methods are applied for establishing various central limit theorems for certain dependent sequences of random variables.

Wednesday, July 11

The talks today are in Conference Hall EE/CS 3-180

Morning Chair: M. Keane

9:00 am	Péter Major Hungarian Academy of Sciences	The large-scale limit of Dyson's vector-valued hierarchical model: The role of continuous symmetries

Abstract: In this talk we investigate the large-scale limit of Dyson's vector-valued model. From a probabilistic point of view the problem we are interested in is a problem for the limit distribution of partial sums of (dependent) random variables with an appropriate normalization. The main step of the proof consists of the investigation of the effect of the powers of an integral operator with respect to a starting function. Formally, this operator is very similar to the convolution of a function with itself. The main difference between these operators is that our integral operator contains a kernel, and because of this kernel the stability property of its fixed points is more complex. Just because of this more sophisticated stability property a much richer picture of limit theorem behaviour arises. In particular, in the case of vector-valued models the continuous symmetry of the model has far-reaching and unexpected consequences. The subject of the present talk is the discussion of these consequences. The talk is based on our papers listed below and some investigations under progress.

References:

[1] Bleher, P. M., Major, P.: Critical phenomena and universal exponents in statistical physics. On Dyson's hierarchical model. *Annals of Probability* 15 1987, 431–477. (Special invited paper)

[2] Bleher, P. M., Major, P.: The large-scale limit of Dyson's hierarchical vector-valued model at low temperatures. The non-Gaussian case. Part I. *Annales de l'Institut Henri Poincaré*, Série Physique Théorique, Volume 49 fascicule 1 (1988), 1–85

[3] Bleher, P. M., Major, P.: The large-scale limit of Dyson's hierarchic al model at low temperatures. The non-Gaussian case. Part II. *Annales de l'Institut Henri Poincaré*, Série Physique Théorique, Volume 49 fascicule 1 (1988), 86–143

[4] Bleher, P. M., Major, P.: The large-scale limit of Dyson's hierarchic al vector-valued model at low temperatures. The marginal case $c = \sqrt{2}$. *Comm. Math. Physics* 125 (1989), 43–69

Joint work with P. M. Bleher.

10:00 am	Coffee Break	Reception Room EE/CS 3-176
10:30-11 am	P. M. Bleher Keldysh Inst. App. Math, Moscow	Statistical properties of a particle moving among a periodic set of scatterers
11:00 am	Coffee Break	Reception Room EE/CS 3-176
11:15-11:45 am	Jim Kuelbs University of Wisconsin	Rates of clustering for some Gaussian self-similar processes

Abstract. The analogue of Strassen's function LIL is known for many Gaussian processes which have suitable scaling properties, and here we establish rates at which this convergence takes place. In particular, our methods apply to Brownian motion, the Brownian sheet, and fractional Brownian motions.

Afternoon Chair: H. Dehling

2:00 pm	Victor Solo The Johns Hopkins University	Intrinsic random functions and the paradox of $1/f$ noise

Abstract. A Flicker Noise or $1/f$ noise is a Stochastic Process with low frequency spectrum of the form $\omega^{-\alpha}$. Such processes seem to be ubiquitous having been observed in such areas as, traffic flow, solid state devices, physiology, economics.

The paradox arises from the fact that for $\alpha \geq 1$ the spectrum is not integrable. This suggests that $1/f$ noise has infinite variance - thus it cannot be second order stationary and so cannot have a spectrum! Yet $\alpha \geq 1$ has been observed in practice along with evidence of certain "stationary-like" behaviour.

The problem has also appeared in another guise with Random Fields. Namely the polynomial variation of the variance of area and volume averages with area and volume, with exponents that cannot be attained by stationary models.

The idea (due to Mandlebrot and Matheron) that stationary increment processes (such as fractional Brownian motion, or the isotropic fractional Brownian Field) can explain these behaviours is pursued. In particular, the statistical behaviour of the Fourier Transform of a Stationary Increment process (or field) is shown to have the same statistical properties that it does in the stationary case (but not at zero frequency). Some new generalized Fejer theorems and central limit theorems are developed for this purpose.

The modelling of these processes will also be discussed. It turns out that the traditional log - log plot has a potentially enormous bias associated with it. Ways to get around this (including exact maximum likelihood estimation) are discussed. It is hoped to illustrate results with a data analysis of 1.4 million observations of resistance fluctuations of thin chromium film.

3:00 pm	Coffee Break	Reception Room EE/CS 3-176
3:15-3:45 pm	Adrian Papamarcou University of Maryland	Stationary interval-valued probability models and long-range dependence

Abstract: Interval-valued probability is a generalization of numerical probability in which the likelihood of events is represented by two set functions, the *upper* and *lower probability*. These two functions are subadditive and superadditive, respectively, and reduce to finitely additive probability measures whenever they are identically equal.

In this talk we discuss potential applications of the interval-valued probability concept to the modeling of long-memory time series such as flicker noise encountered in high-quality quartz crystal oscillators. Although these processes occur in stable, "physically stationary," systems, they are not stationary in the conventional probabilistic sense of the term, as their empirical spectra are non-integrable. The possibility of finding stationary models for such processes in the broader realm of interval-valued probability remains open. A promising development towards this end is the construction of interval-valued probability models which combine features of strict stationarity and monotone continuity, yet violate the ergodic theorem by supporting almost sure divergence (instead of convergence) of time averages.

Thursday, July 12

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

Morning Chair: Jeff Scargle

9:30 am	Yoshihiro Yajima University of Tokyo	Asymptotic properties of estimators for long memory time series

Abstract: Here we shall consider two problems. First we discuss a regression model with long memory stationary errors and derive a necessary and sufficient condition so that the least squares estimator be asymptotically efficient relative to the best linear unbiased estimator. Secondly we consider properties of an estimator when we fit a misspecified model such as ARMA model to long memory time series.

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Jan Beran Texas A&M University	Long-range dependence and linear regression, with special reference to ANOVA

Afternoon Chair: Z. Jurek

2-2:30 pm	A. Yaglom Acad. Sciences, USSR	Long-range dependence modeling of some geophysical and economics time series
2:30-3 pm	Don Johnson Rice University	Analysis of fractal intensity point processes

Abstract: Will show REAL data.

3:00 pm	Coffee Break	Reception Room EE/CS 3-176

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Joint Geometry Supercomputer Project & IMA Presentation

3:30 pm	Benoît B. Mandelbrot IBM/Yale	Fractals: Science and Music

Abstract: Dr. Mandelbrot will present a video of "New York Notes", a show of fractals and accompanying music by Charles Wuorinen which premiered at the Guggenheim Museum in April, 1990. The show will be followed by a short talk.

The PRESENTATION will take place in Lecture Hall EE/CS 3-210

Friday, July 13

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

Morning Chair: J. Peyriere

9:30 am	Yuri A. Davydov Leningrad State University	On the distributions of multiple Wiener-Ito integrals
10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Gennady Samorodnitsky Cornell University	Integrability of the sample paths of stable processes

Afternoon Chair: Ed Waymire

2-2:30 pm	Herold Dehling Groningen	Estimating the marginal distribution in a long range dependent time series
2:30-3 pm	Jacques Peyriere Universite de Paris Sud, Orsay	On multifractals analysis of processes
3:00 pm	Coffee Break	Reception Room EE/CS 3-176
3:15-3:45 pm	Michael Keane Delft U. of Technology	Self-affine processes of zero entropy

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Week 3, July 16-20, 1990

INTERACTIONS OF TIME SERIES AND STATISTICS

Organizer: Emanuel Parzen

Topics include time series model identification, analysis of categorical valued time series, nonparametric and semiparametric methods for time series.

Monday, July 16

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180
The talks today are dedicated in honor of
John Tukey's contributions in Time Series Analysis.

9:00 am	Registration and coffee	Reception Room EE/CS 3-176

Morning Chair: Wayne Fuller

9:30 am **Emanuel Parzen** Time series, statistics, and information
Texas A&M University

Abstract: This paper is a broad survey of ideas for the future development of statistical methods of time series analysis based on investigating the many levels of relationships between time series analysis, statistical methods unification, and inverse problems with positivity constraints. It is hoped that developing these relations will: provide research tools for applied and theoretical statisticians in the 1990's and coming era of statistical information; make possible unification of statistical methods and the development of statistical culture. Topics discussed include:

1. Traditional entropy and cross-entropy,
2. Renyi and Chi-square information divergence,
3. Comparison density functions,
4. Approximation of positive functions (density functions) by minimum information divergence (maximum entropy),
5. Equivalence and orthogonality of normal time series,
6. Asymptotic information of stationary normal time series,
7. Estimation of finite parameter spectral densities,
8. Minimum information estimation of spectral densities and power index correlations,
9. Tail classification of probability laws and spectral densities,
10. Sample Brownian Bridge exploratory analysis of time series.

