Program of the PhD Students in Signals & Systems Workshop
Melbourne 12-13 April, 2007

Venue: Brown Theatre, Level 1, EEE Building, The University of Melbourne
Dinner: Venue to be announced later
Organizer: Prof. Dragan Nesic (d.nesic@ee.unimelb.edu.au)
Supported by: ISSNIP (convenor A/Prof. M. Palaniswami)

IMPORTANT: If you intend to attend this workshop, please send an email no later than 30 March to Prof Dragan Nesic to register (this is needed for catering purposes). Presenters do not need to register.

NOTE: all talks are allocated 25 minutes (please allow 5 minutes for questions).

Program at a glance:

Thursday 12 April 2007	**Friday 13 April 2007**
9:30-9:55 Arrival/coffee	**9:00-10:40 Session 4** ***Nonlinear control***
9:55-10:00 Welcome	**10:40-11:00 Coffee Break**
10:00-12:05 Session 1 ***Bio-medical applications***	**11:00 - 12:40 Session 5** ***Signal processing and telecommunications***
12:05-1:30 Lunch Break	**12:40 - 2:00 Lunch Break**
1:30-3:10 Session 2 ***Networked control systems***	**2:00 - 3:40 Session 6** ***Optimization and numerical methods***
3:10-3:30 Coffee Break	**3:40-3:45 Farewell**
3:30-5:10 Session 3 ***Estimation and control***	
7:00pm Dinner (venue TBA)	

DAY 1

Times	Session 1, Thursday 10:00-12:05
10:00-10:25	**Jamie Granek (Melbourne),** ***EEG analysis to determine sound perception***
10:25-10:50	**Elma O'Sullivan-Greene (Melbourne),** ***Epileptic Seizure Prediction***
10:50-11:15	**Andrea Varsavsky (Melbourne),** ***Classification of Epileptic EEG***
11:15-11:40	**Craig O. Savage (Melbourne),** ***Random Genetic Analysis***
11:40-12:05	**Boris Godoy (Newcastle),** ***A model-based control strategy for Bioleaching Processes***
	Session 2, Thursday 1:30-3:10
1:30-1:55	**Milan Derpitch (Newcastle),** ***Sequential Quantization of Frame Expansions***
1:55-2:20	**Assaf Gurt (Melbourne),** ***Performance analysis of bit-rate-limited stochastic control systems with quantized state feedback***
2:20-2:45	**Tania Kamenev (Melbourne),** ***Robust stabilization of linear control systems with quantized feedback***
2:45-3:10	**Eduardo I. Silva (Newcastle),** ***Optimal Noise Shaping for Networked Control Systems***
	Session 3, Thursday 3:30-5:10
3:30-3:55	**Chih Feng Lee (Melbourne),** ***Identification of Disc Thickness Variation Using an Extremum Seeking Method***
3:55-4:20	**Hua Ouyang (ADFA, UNSW),** ***Guaranteed Cost State Estimation of Stochastic Uncertain Systems with Slope Bounded Nonlinearities via the use of Dynamic Multipliers***
4:20-4:45	**Rahul Sharma (Melbourne),** ***Fault and disturbance reconstruction in nonlinear systems with unknown inputs using sliding mode observers***
4:45-5:10	**Iskandar Mahmood (Newcastle),** ***Precise Tip Positioning of a Flexible Manipulator using Resonant Control***

