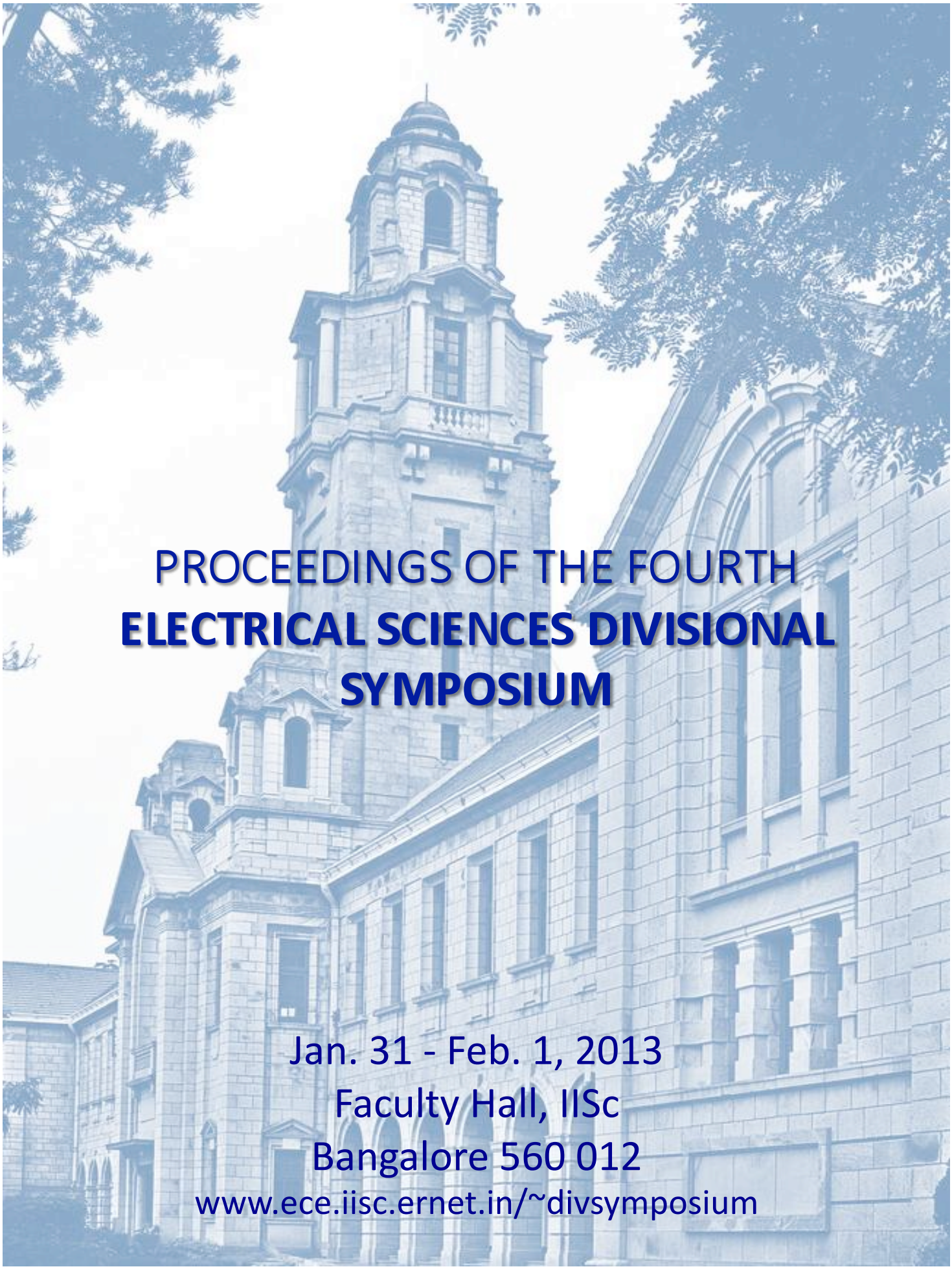


PROCEEDINGS OF THE FOURTH
ELECTRICAL SCIENCES DIVISIONAL SYMPOSIUM

Jan. 31 - Feb. 1, 2013

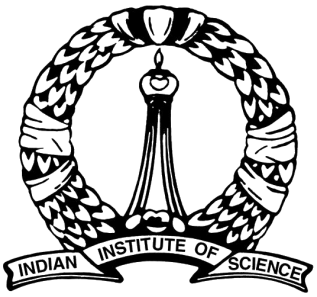
Faculty Hall, IISc

Bangalore 560 012

www.ece.iisc.ernet.in/~divsymposium

Proceedings of the Fourth

Electrical Sciences Divisional Symposium



Indian Institute of Science
Bangalore – 560 012 (INDIA)

January 31 - February 1, 2013

Foreword

The departments of the Electrical Sciences Division, and the Supercomputer Education and Research Centre, together comprise faculty members specializing in electronics, power engineering, communications, computer science, control, electromagnetics, photonics, and signal processing. With a view to establishing an annual forum that would present a cross-section of the research being conducted in the broad areas of electrical engineering and computer science, in IISc, an annual in-house symposium was started in 2010. Each year, several senior PhD students present short talks on their work, to an audience comprising faculty members, industry invitees, and other students.