10:30 am **Coffee Break** Reception Room EE/CS 3-176

11:00 am **Peter M. Robinson** Semiparametric methods in time series
London School of Economics

Abstract: A variety of methods of semiparametric inference in time series are discussed, each involving some form of smoothed estimation of a nonparametric component. Four main topics are covered. The first is efficient or robust inference on regression-type models in the presence of disturbance autocorrelation of unknown form, with extension to multiple systems in which only some equations are parameterised and the full system has a nonparametric frequency response function. Nonparametric spectral and cross-spectral estimation is involved here, and some discussion of automatic bandwidth determination is included. In the second topic the spectral density itself has a semiparametric character. In a time series exhibiting long-memory behaviour, the logged spectrum is dominated near the origin by a linear component, with unknown slope, but nonparametric effects can be significant at other frequencies, as when no attempt is made to parameterise the smooth spectrum of a fractionally differenced process. Several methods of estimation, and their impact on the first topic, are discussed. The third topic concerns semiparametric models for time series in which even getting root-n consistent parameter estimates is challenging, and smoothed nonparametric regression and derivative-of-probability-density estimation plays a useful role. Such models include ones for discrete-valued and censored time series, whose conditional expectation given explanatory variables is a nonparametric function of a linear combination, and regression models containing both a parametric and a nonparametric component. It is possible to estimate parameters up to unknown scale, and carry out tests of certain hypotheses. The final topic is concerned with developing tests with good consistency properties, based on an approximation of the Kullback-Leibler information criterion which employs nonparametric probability density estimates. The main application is to testing for independence in time series with marginal density of unknown form; another is to testing for reversability in time series.

Afternoon Chair: Emanuel Parzen

2:00 pm **Scott Zeger** Regression models for discrete time series
John Hopkins University

Abstract. Linear regression models for Gaussian time series data $\{y_t, t = 1,\ldots,n\}$ are in common use. A linear model has two parts. a regression in which $E(y_t)$ is expressed as a function of a covariate vector x_t; and a parametric, typically ARMA, model for the correlation in the residual series $\{\varepsilon_t, t = 1,\ldots,n\}$. A desireable property of linear models is that the interpretation of regression coefficients is invariant with respect to the choice of the correlation model. In fact it quite generally possible to make consistent inferences for regression coefficients when the correlation model is incorrectly specified given a stationary error series.

Regression models for binary or count time series are less commonly used and do not necessarily share the model robustness mentioned above. In most cases, the interpretation of regression coefficients is tightly bound up with the model for time dependence. This is because time series extensions of the common regression models for independent discrete data are neither linear, additive nor stationary. One exception is the class of "marginal" models in which a known function of the marginal expectation of y_t is assumed to depend linearly on x_t, i.e. $h(Ey_t) = x_t\beta$. For example, with binary responses, the logit (log odds) of the marginal probability of a success is modelled; with count data, the log of the expected count is expressed in terms of x_t.

This talk will discuss marginal models for discrete time series data. Time dependence is accounted for by modelling the covariance matrix of the sequence $\{y_t, t = 1, \ldots, n\}$ as a function of the marginal mean and of additional covariance parameters α. Estimation is performed using "generalized estimating equations" (GEE). The methods will be illustrated with time series data from public health research.

3:00 pm	John W. Tukey Princeton University	Reflections
4:15 pm	Vincent Hall 502 (The IMA Lounge)	Reception in honor of John Tukey

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Tuesday, July 17

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

Morning Chair: Ludwig Fahmier

8:30 am	Ludwig Fahrmeir University of Regensburg, F.R.G.	State space modeling and conditional mode estimation for categorical time series

Abstract: In this talk the following state space models for time series of ordered or unordered categorical responses are considered: Conditional upon time-varying parameters or states, observation models are dynamic versions of categorical response models for cross-sectional data. State transition models may be Gaussian or not.

As an alternative to conditional mean filtering and smoothing, which generally will require repeated multidimensional integrations, estimation is based on modes of the posterior distribution. Factorization of the conditional information matrix leads to Gauss-Newton iterations which are closely related to extended Kalman filtering for non-Gaussian data. Estimation of unknown hyperstructural parameters is discussed and the methods are illustrated by some examples. Relations to non- and semiparametric approaches are outlined.

Finally, extensions to general non-Gaussian state space models are indicated.

9:30 am	Coffee Break	Reception Room EE/CS 3-176
10-10:30 am	Ed Carlstein University of North Carolina	Resampling for time series

Abstract. Resampling enables us to nonparametrically estimate features of the distribution of a general statistic T, using only the n observations at hand. Particular features which may interest us include the mean, variance, skewness, and percentiles of T's distribution. The fundamental strategy in resampling is to generate "replicates" of T from the available data, and then use these replicates to model the true sampling distribution of T. The jackknife, the bootstrap, and the typical-value principle are specific resampling algorithms for generating replicates, these methods were first introduced and extensively studied in the case where the original observations are iid. When the observations are serially dependent (but stationary), the resampling algorithms must be modified in order to yield valid replicates of T. The modified resampling algorithms can be model-based (i.e., they can exploit an assumed dependence structure in the time series) or model-free (i.e., no knowledge of the dependence mechanism is needed). Model-based resampling algorithms include the Markovian bootstrap and bootstrapping of residuals; model-free approaches include the blockwise jackknife, the blockwise bootstrap, the linked blockwise bootstrap, and subseries methods.

10:30-11 am	Clifford M. Hurvich New York University,	Selection of time series models and spectrum estimates using a bias-corrected generalization of AIC

Abstract: We address a general selection problem for time series, namely: Given data from a stationary Gaussian process having a spectral density, and given a class C of candidate spectrum estimates, how should one select a candidate from C for use as a description of the process? Special cases of this problem include order selection for autoregressive models and spectrum estimates, as well as bandwidth selection for nonparametric spectrum estimates. In this paper, we discuss AIC_C, (a bias-corrected generalization of the well-known Akaike Information criterion AIC) which provides a unified solution to the problem. For autoregressive order selection, AIC_C is asymptotically equivalent to AIC, is asymptotically efficient, and provides superior selections in small samples, as shown in Hurvich and Tsai (1989). For nonparametric spectrum estimation, AIC_C produces good bandwidth selections, as shown in Hurvich and Beltrao (1990). Further, if one allows the class C of candidates to simultaneously contain parametric and nonparametric spectrum estimates, then AIC_C allows the data-driven selection of estimate type (e.g., autoregressive or nonparametric) as well as the corresponding smoothness parameter (e.g., model order or bandwidth). Finally, we briefly discuss some recent improvements in AIC_C for selection of autoregressive models, based on numerical tabulation of penalty functions.

11:15-Noon	Informal Discussions, Expanded Presentations

Afternoon Chair: Ludwig Fahmier

1:30 pm	Mohsen Pourahmadi Northern Illinois University	Can the idea of regression provide a foundation for time series analysis?

Abstract: Time series analysis as an area of statistics does not seem to have an easily accessible foundation emanating from probability theory or familiar statistical models. While regression methods are frequently used to analyze various time series data sets, other than the work of Wold the idea of regression in the finite dimension has not been used in the study of structure of stationary processes which is so crucial in the statistical analysis of time series. In this talk, by using an abstraction of the idea of linear regression, we extend the approach of Wold and obtain, essentially, all fundamental results concerning the structure of a stationary process in the time domain. In particular, we derive AR-, MA-, and ARMA- representations for a time series, and study the three crucial problems of prediction, interpolation, and computation of canonical correlations. This approach allows a new way of introducing and interpreting various parameters of a time series with useful pedagogical implications. Also, we compare this approach with the standard Kolmogorov-Wiener prediction theory which is developed in the spectral domain and can be viewed as regression in the the infinite dimension.

2:30 pm	Coffee Break	Reception Room EE/CS 3-176
3-3:30 pm	R.J. Bhansali University of Liverpool	Estimation of the forecast mean squared error and an R^2 measure for stationary time series

Abstract: For forecasting the future values of a stationary process, $\{x_t\}(t = 0, \pm 1, \pm 2, \ldots)$, on the basis of its past, two key parameters are the variance, $V(h)(h \geq 1)$, of the h-step forecasting error and $Z(h) = \{R(0) - V(h)\}/R(0)$, the corresponding R^2 measure of the predictability of x_t from its past, where $R(0)$ denotes the variance of x_t. The estimation of $V(h)$ and $Z(h)$ from a realization of T consecutive observations of $\{x_t\}$ is considered, without requiring that the process follows a finite parameter model. Three different autoregressive estimates are examined and shown to be asymptotically equivalent in the sense that as $T \to \infty$ they have the same asymptotic normal distributions. The question of bias in estimating these parameters is also examined and bias correction proposed. Some of the applications of the results are described.

3:30-4 pm	H. Salehi Michigan State University	Infinite order ARMA systems

Abstract: The structure of solutions to infinite order ARMA equations of the form

$$\sum \phi(k)X(n-k) = \sum \theta(k)Z(n-k), \qquad (*)$$

where summations are taken over all integers and $Z\{(k)\}$ is a discrete parameter white noise, is studied. As in the finite order ARMA models the functions

$$\phi(t) = \sum \phi(k)\exp(ikt) \quad \text{and} \quad \theta(t) = \sum \theta(k)\exp(ikt),$$

$t \in [0, 2\pi]$, play important roles in this study. In particular it is proved that $(*)$ has a harmonizable solution if and only if it has a stationary solution; and the later holds if and only if the quotient ϕ/θ is square integrable. Furthermore under some additional analytic conditions which are automatically met for finite-order ARMA systems it is shown that any L^2-bounded solution to $(*)$ is harmonizable.

Joint work with A. Makagon.