DAY 2

Times	Session 4, Friday 9:00-10:40
9:00-9:25	**Bilal Ahmed (ADFA, UNSW),** ***Rotary Wing UAV Position Control using Backstepping***
9:25-9:50	**Christian Lovaas (Newcastle),** ***Robust Model Predictive Control of Input-Constrained Stable Systems with Unstructured Uncertainty***
9:50-10:15	**Germane Xavier Athanasius (ADFA, UNSW),** ***Switching strategy for Robust Decentralized Output Feedback Power System Controllers***
10:15-10:40	**William H. Moase (Melbourne),** ***Towards plant independence in extremum-seeking control***
	Session 5, Friday 11:00-12:40
11:00-11:25	**John Kitchen (DSTO),** ***Space-Time Wireless Communications Surveillance***
11:25-11:50	**Meng Wang (Newcastle),** ***OFDMA Uplink PAR Reduction via Tone Reservation***
11:50-12:15	**Alex Leong (Melbourne),** ***Probability of Error Analysis for Hidden Markov Model Filtering With Random Packet Loss***
12:15-12:40	**Cristian R. Rojas (Newcastle),** ***Frequency Localising Basis Functions for Wide-band System Identification: A Condition Number Bound for Output Error Systems***
	Session 6, Friday 2:00-3:40
2:00-2:25	**Huibo Ji (ANU),** ***A Globally Convergent Conjugate Gradient Method for Minimizing Self-Concordant Functions On Riemannian Manifolds***
2:25-2:50	**Yantao Feng (ANU),** ***An iterative procedure to compute nonnegative stabilizing smooth solutions to HJBI equations***
2:50-3:15	**Bahman Tahayori (Melbourne),** ***Optimal Input Design for MRI System***
3:15-3:40	**Gavin Buskes (Melbourne),** ***Reduced-order approximation in the mu-gap metric***

ABSTRACTS

- **Jamie Granek (University of Melbourne)**

Title: EEG analysis to determine sound perception

Abstract: Sinusoidal amplitude modulated sounds are used to evoke small sinusoidal electric fields in the head. The presence of these sinusoids are an indication of hearing function. The major task is detection of the sinusoid signal buried in background EEG activity 10 to 100 times its size. Both the signal and noise are modeled and statistical detection methods are applied to detect whether the signal is present and to estimate its parameters. An acquisition system with a graphical, user-friendly software interface has been created to allow future research by non-technical researchers.

- **Elma O'Sullivan-Greene (University of Melbourne)**

Title: Epileptic Seizure Prediction

Abstract: Epilepsy is a neurological disorder characterised by recurrent "seizures" and is associated with abnormal neuronal activity in the brain. Epilepsy the single most common serious neurological condition in the world today, with the World Health Organisation estimating that the prevalence of epilepsy varies across geographical regions within the range of 0.5% to 4% of the total population. The ability to predict seizures would have a profound impact on the quality of life of epilepsy suffers. An ideal solution would be the development of an implanted device, incorporating seizure prediction and an electric stimulation treatment, that could prevent a seizure from occurring once an imminent seizure is predicted. While electric stimulation treatment for epilepsy is already undergoing trial, no robust seizure prediction algorithm has been published to date. With this motivation for seizure prediction, this work aims in part to investigate a suitable algorithm for prediction of the onset of epileptic seizures. This work also aims to evaluate the current strategy of non-linear dynamical system approaches to seizure prediction and provide a theoretical framework with which to interpret these dynamical system measures as applied to electroencephalographic data. Electroencephalographic data is that resulting from recordings of the fluctuating electric fields of the brain.

- **Andrea Varsavsky (University of Melbourne)**

Title: Classification of Epileptic EEG

Abstract: Whilst being able to predict the onset of an epileptic seizure would have an enormous impact on the quality of life of a significant proportion of the population, the "simpler" problem of detection is far from suitably solved. State of the art patient-unspecific algorithms can only identify about 80% of epileptic seizures, and whilst

patient-specific modifications improve on this figure performance remains unacceptable for practical use in many situations.

This talk will outline the different uses of seizure detection, why there is need for better algorithms, and how these algorithms may be used as an alternative to seizure prediction in implantable devices. A strategy for better detection rates will also be introduced.

- **Craig O. Savage (University of Melbourne)**

Title: Random Genetic Analysis

Abstract: Gene expression is one a number of new analysis methods in cancer prediction. In the past, family histories were used to attempt to guess the genetic risk of an individual patient; today, we can gain some information about any given patient's DNA. However, finding the gene, or, more generally, set of genes that "best" predict the onset of breast cancer from a data set is akin to finding a needle in a haystack. One such data set is that of van't Veer et al. [3]. Those data represent 24481 individual genes from a set of 97 patients. Traditional data analysis involves several steps:

1. Partition the data into training and performance sets.
2. Develop an algorithm for cancer prediction based solely upon the training data.
3. Implement the algorithm on the performance data set.