Wednesday, July 18

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

Morning Chair: Scott Zeger

8:30-9 am	R. Shumway & D. Stoffer UC Davis & U. of Pittsburgh	Dynamic linear models with switching
9-9:30 am	D. Stoffer & K. Wall U. of Pittsburgh & Naval Postgraduate School	Bootstrapping state space models
9:30 am	Coffee Break	Reception Room EE/CS 3-176
10-10:30 am	Brockwell, Davis, Salehi Melbourne, Colorado State & Michigan State Universities	A state space approach to transfer function modeling
10:30-11 am	Richard A. Davis Colorado State University	On noncausal AR processes: reversibility, identifiability, and estimation
1:30 pm	Emanuel Parzen Texas A.& M. University	On time series, statistics and information (continued)
2:30 pm	Coffee Break	Reception Room EE/CS 3-176
3:00-4 pm		Forum

Abstract. All participants who are not speakers this week introduce themselves, general discussion of role of time series analysis in statistics; time series courses, books.

4-4:30 pm	Jim Ramsey NYU	Some exploratory techniques for discovery of nonlinear dynamics

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Thursday, July 19

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

Morning Chair: Myron Katzoff

8:30 am	Gregory Reinsel University of Wisconsin, Madison	Modeling with reduced rank structures for stationary and nonstationary multivariate autoregressive models

Abstract: The analysis of vector autoregressive models which incorporate different forms of reduced-rank structure in their coefficient matrices is examined. To address the problem of increased complexity in the analysis of multiple time series $Y_t = (Y_{1t}, \ldots, Y_{kt})'$ as the number k of series grows, various approaches have recently begun to be investigated concerning specification and modeling techniques that identify and incorporate simplifying structures into the model (e.g., Ahn and Reinsel, 1988, Tiao and Tsay, 1989). In addition, investigations concerning the structure of the joint nonstationarity among multiple series, especially for economic time series data, have developed leading to interests in co-integration of multiple time series (Engle and Granger, 1987, Stock and Watson, 1988, Johansen, 1988). The need to adequately represent both the nature of nonstationarity among the series and the structural dependencies among parameters in the vector time series model is important for proper model specification, increased understanding, efficient prediction, and to avoid the difficulties associated with multivariate "over-differencing" (that is, over-specification of the number of unit roots) in nonstationary vector time series models. A useful approach for vector time series modeling involves a combination of the two structural modeling components associated with the dependencies among model parameters and with the nature of nonstationarity among series.

We are concerned with the vector autoregressive (AR) model for Y_t given by

$$Y_t = \sum_{j=1}^{p} \Phi_{t-j} + \varepsilon_t, \qquad 1$$

where Φ_j are $k \times k$ matrices of coefficients, and the ε_t are a k-dimensional white noise process with zero mean and covariance matrix $\sum$. Ahn and Reinsel (1988) studied the nested reduced-rank AR model where the rank of the coefficient matrix Φ_i is assumed to equal r_i and the r_i are nonincreasing as the lag i increases, with $\Phi_i = A_i B_i$, and the nested reduced rank assumption that $range(A_i) \supset range(A_{i+1})$ is imposed. The model is considered in order to simplify and provide a more detailed description of the structure of the vector time series model and to reduce the number of parameters in the modeling. Appropriate procedures, based on partial canonical correlation analysis between Y_t and Y_{t-j}, to identify the reduced rank structure are described, procedures for Gaussian estimation of parameters in the specified reduced rank model are presented, and properties of the Gaussian estimators are provided.

Another situation of special interest occurs when Y_t is nonstationary with $\det\{\Phi(B)\} = 0$ having $d < k$ unit roots and all other roots are outside the unit circle. It is also assumed that $rank\{\Phi(1)\} = r, r = k - d$, which implies that each component of the first differences $W_t = Y_t - Y_{t-1}$ is stationary. The model can then be expressed in the error-correction form as

$$W_t = CY_{t-1} + \sum_{j=1}^{p-1} W_{t-j} + \varepsilon_t, \qquad 2$$

where $C = -\Phi(1) \equiv AB$ is of reduced rank $r = k - d$, and $\Phi_j^* = \sum_{i=j+1}^{p} \Phi_i$. One implication of such models is that although all k component series may exhibit nonstationary behavior, there are r linear combinations of Y_t which are stationary, and hence there is a reduced dimensionality to the nature of the nonstationarity among the k series. Recent work by Ahn and Reinsel (1990) and others on Gaussian estimation procedures for the model (2) with the reduced rank structure for C imposed (that is, with d unit roots imposed on the AR operator in (1)) and asymptotic properties of the estimators is reviewed. Also investigated are the asymptotic properties of the likelihood ratio statistic to test for the number of unit roots d in the model, that is, the rank r of the matrix C. In addition, it is noted that if a nonstationary (unit root) AR model (1) has a nested reduced-rank structure, then the coefficient matrices Φ_j^* in the error-correction form (2) will also possess a nested reduced-rank structure. Hence, such a model will combine the reduced-rank structure for the matrix C to represent the reduced dimensionality in the long term (nonstationary) dynamics of the process

and a separate nested reduced-rank structure for the matrices Φ_j^* to represent the shorter-term (stationary) dynamics. Gaussian estimation procedures for such combined reduced rank models and associated likelihood ratio testing procedures are described and their asymptotic properties are indicated. Numerical examples are considered to illustrate the nested AR and the nonstationary unit root reduced rank model specification and estimation methods.

9:30 am Coffee Break Reception Room EE/CS 3-176

10-10:30 am Jonathan D. Cryer Some exact distribution theory for inference in
University of Iowa time series models

Abstract. When dealing with time series models, most of the distribution theory for estimators, test statistics, forecasts, and forecast errors must be approximate and based on asymptotics. This paper reviews some recent work on the exact distribution theory for inferential statistics associated with ARIMA models. This recent work has the effect of simplifying and extending much earlier work which considers distributions based on simulation or asymptotics.

10:30-11 am Forum: Time series open questions

Afternoon Chair: Gregory Reinsel

1:30 pm Benjamin Kedem Contraction mappings in mixed spectrum
University of Maryland estimation

Abstract. Families and sequences of zero-crossing counts generated by parametric time invariant filters are called higher order crossings or HOC. Because of the close relationship between zero-crossing counts and first order autocorrelations, families of first order autocorrelations are also referred to as HOC. By means of HOC from repeated differencing and repeated summation, it is possible to obtain a complete solution of the the problem of hidden periodicities in the purely discrete spectrum case. However, when noise is present, a modification is needed. It is shown how to locate discrete frequencies in the presence of colored noise, using HOC sequences obtained by recursive filtering. By this method, the cosine of each discrete frequency is obtained as a fixed point of a certain contraction mapping. A special feature of this method is that the contraction rate can be enhanced considerably by the iterative reduction in the filter bandwidth.

2:30 pm Coffee Break Reception Room EE/CS 3-176

3-3:30 pm Robert V. Foutz Small-sample spectral estimation
VPI & SU

Abstract. A general technique is described for estimating spectral parameters for multiple time series, including spectral densities, coherence, phase and group delay. The primary purpose of the technique is to provide point estimators that are uniformly minimum variance unbiased (UMVU), under certain ideal conditions, and also to provide confidence interval estimators that have exact confidence coefficients when the ideal conditions are met. Because the proposed techniques may have known properties for each fixed sample size, they may be of use in small samples where the exact properties of the standard asymptotic procedures are not known. An example concerns the time series Z_1 of the annual harvest of Maine lobsters and the time series Z_2 of annual sea surface temperatures at Boothbay Harbor, Maine. A small sample of eighty-eight annual Z_1, Z_2 values is used to compute the periodogram and cross periodogram ordinates at the Fourier frequencies, then appropriate functions of these are transformed to satisfy linear models with independent, normal errors. It is shown that a method due to Neyman and Scott leads to UMVU estimators for functions of the spectral densities of Z_1 and Z_2, the squared coherence between Z_1 and Z_2, and the phase spectrum between Z_1 and Z_2. In addition, exact 81% confidence intervals are obtained for these spectral parameters and also for the group delay between the Z_1 and Z_2 series.

Joint work with Philip J. Ramsey.

3:30-4 pm S. Mittnik State space modeling of non-linear time series
SUNY Stony Brook and chaos

5:45 pm	Time Series Dinner	Buffet dinner at the Campus Club, Coffman Union, 4th floor. Wine and cheese served at 5:45 pm, dinner at 6:30 pm.

Friday, July 20

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

Morning Chair: Mohsen Pourahmadi

8:30 am	Wayne Fuller Iowa State University	Nonlinear estimation for time-series

Abstract: Estimation for nonlinear models in which some of the variables are time series is investigated. Large sample results for models in which the sum of squares of the derivatives increase at different rates are obtained. Example models include the linear model with autoregressive errors, the autoregressive moving average with an autoregressive unit root and models with time trends.

Joint work with Neerchal K. Nagaraj.

9:30 am	Coffee Break	Reception Room EE/CS 3-176
10-10:30 am	Young K. Truong University of North Carolina	A nonparametric framework for time series analysis

Abstract: Much of time series analysis deals with inference concerning the unknows in the stochastic model for a random phenomena. In parametric approach the unknowns are a specific finite number of parameters while in the nonparametric approach they are smooth functions. In this paper, the problem of estimating the conditional mean and conditional median functions involving time series is considered. Specifically, the effect of correlated structure on smoothing procedures such as kernel method based on local mean and local median will be examined, and recent results on selecting a sequence of estimators that achieves the optimal rates of convergence will also be addressed.

10:30-11 am	Bill Dunsmuir Bond University, Queensland	L1 estimation for stationary time series models

Abstract: This paper will review L1 estimation for stationary time series models. In particular the asymptotic properties of the parameter estimates will be reviewed and some finite sample simulation results presented. Use of linear programming methods for obtaining the estimates will be discussed and applied to some monthly product data.

Afternoon Chair: Peter Brockwell

1:30 pm	Madan L. Puri Indiana University	Rank-based methods in time series analysis
2:30 pm	Coffee Break	Reception Room EE/CS 3-176
3-3:30 pm	Greta Ljung MIT	Missing values and outliers in time series
3:30-4 pm	Jovan Malisic Belgrade U., Yugoslavia	Stationary AREX time series models

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Week 4, July 23-27, 1990

TIME SERIES RESEARCH COMMON TO ENGINEERS AND ECONOMISTS

Organizers: John Geweke and Peter Caines

Topics will include modeling of multivariate (possibly non-stationary) time series, especially by state space and adaptive methods.

Monday, July 23

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

10:00 am	**Registration and coffee**	Reception Room EE/CS 3-176

Afternoon Topic: Structural Problems in Econometrics & TSA

Afternoon Chair: Peter Caines

12:45-1 pm.	A. Friedman & W. Miller IMA	Welcome and orientation
1-1:30 pm	Cornelis A. Los University of Florida	A scientific view of economic data analysis (Kalman's theory for the identification of linear relations applied)

Abstract. Identification of systems from data is one of the basic problems of science and, automatically, a central problem of system theory. When the data is exact, the problem is well understood; in principle, since Newton ("hypotheses non fingo"). When the data is noisy, attempts have been made to deal with the problem for more than a century, but the results (Galton's "regression") are wrong or at least unsatisfactory. The reason is diagnosed to be a problem of prejudice. This means,
(i) in mathematics: asking the wrong questions (so-called "ill-posed problems", e.g. Tikhonov's numerical computation example);
(ii) in econometrics: assuming a model without reference to the data and without evidence that the data was generated by such a model (e.g., the Cobb-Douglas production function), and so misusing the word "identification";
(iii) in statistics: assuming that any data is the result of independent random sampling (the "standard statistical prejudice"), and then implementing the nonidentifying maximum likelihood method.
In all cases, the difficulty is that additional, ad-hod assumptions are imposed on the data, which in effect means assuming more data than there is. The results of such analyses usualy depend on the prejudices and not on the data.
Prejudice-free identification means that the data is allowed to speak for itself. How this can be done will be illustrated by the analysis of the "regression" problem. A new formulation of this problem will be presented (essentially the problem of defining the rank of a nonnegative definite matrix), from which new methods for prejudice-free identification have been deduced. This implies, for the first time since Gauss, the development of new theorems (Kalman) concerning least squares.
The emphasis in this paper will be on explaining what went wrong with "regression" analysis (and its derivatives) and on illustrating the new theorems with examples partly drawn from the academic (mathematical and economic literature and partly from empirical (Wallstreet) practice.

1:30-2 pm	B. Hanzon Free University of Amsterdam	On parameter-independent characterizations of the structure of a linear dynamical model

Abstract. Often the structure of a model is described by putting certain parameters equal to zero or one (or some other fixed value). For several reasons (to gain better understanding and to be able to apply overlapping parametrization methods etc.) it is desirable to have parameter-independent characterizations of such a structure.One approach is to study the Hankel matrix of a linear dynamical model. It is independent of the parametrization of the model. Its linear algebraic structure can reveal many of the well-known determinants of the structure, like the McMillan degree, the Kronecker indices, the Cauchy index and the degrees p, q of an ARMA(p,q) representation. Another approach takes a more geometrical point of view. It is argued that if one considers the class of all models with some given stucture (for instance the maximal delay in each of the equations of a multivariable ARMA model) then one has effectively also the boundaries in the model set (within any positive tolerance level). Therefore we will take these boundaries into account. E.g., for multivariable ARMA models we are led to the specialization order.

The number and choice of inputs and outputs are part of the structure of a model. Taking this into account as well, leads to a nice compact geometrical set-up for families of linear systems. Some examples will be given of how a family of systems with a certain structure looks like geometrically. The structure of the system is reflected in the geometrical structure of the family. There are direct links with questions of (overlapping) parametrizations, model order reduction and recursive and nonrecursive system identification.

2:00 pm	A. Lindquist Royal Inst. of Tech., Stockholm	Stochastic realization theory & factor analysis in TSA
3-3:30 pm	Andrea Gombani Corso Stati Uniti 4, Padova	Approximate stochastic realizations

Abstract: The problem we consider here occurs quite frequently in the construction of Markovian representations of a stochastic process y. There is a complete and general theory (see e.g., Lindquist, Picci [1]) to construct an exact stochastic realization of y, which makes use of the factorization of the spectral density $F(z)$. Nevertheless, if the degree of the density is very high, the realization we obtain is not very useful for computational purposes. This sometimes happens because, in presence of noise in the data, the estimation procedure for the density generates some unnecessary poles. The question we try to answer in this paper is whether these redundant poles can be eliminated through some reasonable approximation procedure. The idea is to start with an exact realization (no matter how large) of the process y, and then seek an approximate submodel (in the sense explained below) within the state space of this original model. The submodel which best represents y within all submodels of a fixed degree k is our approximant. This yields an interesting representation of a Markovian space through a Markovian basis, and sets up a correspondence of this basis with the Malmquist basis in the spectral domain ([2]). Then it is shown that a minimal realization can be obtained with a very simple algorithm of polynomial from a nonminimal one, and that this algorithm can be extended to give an approximate realization of fixed degree k (see [3]). We also show that different realizations yield different approximation errors, and discuss how to choose the representation which gives the best approximant.

[1] Lindquist A., Picci G., Realization Theory for Multivariate Stationary Gaussian Processes, SIAM J. Control and Optimization, Vol 23, No. 6, 1985, 809-857. [2] Nikol'skii, N.K., Treatise on the shift operator, Spinger-Verlag, 1986. [3] Gombani A., Consistent approximations of linear stochastic models, SIAM Journal on Control and Optimization, 27, 1989, 83-107.

Joint work with Claudia Polini.

4:00 pm	Vincent Hall 502 (The IMA Lounge)	IMA Tea (and more!)

Tuesday, July 24

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Morning Topic: Complexity in System Identification & TSA

Morning Chair: Manfred Deistler

9:30-10 am	L. Gérencsér McGill University	Stochastic complexity and modelling

Abstract: We present the highlights of the theory of stochastic complexity as developed in the last few years, with special attential to the problem of modelling linear stochastic systems. We discuss the effect of the uncertainty due to estimation of parameters onto prediction errors (Davisson's formula), and we also discuss the basic inequality of the theory (Rissanen, Ann. of Stat's). Several almost sure asymptotic results for a computable version of the so-called predictive stochastic complexity will be given, both for ARMA processes and for multivariable systems. Recent applications of the theory of stochastic complexity in cluster analysis and computer vision indicate that a particularly exciting trend of the theory is the analysis of nonparametric problems. As an illustration we give asymptotic results of the approximation of linear stochastic systems by an $AR(\infty)$ system.

10-10:30 am	C.Z. Wei University of Maryland	On predictive least squares principles
10:30 am	Coffee Break	Reception Room EE/CS 3-176
11-11:30 am	J. Baikovicius & L. Gérencsér McGill University	Change point detection in a stochastic complexity framework

Abstract: We present a new method for solving the change point detection problem for ARMA systems which are assumed to have a slow and non-decaying drift after the change occurs. The proposed technique is inspired by the stochastic complexity theory, which gives a basis of comparison of different models with different change point times. Some partial results on the analysis of the estimator are stated. Several simulations are included which show that the approach exhibits surprisingly good detection capabilities. They also illustrate the robustness of the detectors with respect to a window size w and the rate of change of the slowly time-varying system.

11:30-Noon	J.M. Maciejowski Cambridge University	Balanced realizations, linear systems, and identification

Abstract. We have had a program of research into the use of balanced realizations for system identification for some time. This talk will review the motivation for this, the results already published, and give some account of current work.

The basic idea is to identify linear systems and time series in state-space form, and to use balanced realizations as canonical forms, rather than the more usual canonical forms based on selecting linearly independent rows from a Hankel matrix. Perceived possible advantages of doing this are (1) that it may be easier to handle changes in assumptions about the McMillan degree, (we do not wish to assume that this is known a priori), and (2) that better performance of estimation may result, essentially because of better numerical conditioning.

We have obtained a lot of new results in system theory, which are directly useful for system identification, but a lot is still left to do. For example, even points (1) and (2) above are by no means established.

The fundamental result is that balanced realizations are indeed true canonical forms for linear systems, and that we have explicit parametrizations for these realizations. Furthermore, similar balanced canonical forms and parametrizations can be obtained for several sub-classes of linear systems. The most important ones for identification are. asymptotically stable systems, minimum phase systems, and predictors. So we have a parametrization, for instance, which has the property that as the parameters range over a simple open subset of Euclidean space, generates predictors of given McMillan degree, there are no nasty hypersurfaces at which the McMillan degree may drop. The most important implication of this is that parameter estimation can be performed using unconstrained optimization. All the results of this type apply to multi-input, multi-output systems.