Many algorithms search for a set of N "best" genes to explain the difference between the good and bad prognoses of breast cancer; van't Veer et al. sought a set of 70 genes. However, later analysis by Ein-Dor et al. [1] showed that repartitioning the data set into different training and performance sets yielded different sets of the 70 "best" genes. Furthermore, they note that there is little agreement in the set of "best" genes across different studies [1]. The research presented here uses the theory of random projections to perform data reduction and finds the "best" random dimension for classification. Results indicate that more consistent performance can be achieved by using fewer dimensions. This talk focuses on the trade-offs made possible by the random projection method, as well as the underlying mathematical theory, the Johnson-Lindenstrass Theorem [2], and other concerns for data analysis in "high" dimensions (i.e. problems with a large haystack).

References

[1] L. Ein Dor, I. Kela, G. Getz, D. Givol, and E. Domay. Outcome signature genes in breast cancer: is there a unique set? Bioinformatics, 21(2):171–178, 2005.
[2] W. Johnson and J. Lindenstrauss. Extensions of Lipschitz mappings into a Hilbert space. In Proceedings of the Conference in Modern Analysis and Probability, pages 189–206, New Haven, CT, 1982.
[3] L. J. van't Veer, H. Dal, M. H. van de Vijver, Y. D. He, A. A. M. Hart, M. Mao, H. L. Peterse, K. van der Kooy, M. J. Marton, A. T. Witteveen, G. J. Schreiber, R. M.

Kerkhoven, C. Roberts, P. S. Linsley, R. Bernards, and S. H. Friend. Gene expression profiling predicts clinical outcome of breast cancer. Letters to Nature, 415(31):535–536, Jan. 2002.

- **Boris Godoy (University of Newcastle)**

Title: A model-based control strategy for Bioleaching Processes

Abstract: The present work aims to contribute to the optimisation of the bioleaching technology by proposing a model-based feedback control method. Heap bioleaching facilities around the world operate in essentially an open-loop mode, with fixed set-points for the entire life of the process (typically of the order of two years long).

Although there exist accurate models to describe important aspects of the process such as oxidation, bacterial growth, and temperature, such models are of a great mathematical complexity, which makes the design of model-based control strategies very hard.

Our approach is based on the estimation of linear models to describe dynamic variations of the heap response around nominal trajectories. To generate model estimation data we use a comprehensive high complexity mathematical model developed by BHP-Billiton, which we shall refer to as the BHPB model. The BHPB model has been validated against real data from an experimental bioleaching test column. Given the typical proportions of real heap bioleaching implementations (several square kilometres in area) and time scales (transients of the order of months), the use of accurate models such as the BHPB model appear as a necessary step in devising effective feedback control strategies for these processes.

A reduced number of input variables for control is selected based on an open-loop sensitivity analysis performed on the BHPB model. Such sensitivity analysis quantifies the effect of small input variations around nominal set-point values on the total amount of extracted copper after a full life-cycle of the heap.

The outputs of interest in the present work are the average temperature in the heap and the copper concentration in the leached solution. We use the Expectation Maximisation (EM) algorithm to find linear Maximum Likelihood (ML) model estimates. The linear model obtained describes incremental variations of the outputs of interest to the selected control inputs around nominal trajectories, which are generated with the BHPB model under nominal conditions. The perturbations on the nominal values of the inputs are generated as pseudo-random binary sequences (PRBS).

We use the linear incremental model estimated to design a feedback controller using the Internal Model Control (IMC) architecture to regulate small increments around the nominal values of the outputs. The closed-loop results show around 5 % improvement in the total mass of extracted copper. These results appear to be promising given the extreme simplicity of the estimated model (second order) used, and the limited

(incremental) action of the control inputs applied, and indicates good potential for feedback operation of heap bioleaching processes.

- **Milan Derpitch (University of Newcastle)**

Title: Sequential Quantization of Frame Expansions

Abstract: The talk will present insights and new results on the quantization of frame expansions. The theory of frames in Hilbert spaces allows for a unified view of the sampling-and-reconstruction process. This view encompasses diverse sampling paradigms, such as the Wavlet transform, non-uniform sampling, filterbanks, and sampling of non-bandlimited signals. However, quantization techniques for general frame expansions have begun to be studied only in recent years. Simple scalar quantization of frame coefficients is currently well understood. However, the generalization of more sophisticated sequential quantization schemes, such as Sigma-Delta modulation, for the task of quantizing frame expansions, still poses interesting problems. Some of the latter can be stated as the following questions, to be answered during the talk: "Is it possible to achieve optimal quantization based only upon sampled data?". "Can optimal quantization be achieved by means of a sequential algorithm?". "Under what conditions can a sequential quantization algorithm without "look ahead" be optimal?" "How can Model Predictive Control techniques be applied to the quantization of general frame expansions?"

- **Assaf Gurt (University of Melbourne)**

Title: Performance analysis of bit-rate-limited stochastic control systems with quantized state feedback

Abstract: Networked control systems employing multiple sensors and actuators that are geographically distributed, are an area of research which attracted much attention in the last decade. When we wish to control systems consisting of many components connected by a digital channel, communication channel constraints have to be taken into account. The reason for this is that classical control theory usually assumes that the plant and feedback controller are either collocated or they can communicate with each other over a channel with infinite capacity, whereas the core of the problem here is that the plant and the feedback controller communicate over a digital channel with finite capacity.

In this talk, we look into performance analysis of bit-rate-limited stochastic control systems with quantized state feedback. We propose a new quantization scheme, and a new functional as a design tool, for computing an a priori bound on the mean square state.

- **Tania Kamenev (University of Melbourne)**

Title: Robust stabilization of linear control systems with quantized feedback

Abstract: Control of systems with quantized feedback is an emerging research area that

brings together elements of control and information theory
to provide novel insights into control over networks with bandwidth limitations. In this talk, we will extend results from a recently developed scheme introduced by Nesic and Liberzon where input-to-state stabilization (ISS) of linear systems with quantized feedback was considered. We show that using the scheme proposed by Nesic and Liberzon it is also possible to achieve (nonlinear gain) l_2 stabilization for linear systems. We conclude the talk by proposing several future research directions.

- **Eduardo I. Silva (University of Newcastle)**

Title: Optimal Noise Shaping for Networked Control Systems

Abstract: In Networked Control Systems (NCS's) achievable performance is limited by the characteristics of the communication links used to transmit signals in the loop. In this paper we focus on ideal bit-rate limited channels, i.e., channels in which signals need to be quantized prior to transmission. We use noise shaping quantization ideas to develop a novel NCS architecture that takes quantization into account. Using linear time invariant system theoretical tools, we show how to design a noise shaping quantizer that minimizes the impact of quantization noise on loop performance, as measured by the variance of the tracking error component due to quantization. We provide explicit analytical expressions for both the optimal noise shaping quantizer parameters and the optimum achievable performance. It is also shown that the proposed NCS architecture outperforms other schemes recently proposed in the literature.

- **Chih Feng Lee (University of Melbourne)**

Title: Identification of Disc Thickness Variation Using an Extremum Seeking Method

Abstract: Electromechanical brake (EMB) are being proposed as a future alternative to a traditional hydraulic brake for use in automobiles. Ideally, an EMB is able to deliver brake force according to a set point clamp force command. However, due to manufacturing inaccuracies and wear, the thickness of brake disc varies over a rotation of the rotor and causes a deviation in brake force during a frequency-varying perturbation in a clamp force event. Due to the frequency dependency of EMB current to force transfer function gain magnitude, the effect of disc thickness variation (DTV) on clamp force varies as the wheel decelerates, making the estimation of DTV profile parameters an optimisation problem with time-varying cost. When the time-related variation of cost is large, traditional sinusoidal perturbation based extremum seeking method fail to perform. In this presentation, a stochastic extremum seeking method adapted for relatively fast time-varying cost metrics will be introduced and shown to successfully be used in the problem of DTV identification.

- **Hua Ouyang (ADFA, UNSW)**

Title: Guaranteed Cost State Estimation of Stochastic Uncertain Systems with Slope Bounded Nonlinearities via the use of Dynamic Multipliers

Abstract: This paper studies robust state estimation for a class of nonlinear stochastic system with structured uncertainties. This paper presents a new approach to robust nonlinear state estimation based on the use of Integral Quadratic Constraints and minimax LQG control. The approach involves a class of state estimators which include copies of the slope bounded nonlinearities occurring in the plant. In the formulation of the problem, this copy of the nonlinearity has been combined into the plant. Integral Quadratic Constraints and dynamic multipliers are introduced to exploit these repeated nonlinearities. After a series of transformations, the system is written as an augmented system which can be processed by the minimax LQG approach. The linear part of the state estimator is synthesized by solving a minimax LQG control problem and this leads to a nonlinear state estimator which gives an upper bound on the closed loop value of a quadratic cost functional.