The set of linear systems of given McMillan degree and input-output dimensions is known to be a differentiable manifold. We are using our balanced parametrizations to investigate the Riemannian geometry of this manifold. Exploiting results obtained by Hanzon, we use computer algebra to compute Riemannian metrics, curvature tensors, etc. The purpose of this is both to try to obtain an understanding of the intrinsic geometry, and to develop parameter estimation algorithms which take account of that geometry - computing gradients which are 'intrinsic' to the manifold, for example. To date, everything has been done using an L_2 norm of systems. We hope to investigate other norms in the future.

It was established a long time ago, by Kalman and Hazewinkel, that the set of (multivariable) linear systems of a given McMillan degree cannot be parametrized by a single, continuous canonical form. The system identification problem therefore includes not only the problem of estimating the McMillan degree, but also of estimating further structure parameters, which determine a particular cell of any parametrization. For the last 15 years 'overlapping' parametrizations have usually been considered to be preferable for identification, because they allow identification to be started in any component, and the results to be used for selection of a better component. Our balanced parametrizations are not overlapping; on the other hand, they do give a decomposition of the manifold of systems into cells, each of which is diffeomorphic to Euclidean space. The number of cells is very large, and considerably larger than the number obtained with previously suggested parametrizations. In mitigation of this, many of the components are clearly 'non-generic', in the sense that they are associated with very special input-output properties, and initial indications are that the selection of a correct cell is not particularly difficult.

Nevertheless, there remains a problem of structure selection. As a tentative connection between this problem, our work to date, and the question of complexity, we point out that (one version of) Rissanen's Minimum Description Length principle takes account of the intrinsic geometry of the manifold of linear systems, and that we can in principle compute the relevant quantity exactly, without having to estimate it from the performance of the estimator.

Joint work with R.J.Ober and B.P.McGinnie.

Afternoon Topic: Engineering & TSA

2:00 pm	Christopher A. Sims University of Minnesota	Applying the likelihood principle to inference about possibly nonstationary time series

Abstract: The likelihood principle conflicts with what has become common practice in econometric analysis of possibly nonstationary time series. Either the likelihood principle needs modification, or our practices in statistical analysis and reporting do. Some of the most unsettling implications of the likelihood principle are avoided if we recognize that we seldom are dealing with a complete catalog of possible models and that computation is not free. Thus we should report absolute likelihood functions, not merely normalized likelihood functions, and should recognize that likelihood functions can be summaries of computations rather than replacements for the sample data. But this leaves unchanged the most important implications of the likelihood principle for nonstationary models - that test statistics constructed from special distribution theory conditioned on nonstationarity are unnecessary and misleading. The claim that hypothesis testing is an advantage in that it obtains approximate asymptotic theoretic semiparametric assumptions is shows to be spurious. Partial results toward a semiparametric asymptotics for the likelihood function in nonstationary models are presented.

3:00 pm	Coffee Break	Reception Room EE/CS 3-176
3:15-3:45 pm	Eric Ghysels University of Montreal	On the economics and econometrics of seasonality
3:45-4:15 pm	John Geweke Duke University	Inference and forecasting for imprecisely measured deterministic nonlinear time series

Abstract: Inference and forecasting for the tent map and logicstic processes are considered for the case in which the time series is observed subject to measurement error. These simple models provide paradigms for more complex and realistic deterministic nonlinear models. Several novel findings are reported.

(1) The likelihood function is characterized by local maxima whose number is on the order of L^{2N}, where L is the Lyapunov exponent and N is sample size. Yet virtually all of the mass is concentrated in neighborhoods of a few of these points whose areas are on the order of L^{-N}. Graphical presentations indicate the influence of sample size, the Lyapunov exponent, and the severity of measurement error on the likelihood function.

(2) Steepest ascent and conventional grid methods cannot locate mass points of the likelihood function. New, adaptive grid methods developed specifically for the models succeed in doing so.

(3) The adaptive grid methods permit the construction of exact posterior densities for the unobserved signals, and predictive densities for future signals. The length of the interquartile range for signal at time t is proportional to L^{t-N}, which has important implications for sampling and forecasting.

Wednesday, July 25

Unless otherwise stated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Morning Topic: Engineering & TSA

9:30 am	John Rust University of Wisconsin, Madison	On the optimal retirement of older male workers
10:30 am	Coffee Break	Reception Room EE/CS 3-176
11-11:30 am	Mark W. Watson Northwestern University	Measures of fit for calibrated models

Abstract: This paper discusses measures of fit for dynamic economic models. For concreteness, consider an economic model which describes the evolution of an $n \times 1$ vector of variables x_t which is covariance stationary with autocovariance generating function (acgf) $A_x(z)$. The empirical counterparts of x_t are denoted y_t whose acgf is denoted by $A_y(z)$. The question under consideration is: Does the model generate data that "looks like" the actual data? Or, in the context of the setup described above: is $A_x(z)$ close to $A_y(z)$? This paper proposes an answer to the question by asking how much "error" has to be added to x_t so the acgf x_T+error matches the acgf of y_t. The answer depends on the assumed cross covariances between the error and x_t and y_t. This paper proposes a representation of the joint model-data-error process in which the variance of error minimized. This representation is used to construct measures of fit for the model analogous to R^2 measures used in linear regression.

11:30-Noon	Ruey S. Tsay University of Chicago	Model specification in multivariate time series analysis

Abstract. We propose methods for solving the problem: How to specify an appropriate yet parsimonious vector ARMA model for a given multivariate time series? By considering contemporaneous linear transformations of the vector process, we introduce the concept of *scalar component models* within the vector ARMA framework (a) to reveal possibly hidden, simplifying structures of the process, (b) to achieve parsimony in parameterization, and (c) to identify the exchangeable components. The simplifying structures are of particular importance in the analysis of multivariate time series because they are often not obvious from the observed data but can be used to find parsimonious models that can adequately represent the process under study. Consequently, in model specification we emphasize not only the order determination but also the detailed structure of a vector process. The analytical tool we use to search for scalar component models is a canonical correlation analysis of vector processes. The paper also discusses the identifiability of ARMA model and properties of the statistics involved in model specification. Finally, we illustrate the proposed procedures via two real examples.

Afternoon Topic: Stochastic Adaptive Control of Time-Varying Systems

Afternoon Chair: Will Gersch

1:00 pm	Sean P. Meyn University of Illinois, Urbana	Estimation and control of time varying systems: A Markov chain analysis of stability and performance

Abstract. We consider the problem of simultaneously controlling, and estimating the parameters of a linear time varying stochastic system. The time variations prevent an application of the classical least squares algorithm, which leads us to consider the Kalman filter based estimation algorithm which has recently been the subject of much interest.

Using recent results from the theory of Markov chains and from nonlinear control theory, we obtain geometric ergodicity of a Markovian state process. This allows a detailed description of the statistics of the output and parameter estimation error processes of the system.

In particular, we demonstrate that

(i) The Central Limit Theorem and Law of Large Numbers is valid for the stochastic processes subject to analysis;

(ii) The expectation of the square of the output and parameter estimation error processes converge to their expectation with respect to an invariant probability at a geometric rate;

(iii) The steady state expectation of the mean square parameter estimation error converges to zero as the disturbances converge to zero under a persistence of excitation condition.

The methods used in the stability proof, and in the analysis of the Markovian state process are general, and are shown to have bearing on other topics in time series analysis. In particular, it is shown that the techniques provide new results for a class of bilinear time series models.

2:00 pm	Coffee Break	Reception Room EE/CS 3-176

2:15-2:45 pm	Peter E. Caines McGill University	On the adaptive stabilization and ergodic behaviour of linear stochastic systems with jump Markov parameters

Abstract: We consider the situation where a completely observed stochastic process $y_t, t \in \mathbf{R}$, is generated by a linear stochastic system whose unobserved parameters constitute a Markov process or evolving on a finite set Θ.

As in [1, 2], we use the Wonham filter to generate the posteriori probability distribution of θ_t given the observations. These estimates are then used to generate a class of feedback control laws which are time independent. A Lyapunov function argument then establishes (subject to limits on the variations of the parameters) the boundedness of the sequence of second moments of the state process and hence, by the Beneš-Saperstone Theorem, the existence of an invariant probability measure for the state process (y_t, θ_t) of the system. Finally, we verify a Lie algebraic condition implying the hypo-ellipticity of the diffusion operator of the system process, hence we establish the uniqueness and smoothness of the invariant measure for general initial conditions.

References

1. P.E. Caines, H.F. Chen, Optimal Adaptive LQG Control for Systems with Finite State Process Parameters *IEEE Transactions on Automatic Control*, Vol. AC-30, Feb. 1985, pp. 185-189
2. H.F. Chen, P.E. Caines, On the Adaptive Stabilization of Linear Stochastic Systems with Jump Process Parameters, Proc. of 1989 *IEEE Control Systems Society Conference on Decision and Control*, pp. 742-745

This is joint work with K. Nassiri-Toussi.

2:45-3:15 pm	Wei Ren . University of Illinois, Urbana	The convergence of parallel model adaptation schemes in the presence of colored noise

Abstract. We establish the long standing conjecture of the global convergence and parameter unbiasedness of the output error identification and adaptive IIR filtering schemes in the presence of independent additive colored noise. The algorithms considered employ a projection of the parameter estimates onto a compact convex set containing the true parameters. The colored noise is allowed to be a general nonstationary moving average noise of finite but unbounded order. An adaptive feedforward control scheme, which is a natural extension of adaptive filtering, is also discussed.

Joint work with P.R. Kumar.

3:15-3:45 pm	H.F. Chen Academia Sinica, Beijing	Convergence of Aström-Wittenmark's self-tuning regulator and related topics

Abstract: Let the system be described by an m-dimensional ARMAX model

$$A(z)y_n = B(z)u_{n-1} + C(z)w_n, \quad n \geq 0, \quad (zy_n = y_{n-1})$$

with unknown coefficient

$$\theta^\tau = [-A_1 \ldots - A_p \; B_1 \ldots B_q \; C_1 \ldots C_r],$$

where p, q and r are upper bounds for orders of polynomial matrices $A(z), B(z)$ and $C(z)$ respectively.
The problem discussed here is to design adaptive control in order for the system output $\{y_n\}$ to track a given bounded reference signal $\{y_n^*\}$.
For the special case where $m = 1, y^* \equiv 0, C(z) = 1$ and B_1 is known, the self-tuning regulator proposed by Aström and Wittenmark (1973) is characterized by 1) the unknown coefficient is estimated by the recursive least squares (LS) algorithm and 2) the open loop may be unstable.
Following the well-known work of Goodwin-Ramadge-Caines there has been a great effort devoted to analysing the convergence of various adaptive trackers, which can be grouped under four classes:
1) Trackers not based on the LS or ELS algorithm but on some of their modifications;
2) Trackers based on LS or ELS but with additional stability assumption on $A(z)$;
3) Trackers using parallel estimation algorithms in addition to LS or ELS;
4) Trackers based on LS but under assumptions that $C(z) = I$ and $\{w_n\}$ is Gaussian white noise. The difficulty of this approach is that in the sample space of θ there is an exceptional set of Lebesgue measure zero which may vary with initial values of the algorithm. Whenever the system coefficient θ falls into this set, the convergence analysis fails for almost all ω.
Thus, the convergence of the ELS-based adaptive trackers, even the convergence of the original Aström-Wittenmark's self-tuning regulator has been an open problem for years. This problem is solved in the present paper.
We will use only the ELS algorithm without any modification and will work under the following standard set of conditions:
(A1) $\{w_n, \mathsf{F}_n\}$ is a martingale difference sequence with

$$\sup_{n\geq 0} E[\|w_{n=1}\|^{\beta}|\mathsf{F}_n] < \infty \text{ a.s. for some } \beta > 2$$

and

$$\lim_{n\to\infty} \frac{1}{n}\sum_{i=1}^{n} w_i w_i^T \overset{\Delta}{=} R > 0 \text{ a.s. };$$

(A2) $C^{-1}(e^{i\lambda}) + C^{-\tau}(e^{-i\lambda}) - I > 0, \quad \forall\lambda \in [0, 2\pi]$;
(A3) $B(z)$ is of minimum phase.
Within this framework the following results are presented in this paper.
1) The Aström Wittenmark's self-tuning tracking (y_n^* may differ from 0) is convergent and optimal. The convergence rate of tracking error is derived as well.
2) When B_1 is unknown the adaptive control is given so that the adaptive tracker is convergent and optimal.
3) Adaptive tracker with diminishing excitation technique applied gives convergence rates for both the parameter estimation error and the tracking error.
Joint work with L. Guo.

3:45-4:15 pm L. Guo — Identification and adaptive control for time-varying stochastic systems
Academia Sinica, Beijing

Abstract: Consider the following time-varying stochastic model

$$y_{n+1} = \phi_n^{\tau}\theta_n + v_{n+1}$$

where y_n, ϕ_n and v_n are the system output, regression vector and random noise, respectively.
Most of the previous work done in the area of adaptive estimation and control is concerned with the case of constant parameters, i.e. $\theta_n \equiv \theta$. In the time-varying parameter case, few concrete results are available. In this paper, we will present some precise results on both identification and adaptive control for time-varying systems.
a). Parameter tracking. Let $\hat{\theta}_n$ be the estimate for θ_n, which is generated by either the Kalman filtering algorithm or the lease mean squares (LMS) algorithm. It is shown that if $\{\phi_n\}$ satisfies a "conditional richness" condition, then the tracking error $E\|\hat{\theta}_n - \theta_n\|^r, r \in (0, s)$, is of order $O([\sigma_s]^{r/s})$, where

$$\sigma_s = \sup_{n\geq 0} E\{\|v_n\|^s + \|\theta_n - \theta_{n-1}\|^s\}, \quad s > 0$$

The main feature of this result is that no stationarity and independence assumptions are imposed on the system signals $\{\phi_n, \theta_n, v_n\}$.

b). **Adaptive control.** We consider the case where

$$\phi_n = [y_n, \ldots, y_{n-p+1}, u_n, \ldots, u_{n-q+1}]^\tau$$

The objective is to design an adaptive control such that the output $\{y_n\}$ is bounded in an average sense. The input u_n is taken as the "certainty equivalence" minimum variance control, which is solved from

$$\phi_n^\tau \hat{\theta}_n = 0$$

where $\{\hat{\theta}_n\}$ is generated by a projected gradient algorithm with small step size. It is shown that if the unknown parameter θ_n varies slowly in some sense, then the closed-loop system in stable. Both the parameter process and the random noise are allowed to be e.g., a constant vector plus an ARMA process.

Joint work with H.F. Chen.

4:15-4:45 pm	Jian Liu University of British Columbia	On some nonlinear models

Abstract: Beginning with a brief introduction of nonlinear time series models, I address problems such as finite parameterization and stability, invertibility, parametric inference and identification of bilinear systems.

Thursday, July 26

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Morning Topic: System Identification & TSA I

9:30 am	Jan C. Willems University of Groningen	Continuous parametrization of linear systems

Abstract: This talk describes an approach to the problem of obtaining a parametrization of the behavior of linear systems in which the continuity of the behavior corresponds to continuity in the parameters. This problem occurs both in stochastic and deterministic systems and in discrete-time and continuous-time systems. However, in this talk we will treat only discrete-time deterministic systems. Two results will be presented: First, that AR behavioral equations (linear constant coefficient difference equations) provide a continuous parametrization of the resulting behaviors. Second, that ARNA-behavioral equations (linear constant coefficient difference equations involving both manifest and latent variables) provide a continuous parametrization if the ARMA-system is observable.

10:30 am	Coffee Break	Reception Room EE/CS 3-176
11:00 am	Will Gersch University of Hawaii	Smoothness priors

Abstract. Several time series signal extraction/optimal smoothing problems are considered from a "smoothness priors" point of view. The origin of the subject is a smoothing problem posed by Whittaker (1923). It is developed here both from a stochastic regression linear model-Gaussian disturbances framework, and a reproducing kernel Hilbert space, (RKHS), framework. We do power spectral density and transfer function estimation for stationary time series and also model nonstationary mean and nonstationary covariance times series. Also, we show the relationship of smoothness priors to spline and partial spline smoothing. Smoothness priors distributions on the model parameters are expressed either in terms of time domain stochastic difference equation or frequency domain constraints. A small number of (hyper)-parameters specify very complex time series behavior. The critical computation is the likelihood of the Bayesian model. Examples are shown.

Afternoon Topic: Engineering & TSA

Afternoon Chair: Jim Stock

1:00 pm		OPEN FORUM

Abstract: Open Forum for general discussion of new directions of interdisciplinary research in time series analysis between economists, engineers, statisticians.

2:00 pm	Herman K. van Dijk Erasmus University, Rotterdam	Posterior analysis of possibly integrated time series with an application to real exchange rates and real gross national product

Abstract: In the econometric literature on time series that are possibly integrated two issues are of particular interest: model representation and the distribution of test statistics when there might be a unit root. Bayesian statistical inference for univariate time series models is considered where one of the autoregressive roots is close to or equals unity. Classical sampling theory for this type of models is hampered by the vast differences between asymptotic approximations in the stationary case and under the unit root hypothesis. Because of this dichotomy one has to decide early on in an empirical study whether a given time series is stationary or not. It is shown that a Bayesian approach allows for a smooth continuous transition between stationary and integrated time series models. A normal prior on the unconditional mean is specified with a variance that continuously increases as an autoregressive root approaches unity, in which case the variance becomes infinite.

Empirical results are presented for time series of monthly real exchange rates of eight countries and of annual real per capita GNP for 16 OECD countries.

3:00 pm	Coffee Break	Reception Room EE/CS 3-176
3:15-3:45 pm	Charles H. Whiteman University of Iowa	Unit roots in U.S. macroeconomic time series: A survey of classical and Bayesian perspectives

Abstract: The issue of whether macroeconomic time series such as GNP follow autoregressive (AR) processes which contain unit roots has several theoretical and statistical implications which have led to the development and widespread application of "unit root" tests. A stylized fact which has emerged from applications of classical unit root tests is that it is difficult to reject the null for a wide range of U.S. time series (e.g., see Nelson and Plosser (1982)).

However, in recent work (DeJong, Nankervis, Savin, and Whiteman 1989a,b) we have shown that the power of these tests against plausible trend-stationary alternatives is quite low - often much less than 50%. Further, plausible trend-stationarity hypotheses are often not rejected by the data, thus nonrejections of the unit root hypothesis must be interpreted with caution (see also Schwert (1989)).