- **Rahul Sharma (University of Melbourne)**

Title: Fault and disturbance reconstruction in nonlinear systems with unknown inputs using sliding mode observers

Abstract: One of the significant theoretical developments that accounts for the effects of disturbances in nonlinear systems is that of sliding mode control/observer theory, where the dynamics of the system are altered with high speed switching.
This talk presents a new sliding mode approach to estimation of unknown inputs and faults in a class of nonlinear systems. The approach is based on the design of a cascade connection of two sliding mode observers. The first is used for estimation of state and unknown inputs and the second is used for fault detection. In the proposed approach the state trajectories do not leave the sliding manifold even in presence of unknown disturbances and faults. This allows for faults and disturbances to be reconstructed based on information retrieved from the equivalent output injection signal. The proposed approach is implemented on a nonlinear model of Vertical Take Off and Landing (VTOL) aircraft systems to reconstruct unknown disturbances and faults.

- **Iskandar Mahmood (Newcastle),**

Title: Precise Tip Positioning of a Flexible Manipulator using Resonant Control

Abstract: A single-link flexible manipulator is fabricated to represent a typical flexible robotic arm. This flexible manipulator is modeled as a SIMO system with the motor-torque as the input and the hub angle and the tip position as the outputs. The two transfer functions are identified using a frequency domain system identification method, and the resonant modes are determined. A feedback loop around the hub angle response with a resonant controller is designed to damp the resonant modes. A high-gain integral controller is also implemented to achieve zero steady-state error in the tip position response. Experiments are performed to demonstrate the effectiveness of the proposed control scheme.

- **Bilal Ahmed (ADFA, UNSW)**

Title: Rotary Wing UAV Position Control using Backstepping

Abstract: This paper presents a novel position control method for rotary wing UAVs using the backstepping approach. The algorithm, motivated by backstepping control for general rigid body dynamics, is extended for underactuated mechanical systems. The approach also considers the use of nonlinear flapping dynamics when stability derivatives are not available. Further work is needed to include servo dynamics and to make the algorithm adapt to changes in order to make it suitable for practical implementation.

- **Christian Lovaas (University of Newcastle)**

Title: Robust Model Predictive Control of Input-Constrained Stable Systems with Unstructured Uncertainty

Abstract: For open-loop stable systems having input constraints and unstructured model uncertainty, we present a new closed-loop stability test applicable to typical output-feedback model predictive control (MPC) policies. The new stability test is less conservative than a previous proposal, and it enables both analysis and synthesis of input-constrained MPC policies. In particular, we propose a robust MPC design which minimizes, at each step, a quadratic upper bound on a nominal cost function. We determine the upper bound off-line subject to the stability test using convex optimization. Simulation results show that the proposed MPC design can be much less conservative than robustly stable designs based on conventional cost functions.

- **Germane Xavier Athanasius (ADFA, UNSW)**

Title: Switching strategy for Robust Decentralized Output Feedback Power System Controllers

Abstract: This paper addresses the problem of designing robust decentralised output feedback Power System Stabilisers (PSS) for an interconnected power system. Large scale power system grid consists of many generators interconnected with each other and thus forming a large scale interconnected system. The dynamics of these generators are highly nonlinear and each generator is affected by the dynamics of all other machines connected to the grid. To achieve a centralized control it is difficult to access the states of all machines in real time due to geographic separation of these generators. This necessitates to develop decentralised power system controllers which achieves control with local information. Also conventionally a single Power System Stabiliser (PSS) is designed to cover the entire operating range of the generator. This approach makes the controller more conservative and often lead to non linear oscillations in the system when the operating point shifts far from the designed operating point. In this research we consider the above issues in the design of PSS for interconnected power systems. Instead

of single controller for entire operating regime, we propose to have several decentralized robust controllers covering the operating regime. Decentralised robust output feedback controllers are designed for each operating point. In the controller design, the interconnection effects and small parameter variation around the operating point are considered as uncertainties and are defined using Integral Quadratic Constraints (IQCs). Each controller is expected to give robust performance around the designed operating point. When the operating point of the generator changes with the changes in power output, suitable controllers need to be selected and switched. To ensure the stability of the switched system, the concept of slow switching is employed. The stability overlap regions of the adjacent controllers and the time constant of the generator for the power change is related with the minimum dwell time required for stable switching. A methodology to arrive at the minimum dwell time including the effect of interconnections is proposed. During switching between controllers transients could arise. These switching transients may cause undesirable effects on the system performance. To avoid transients during switching a bumpless switching scheme is employed.