Alternatively, in DeJong and Whiteman (1989a,b) we developed a set of Bayesian procedures designed to assess the relative plausibility of unit root and trend-stationary representations within the framework generally utilized in the Classical investigations. The procedures generate inferences which are conditional, given observed data. Posterior distributions of dominant AR roots generally indicate that trend-stationary representations are strongly supported by U.S. time series over unit root alternatives, even when strong prior support in favor of the unit root models is specified.

One drawback of the DeJong-Whiteman (1989a,b) procedures is that to maintain comparability to the Classical approaches, it was necessary to utilize a specification which made the unit root a set of measure zero in the parameter space. In DeJong-Whiteman (1990a) we adopted an alternative specification which makes the trend stationarity specification a point on a continuum of unit root specifications. This involved differencing the data and computing the posterior distribution of the dominant moving average (MA) root - a unit MA root indicates the original series was trend stationary, other values indicate that it contained a unit root. These posteriors continue to suggest that (for the single series we investigated, U.S. Real GNP) the trend-stationarity specification is more plausible than the unit root specification.

Classical skeptics might argue that the posterior distributions we calculated are somehow contaminated by the tendency of MA parameter estimates to "pile up" spuriously at unity. However, in DeJong-Whiteman (1990b) we showed that while Classical sampling distributions are plagued by pileup, Bayesian posterior distributions are not.

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Joint work with David N. DeJong.

3:45-4:15 pm	Peter Schotman Erasmus University	Excess volatility and excess smoothness of long term interest rates

Abstract. The paper re-examines volatility tests of the expectations model of the term structure of interest rates. The sensitivity of the tests with respect to assumptions on the presence of unit roots is investigated in particular. The restrictions of the expectations model are derived in a general multivariate MA representation of the time series process of interest rates. The paper employs Bayesian techniques to compute the distributions of the test statistics efficiently and exactly. Three different tests of the restrictions implied by the expectations model are developed. (1) a test conditional on stationarity of the bivariate process of long and short term interest rate time series, (2) a test conditional on co-integration between long and short rates; (3) a test that takes account of the uncertainty with regard to the presence of unit roots.

4:15-4:45 pm	A. Marcet & R. Marimor Carnegie Mellon U. & U. of Minnesota	Communication, commitment and growth

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Friday, July 27

Unless otherwise indicated, the talks today are in Conference Hall EE/CS 3-180

9:15 am	Coffee Break	Reception Room EE/CS 3-176

Morning Topic: Engineering & TSA

Morning Chair: John Geweke

9:30 am	Ron Gallant & George Tauchen N. Carolina St. & Duke Universities	Nonlinear time series analysis: Estimation and simulation

Abstract. We describe a method of nonlinear time series analysis suitable for nonlinear, stationary processes whose one-step-ahead conditional density depends on a finite number of lags. Such a density can be represented as a Hermite expansion. Certain parameters of the expansion can be set to imply sharp restrictions on the process such as a pure VAR, a pure ARCH, a nonlinear process with homogeneous innovations, etc.

The model is fitted using maximum likelihood procedures on a truncated expansion together with a model selection strategy that determines the truncation point. The estimator is consistent for the true density with respect to a strong norm. The norm is strong enough to imply consistency of evaluation evaluation functionals and moments of the conditional density. We describe a method of simulating from the density. Simulation can be used for a great variety of applications. In this paper, we give special attention to using simulations to set sup-norm confidence bands. Software, in the form of a 5-1/4 2S/2D DOS formatted diskette, is available from the authors. An appendix to this paper describes its use.

10:30 am	Coffee Break	Reception Room EE/CS 3-176

11-11:30 am	James Stock Harvard University	Deciding between I(1) and I(0)

Abstract: A class of procedures is developed to distinguish time series that are integrated of order zero (I(0)) from those that are integrated of order one (I(1)), where I(0) and I(1) are defined nonparametrically in terms of weak properties of the Wold representation of the process. These procedures entail the evaluation of the likelihood of certain statistics, first under the hypothesis that the series is I(0), then under the I(1) hypothesis. The asymptotic distribution of these statistics does not depend on the nuisance parameters, although it does depend on whether the process is I(1) or I(0). Asymptotically, the I(0) and I(1) distributions diverge, so the likelihood ratio (for these statistics) provides a consistent basis for deciding whether the process is I(1) or I(0). Alternatively, a posterior odds ratio can be computed, where the prior distribution needs to be defined only in terms of the points "I(0)" and "I(1)", rather than in terms of parametric specifications within the class of I(0) and I(1) processes.

11:30-Noon	Fallaw Sowell Carnegie Mellon University	Modeling the long run behavior of time series

Abstract: Several researchers have recently been concerned with estimating the low frequency or long run behavior of economic time series. The ARMA models, often used in these studies, are not well suited to capture the long run behavior of a time series. A more appropriate choice is the fractionally integrated ARMA model. Its special long run characteristics are reviewed and contrasted with measures of long run behavior that are based on the spectral density at frequency zero. As an application of this approach, the long run behavior of post war real GNP is investigated.

Afternoon Topic: System Identification & TSA II

1:00 pm	Manfred Deistler Technische U. Wien, Austria	Identification of dynamic systems from noisy data

Abstract: Linear dynamic errors-in-variables (or factor-) models in the framework of stationary processes are considered. The noise process is assumed to have a diagonal spectral density. We analyse the relation between the (population) second moments of the observations and the system- and noise characteristics, of particular interest are the number of equations (or the number of factors) and a description of the set of all systems compatible with the second moments of the observations. Special emphasis is put on the cases of a single equation and of a single factor. The problems considered arise in the context of identification and precede estimation.

2:00 pm	Coffee Break	Reception Room EE/CS 3-176
2:15-2:45 pm	Tze L. Lai Stanford University	Asymptotically efficient recursive identification algorithms in time series models and linear stochastic systems
2:45-3:15 pm	D. Guégan U. Paris-Nord, Villetaneuse	Identification and forecasting in non linear stochastic processes

Abstract: For some non linear stochastic processes $(X(t))$ (bilinear models, ARCH models, state affine polynomial models) we investigate problems concerning:

from one part the different methods of identification. (Cumulants of some order, corner method, Glasbey statistic, canonical analysis), and,
from another part the analytical expression of the non linear predictor $E[X(t+h)|X(s), s \leq t]$, its error and the variance of its error. Developments concerning the confidence intervals for the last predictor is given from two different methods.

CURRENT IMA PARTICIPANTS

POSTDOCTORAL MEMBERS FOR 1989-90 PROGRAM YEAR

NAME	PREVIOUS/PRESENT INSTITUTION
R. Scott Dumas	SUNY, Albany
Mohamed Elbialy	University of Cincinnati
Michael S. Jolly	Princeton University
Maciej Krupa	University of Houston
Stephane Laederich	Boston University
Debra Lewis	Cornell University
Kening Lu	Georgia Institute of Technology
Mary Silber	UC, Berkeley
Matthew W. Stafford	Loyola University
Mary Lou Zeeman	MIT

TIME SERIES PROGRAM AND SHORT TERM VISITORS IN RESIDENCE

Florin Avram	Northeastern University	Jul 9 - 15
Babs Ayeni	3M	Jul 1-7, 25-27
Jimmy Baikovicius	McGill University	Jul 2 - 29
Marilena Barbieri	U. Degli Studi di Roma	Jul 3 - 28
John Baxter	University of Minnesota	
Karim Benhenni	Northern Illinois University	Jul 14 - 21
Jan Beran	Texas A&M University	Jul 8 - 15
R.J. Bhansali	University of Liverpool	Jul 15 - 28
J.A.R. Blais	University of Calgary	Jul 1 - 26
P.M. Bleher	Keldysh Inst. App. Math, Moscow	Jul 7 - 15
Mary Ellen Bock	National Science Foundation	Jul 1-8, 14-22
Jay Briedt	Colorado State University	Jul 1 - Jul 27
David R. Brillinger	UC Berkeley	Jun 30 - Jul 6
Peter J. Brockwell	Colorado State University	Jul 15 - 22
Peter E. Caines	McGill University	Jul 1-9, Jul 25-28
Quanwei Cao	University of Chicago	Jul 1 - 7
Ed Carlstein	University of North Carolina	Jul 16 - 20
Martin Casdagli	Los Alamos Nat. Labs.	Jul 1 - 27
K.S Chan	University of Chicago	Jul 1 - 6
Ngai Hang Chan	Indiana University	Jul 24 - 28
Han Fu Chen	Academia Sinica, Beijing	Jul 14 - 28
Rong Chen	Texas A&M University	Jul 1-6, 15 - 20
Byong Seon Choi	Yonsei University	Jul 2 - 27
Renata Cioczek	Boston University	Jul 7 - 21
H. Cohn	University of Melbourne	Jul 1 - 13
Nuno Crato	University of Delaware	Jul 1 - 28
Jonathon D. Cryer	University of Iowa	Jul 15 - 20
Richard A. Davis	Colorado State University	Jul 15 - 22
Yuri A. Davydov	Leningrad State University	Jul 1 - 18

Herold Dehling	Groningen	Jul 2 - 20
M. Deistler	Technische U. Wien, Austria	Jul 20 - 28
Kevin Dooley	University of Minnesota	Jul 9, 16
William Dunsmuir	Bond University	Jul 2 - 26
Katherine B. Ensor	Rice University	Jul 15 - 27
Ludwig Fahrmeir	Universitat Regensburg	Jul 14 - 21
Robert V. Foutz	VPI&SU	Jul 14 - 20
Avner Friedman	IMA	
Wayne Fuller	Iowa State University	Jul 15 - 20
A. Ronald Gallant	North Carolina State University	Jul 21 - 27
Seymour Geisser	University of Minnesota	
Joseph Gerdiner	Michigan State University	Jul 26 - 27
Laszlo Gerencser	McGill University	Jul 1 - 28
W. Gersch	Naval Postgraduate School	Jul 21 - 27
John Geweke	Duke University	Jul 23 - 27
Eric Ghysels	University of Montreal	Jul 23 - 25
G.B. Giannakis	University of Virginia	Jul 1 - 9
A. Gombani	LADSEB - CNR, Padova, Italy	Jul 22 - 27
Victor Goodman	Indiana University	Jul 9 - 12
Patricia Grambsch	University of Minnesota	Jul 3 - 28
Charles A. Greenhall	Jet Propulsion Lab.	Jul 9 - 13
D. Guégan	Universite Paris-Nord, Villetaneuse	Jun 30-Jul 11, Jul 15-28
Lei Gou	Academia Sinica, Beijing	Jul 14 - 28
M. Guo	Worcester Polytechnic Inst.	Jun 30 - Jul 6
Ben Hanzon	Free University of Amsterdam	Jul 16 - 28
Keith Helmlinger	University of Minnesota	Jul 2 - 27
M.A. Herrero	U. Complutense	Jun 25 - Jul 22
A.J. Heunis	University of Waterloo	Jul 23 - 27
M. Hinich	University of Texas	Jul 1 - 6
Hwai-Chung Ho	Natl. Sun Yat-Sen U.	Jul 3 - 17
Clifford M. Hurvich	New York University	Jul 9 - 20
Naresh Jain	University of Minnesota	
Tae Jeon	Wayne State University	Jul 1 - 15
Don Johnson	Rice University	Jul 9 - 12
Z. Jurek	Wayne State University	Jul 6 - 13
Myron Katzoff	Nat. Ctr. Health Stats.	Jul 1 - 27
Mos Kaveh	University of Minnesota	
Michael Keane	Delft U. of Technology	Jul 7 - 14
B. Kedem	University of Maryland	Jul 16 - 20
Jim Kuelbs	University of Wisconsin	Jul 9 - 13
P. Kulkarni	University of South Alabama	Jul 15 - 21
Pat Kumar	University of Minesota	
Michael Lacey	Indiana University	Jul 7 - 13
Olivier Lafitte	Ecole Nationale Sup.	Jul 19 - 23
T.Z. Lai	Stanford University	Jul 23 - 27
Bruce Lee	University of Minnesota	Jul 17 - 20
Jack Lee	Bellcore	Jul 15 - 20
Yi-teh Lee	Bellcore	Jul 17 - 21
P.A.W. Lewis	Naval Postgraduate School	Jul 2 - 7
Keh-Shin Lii	UC Riverside	Jul 1 - 10
Anders Lindquist	Royal Inst. of Tech., Stockholm	Jul 22 - 26
Jian Liu	University of British Columbia	Jul 2 - 27
Shu-ing Liu	National Central U., Taiwan	Jul 15 - 27

Greta M. Ljung	MIT	Jul 14 - 20
Silvia Lopez	University of Maryland	Jul 15 - 22
Cornelius A. Los	Nomura Research Inst., New York	Jul 22 - 28
Jan M. Maciejowski	Cambridge University	Jul 23 - 29
Peter Major	Hungarian Academy of Sciences	Jul 3 - 20
Jovan Malisic	U. of Beograd	Jun 27 - Jul 28
Benoit Mandelbrot	IBM	Jul 8 - 13
V. Mandrekar	Michigan State University	Jul 1 - 7
Albert Marcet	Carnegie Mellon University	Jul 22 - 30
Andrew McDougall	Rutgers University	Jul 14 - 28
Eddie McKenzie	University of Strathclyde	Jul 1 - 13
J.M. Mendel	USC	Jul 4 - 6
Sean Meyn	Australian National University	Jul 20 - 26
A.G. Miamee	Hampton University	Jul 15 - 25
Willard Miller, Jr.	IMA	
Stefan Mittnik	SUNY Stony Brook	Jul 1 - 28
Luciano Molinari	Children's Hospital, Zurich	Jun 30-Jul 7, Jul 14-21
John Morrison	University of Delaware	Jul 1 - 31
Neerchal K. Nagaraj	University of Maryland	Jul 2 - 10
Sanjeev Naik	University of Illinois, Urbana	Jul 23 - 27
Dankit K. Nassiuma	University of Manitoba	Jul 15 - 27
C.L. Nikias	Northeastern University	Jul 1 - 4
George O'Brien	York University, Ontario	Jul 7 - 14
Stephen Orey	University of Minnesota	
T. Ozaki	Inst. of Stat. Math., Tokyo	Jul 1 - 28
Adrian Papamarcou	University of Maryland	Jul 7 - 13
George Papanicolaou	Courant Institute	Jun 30 - Jul 5
Emanuel Parzen	Texas A&M University	Jul 2 - 27
Joseph D. Petruccelli	Worcester Polytechnic Inst.	Jul 1 - 8
Jacques Peyriere	Universite de Paris Sud, Orsay	Jul 8 - 14
Percy Pierre	Prairie View A&M University	Jul 2 - 6
German Pliego	Purdue University	Jul 1 - 7
Dimitris Politis	Stanford University	Jul 1 - 7
Mohsen Pourahmadi	Northern Illinois University	Jul 1 - 20
Madan L. Puri	Indiana University	Jul 15 - 22
James Ramsey	New York University	Jul 17 - 20
M.B. Rao	North Dakota State University	Jul 1 - 6
T. Subba Rao	University of Manchester	Jul 1 - 13
Ravikanth	University of Illinois, Urbana	Jul 23 - 27
Gregory Reinsel	University of Wisconsin	Jul 16 - 20
Wei Ren	University of Illinois, Urbana	Jul 17 - 27
Peter Robinson	London School of Economics	Jul 13 - 17
Juan Romo	Universidad Compluteuse	Jul 16 - 28
Murray Rosenblatt	UC San Diego	Jul 1 - 10
Phil Rothman	New York University	Jul 1 - 6
Kalyan Roy	Indiana University	Jul 16 - 20
John Rust	University of Wisconsin	Jul 24 - 26
H. Salehi	Michigan State University	Jul 15 - 19
V.A. Samaranayake	University of Missouri, Rolla	Jul 1 - 28
Gennady Samorodnitsky	Cornell University	Jul 7 - 13
Tim Sauer	George Mason University	Jul 2 - 6
J. Scargle	NASA	Jul 1 - 13
Peter Schotman	Erasmus University	Jul 2 - 28

Eric Sheppard	University of Minnesota	Jul 16 - 19
Robert Shumway	UC Davis	Jul 15 - 18
J. Sidorowich	UC Santa Cruz	Jul 1 - 13
Christopher A. Sims	University of Minnesota	Jul 23 - 27
Milton Sobel	UC Santa barbara	Jul 16 - 18
Gerald Sobelman	University of Minnesota	Jul 2 - 27
Victor Solo	Johns Hopkins University	Jul 9 - 13
Fallaw Sowell	Carnegie Mellon University	Jul 22 - 27
James Stevens	Naval Postgraduate School	Jul 1 - 5
James Stock	UC Berkeley	Jul 23 - 27
David Stoffer	University of Pittsburgh	Jul 14 - 20
Shan Sun	Indiana University	Jul 15 - 22
T.C. Sun	Wayne State University	Jul 7 - 13
Mario Taboada	Cornell University	Mar 21 - Aug 10
Allen Tannenbaum	University of Minnesota	
Murad Taqqu	Boston University	Jul 8 - 17
George Tauchen	Duke University	Jul 22 - 26
G. Terdik	University of Arkansas	Jul 1 - 8
David Terman	Ohio State University	Jul 10 - 15
Norma Terrin	Carnegie Mellon University	Jul 8 - 20
Ahmed Tewfik	University of Minnesota	Jul 2 - 27
Lori A. Thombs	University of South Carolina	Jul 15 - 27
Howell Tong	University of Kent	Jul 2 - 7
Kinh Truong	University of North Carolina	Jul 14 - 20
Ruey Tsay	University of Chicago	Jul 19 - 25
Jitendra K. Tugnait	Auburn University	Jul 1 - 6
John W. Tukey	Princeton University	Jul 15 - 18
Zsuzsanna Vago	Tech. U. of Budapest	Jul 1 - 27
Herman van Dijk	Erasmus University, Rotterdam	Jul 19 - 27
Wim Vervaat	Catholic University, Nijmegen	Jul 7 - 14
Mark Watson	Northwestern University	Jul 23 - 26
Ed Waymire	Oregon State University	Jul 1 - 14
C.Z. Wei	University of Maryland	Jul 23 - 28
Charles Whiteman	University of Iowa	Jul 24 - 27
Jan C. Willems	Groningen University	Jul 23 - 27
Akiva Yaglom	Acad. Sciences, USSR	Jul 2 - 20
Yoshihiro Yajima	University of Tokyo	Jul 6 - 28
George Yin	Wayne State University	Jul 22 - 30
Scott Zeger	Johns Hopkins University	Jul 12 - 19
Nien Fan Zhang	Shell Development Co.	Jul 23 - 27
Guofu Zhou	Duke University	Jul 22 - 27