- **William H. Moase (University of Melbourne)**

Title: Towards plant independence in extremum-seeking control

Abstract: A solution is proposed to eliminate the dependence of extremum-seeking controller behaviour on the second gradient of the plant map. The novel extremum-seeking controller drives the control input towards the extremum at a rate which is proportional to the estimated difference between the current input and its optimum. Outlines of a) a stability proof for a general, nonlinear static plant; and b) a locally quadratic plant with linear time-invariant input and output dynamics are presented.

- **John Kitchen (DSTO)**

Title: Space-Time Wireless Communications Surveillance

Abstract: The recent past has seen a strong interest in wireless communications research thanks to the use of antenna arrays in wireless communication systems, at both the receive and transmit sites, which have the potential for large channel capacity gains. Clearly the addition of extra, spatially distributed, transmit/receive resources adds another dimension to the classical ideas of communications from point-to-point.

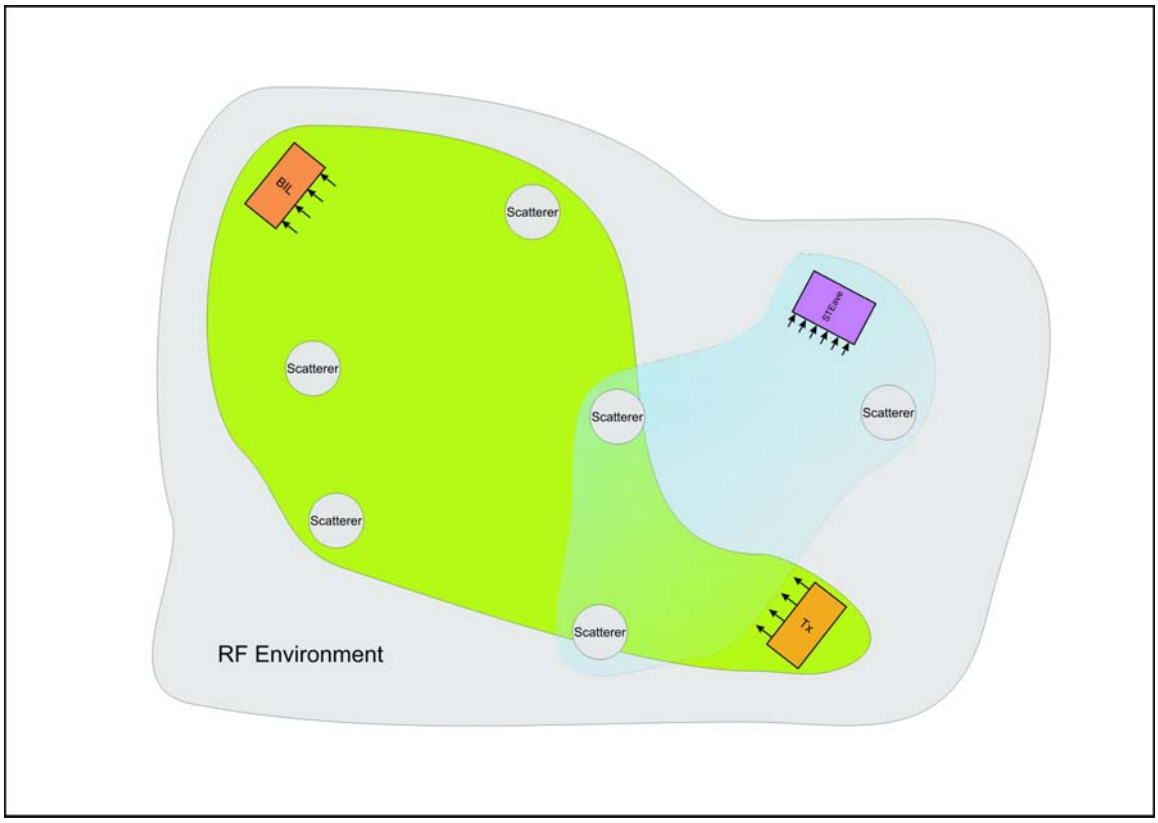

Figure 1: MIMO scenario with a transmission array and a receiving array which is the intended recipient of the signals, a Space-Time eavesdropper and some electromagnetic scatterers in the environment.

In this presentation we shall be analysing the performance of Multiple Input Multiple Output (MIMO) wireless communications channels from both the security and surveillance perspectives. Techniques for enhancing the channel security will be discussed. The problem of estimating both the channel and the source, when neither are known a priori, has been investigated recently where it was found necessary to consider the problem in an information geometric framework for a correct interpretation of the Fisher information matrix and Cramér-Rao lower variance bounds. New tools for analysing the channel capacity performance that make use of the relationship between mutual information and the Minimum Mean Square Error (MMSE) estimation of the input will be introduced.

- **Meng Wang (University of Newcastle)**

Title: OFDMA Uplink PAR Reduction via Tone Reservation

Abstract: Orthogonal frequency division multiple access (OFDMA) has been widely recognized as a promising solution for broadband wireless networks. Unfortunately, in

OFDMA uplink scenarios, high peak-to-average power ratios (PARs) dramatically degrade the power efficiency of the mobile users. This turns out to be one of the most critical problems when implementing OFDMA systems. In this paper, we propose an efficient PAR reduction scheme based upon tone reservation. The scheme exploits the fact that in the OFDMA uplink a large fraction of zero padding is used to avoid multi-access interference. We show by simulation that the PAR can be significantly reduced by the proposed method.

- **Alex Leong (University of Melbourne)**

Title: Probability of Error Analysis for Hidden Markov Model Filtering With Random Packet Loss

Abstract: This talk will be on the probability of error in state estimation of hidden Markov models, where measurements can be either lost or received according to another Markov process. Analytical expressions for the error probabilities are derived for the noiseless and noisy cases. Some relationships between the error probability and the parameters of the loss process are demonstrated via both analysis and numerical studies. In the high SNR regime, approximate expressions which can be more easily computed than the exact analytical form for the noisy case are also presented.

- **Cristian R. Rojas (Newcastle),**

Title: Frequency Localising Basis Functions for Wide-band System Identification: A Condition Number Bound for Output Error Systems

Identifying the parameters of a system possessing a large dynamic range presents a number of difficulties for a least squares type algorithm. Foremost, is that of obtaining reliable parameter estimates from a poor or ill-conditioned least squares formulation. In this paper we examine properties of a technique that utilizes frequency localising basis functions to ensure that ill-conditioning is reduced when solving for the parameter estimates. Specifically, we obtain a bound on the condition number of the least squares problem which is independent of the frequency range for a particular class of models. We also present an example, utilising real data, which demonstrates the potential of the technique when applied to large dynamic range systems.

- **Huibo Ji (ANU)**

Title: A Globally Convergent Conjugate Gradient Method for Minimizing Self-Concordant Functions On Riemannian Manifolds

Abstract: Self-concordant functions in Euclidean space were presented by Nesterov and Nemirovskii and play an important role on the interior point method. They are used to construct the barrier function for the interior point method. We have defined Self-concordance on Riemannian manifolds and the corresponding damped Newton method

has been proposed. As a result, they can provide guidance for the construction of efficient interior-point methods on smooth manifolds. However, the Newton-based method, on Riemannian manifolds as well as in Euclidean space, has a main drawback as a numerical optimization method. It is that in order to obtain the Newton descent direction, a linear system has to be solved at each iteration, which increases the computational cost. Alternatively, the conjugate gradient method can converge to the solution super-linearly without solving a linear system. Therefore, due to nice properties of self-concordant functions, we are motivated to develop a damped conjugate gradient method with a novel step-size rule for optimization of such functions on Riemannian manifolds. Our method provides an explicit step-size rule based on the conjugate gradient method. It is proved to converge to the optimal solution of a self-concordant function. The main advantage of our method is that it only uses the first and second covariant derivatives of the cost function without the need of computing a linear system. In each step, the complexity of our method is $O(n2)$ instead of $O(n3)$ for the damped Newton method, where n is the dimension of the Riemannian manifold. To show the convergence of our method, we applied it on an example. Given some points $p1; : : : ; pk$ on the Hyperboloid model In, the problem is to find the point on In which minimizes the mean squared intrinsic distance to every point of $p1; : : : ; pk$. This point is also known as the "Karcher mean", first introduced by Karcher as the centre of mass on a Riemannian manifold. It is proved that the "Karcher mean" cost function defined on the Hyperboloid model is self-concordant. Simulation results show our method converges to the "Karcher mean" of given points on the Hyperboloid model super-linearly.

- **Yantao Feng (ANU)**

Title: An iterative procedure to compute nonnegative stabilizing smooth solutions to HJBI equations

Abstract: In this paper, an iterative algorithm to solve Hamilton-Jacobi-Bellman-Isaacs (HJBI) equations for a genetic nonlinear control system is proposed. By constructing two series nonnegative functions, we reduce a generic HJBI equation to a series of successive iterations of Hamilton-Jacobi-Bellman (HJB) equations whose solutions can be approximated recursively by existing methods. The local convergence and local quadratic rate of convergence of the algorithm are guaranteed and a proof is given. Numerical examples are also provided to demonstrate the superior accuracy of the proposed algorithm when compared with the method of characteristics in [1]. A game theoretic interpretation of the algorithm is also provided.

- **Bahman Tahayori (University of Melbourne)**

Title: Optimal Input Design for MRI System

Abstract: Magnetic Resonance Imaging (MRI) is a non-invasive imaging method. It is primarily used in medical imaging to demonstrate pathological or other physiological alterations of living tissues. While it is a well established modality in some cases, for example the brain, spine, and the joints, MRI is actively expanding into other fields of

medicine. Magnetic resonance images are obtained by observing the fluctuations in nuclear magnetization produced by sequences of RF pulses and applied magnetic field gradients. Shaped RF pulses are used in MRI to selectively encode spins within a sample. Since short pulses excite everything in the spin system they are called hard or nonselective pulses. Long pulses excite nuclei resonating in a selected frequency range and are called soft or selective pulses. However from a system theoretic perspective, problems in this area can be thought of as identification problems involving bilinear time-varying systems. They are distinguished from linear systems identification problems by the fact that the quality of identification is strongly dependent on the form of the excitatory input applied to the system. We will take a fresh look of MRI with the view of finding procedures that will determine the input(s) which will optimize specific performance measure (e.g. image contrast). We observe that it may be feasible to distinguish between a closed loop and open loop version of this problem. In the closed loop situation the input can be any measurable function of the output. This is an untried approach in present MRI. In the open loop case which is classical in MRI the input is specified in advance, independent of the output. The design of an input is based on the expected response of the nuclear magnetization. We have applied an on-resonance continuous-wave input modulated with Rabi frequency to the Bloch equation and have simulated the result for a number of isochromats. Simulation results show that the spins will not loose their coherency in the transverse plane in steady state. We are using Galerkin approximation idea to solve the problem underpinning MRI sequence design.

REFERENCES

[1] K. A. Wise and J. L. Sedwick, “Successive approximation solution of the HJI equation”, Proceedings of the 33rd Conference on Decision and Control, FL-December 1994.

- **Gavin Buskes (University of Melbourne)**

Title: Reduced-order approximation in the mu-gap metric.

Abstract: Approximation of a linear system by a model of lower complexity (i.e. the order of a state-space realisation) is an important, and consequently, well-studied problem. Most model order reduction techniques involve measures of approximation error that reflect differences in open-loop behaviour. Within the context of feedback compensator design, however, it is arguably more important to measure approximation error in terms of how a model and its approximation would behave in closed-loop. The gap metric and its variants are known to capture the difference between open-loop models in terms of closed-loop behaviour. In this talk, we consider order reduction problems in which approximation error is quantified using the mu-gap metric. In particular, a parameterisation of all fixed-order models within a specified mu-gap distance of a nominal full-order model is obtained in terms of Linear Matrix Inequalities (LMIs) and a rank constraint. This characterisation can also be extended to the weighted mu-gap approximation case. An example is presented demonstrating the use of this LMI characterisation to obtain a reduced-order model that has a guaranteed mu-gap error bound.