The idea of such an annual symposium originated during a feedback session with the students in 2009. In keeping with these origins, the symposium is organized mainly by PhD students, with guidance from a faculty committee with one member from each department. In this fourth symposium, the organizers have introduced two new features:

1. A few invited talks by faculty members, and
2. A compilation of the abstracts of the talks to be presented.

I would like to congratulate the organizers on setting up an excellent program, and for taking the above novel initiatives. I hope that the symposium will give the attendees a chance to obtain a glimpse of the diversity and quality of the research being conducted.

Anurag Kumar

Chair, Electrical Sciences Division

Organizing Committee and Program Schedule

Committee

Faculty Coordinators

Chandra R. Murthy	ECE
Vijay Natarajan	CSA
Shayan Srinivasa Garani	DESE
Chandra Sekhar Seelamantula	EE
Phaneendra Yalavarthy	SERC

Student Organizers

Swaprava Nath, Nithin Shivashankar	CSA
Vijayashree Bhat, Arpan Chattopadhyay, Arkaprovo Das	ECE
Saurabh Aggarwal, Mathew K, Jaison Mathew	DESE
K. Venkata Vijay Girish, Satish M, Subhadip Mukherjee	EE

Time	January 31, 2013 (Thursday)	February 1, 2013 (Friday)
08.30 - 08.50	**Registration**	
08.50 - 09.00	**Opening Remarks from the Divisional Chairman**	
09.00 - 09.30	**Faculty Talk (CSA)** **Speaker: Murali Krishna Ramanathan** **Title:** Scalable program analysis techniques for software bug detection	**Faculty Talk (DESE)** **Speaker: Santanu Mahapatra** **Title:** Updates on indDG compact model
09.40 - 11.00	**Networks and Graphs** **Session Chair: Sunil Chandran** **Pradeesha Ashok**: Epsilon nets and hitting sets for geometric objects **Deepak Rajendraprasad**: Rainbow colouring of graphs **Abhijeet Khopkar**: Geometric proximity graphs **Mustafa Khandwawala**: Belief propagation for optimal edge-cover in the random complete graph	**Electron Devices and MEMS - I** **Session Chair: Navakanta Bhat** **Ramkrishna Ghosh**: Atomically thin tunnel field effect transistor **Revathy Padmanabhan**: High-k dielectrics for MIM capacitors **Sindhuja Sridharan**: Low temperature hetero-junction photovoltaic devices **Rekha Verma**: Analysis of electro-thermal effects in CNT/Graphene interconnects
11.00 - 11.30	**Tea Break**	
11.30 - 12.50	**Game Theory and Image Analysis** **Session Chair: Venu Madhav Govindu** **Swaprava Nath**: Strategy-proof crowdsourcing over networks **Nithin Shivashankar**: Morse-Smale complexes: computations and applications **Ravi Prasad Jagannath**: Novel computational techniques for image reconstruction in diffuse optical tomography **Deepak Kumar**: Segmenting image for text (SIFT) algorithms	**Electron Devices and MEMS - II** **Session Chair: Manoj Varma** **Thejas**: Displacement sensing mechanisms for MEMS devices **Nityanand Kumawat**: Differential reflectance modulation sensing with diffractive microstructures **Rajath Vasudevamurthy**: A time-based all-digital technique for analog built-in-self-test **Sudhanshu Shekhar**: Theoretical and experimental investigations on the switching dynamics and reliability improvement of an RF MEMS switch
12.50 - 14.00	**Lunch**	
14.00 - 14.30	**Faculty Talk (ECE)** **Speaker: Dipanjan Gope** **Title:** High frequency system modeling aided by the cloud	**Faculty Talk (EE)** **Speaker: Manojit Pramanik** **Title:** Listening to light: photoacoustic imaging and its future
14.40 - 16.00	**Signal Processing and Power Systems** **Session Chair: A. G. Ramakrishnan** **Shiva Kumar H R**: Robust symbol segmentation in degraded Indic printed documents **J V Satyanarayana**: OASIS: Optimal avionics systems based on intelligent sampling **Lalit Patnaik**: Energy efficient legged vehicle - modeling, implementation and control **Rex Joseph**: Variable speed micro-hydel power generation	**Wireless Communication** **Session Chair: P. Vijay Kumar** **Naveen K P**: Relay selection for geographical forwarding in sleep-wake cycling wireless sensor networks **A. Karthik**: Fast scalable selection algorithms for OFDMA and cooperative wireless networks **Bharath Bettagere**: Channel dependent reverse channel training in TDD-MIMO systems **M. Ashok Kumar**: Transitive statistical inference rules
16.00 - 16.30	**Tea Break**	
16.30 - 17.30	**Networks and Coding** **Session Chair: Neelesh B. Mehta** **Prakash Narayana Moorthy**: Codes with locality and local regeneration for distributed data storage **Lalitha Vadlamani**: Linear coding schemes for the distributed computation of subspaces **Mohan Raghavan**: First spike latency codes in neuronal networks, their applications and relation to network structure	**Panel Discussion** **Topic:** The role of theory in engineering research
17.30 - 18.00	**Faculty Talk (SERC)** **Speaker: Phaneendra Yalavarthy** **Title:** Recent computational advances in diffuse optical tomographic image reconstruction	**Closing and Vote of Thanks**

Contents

Session 1

Invited Talk: Department of Computer Science and Automation

Scalable program analysis techniques for software bug detection

Speaker: Murali Krishna Ramanathan

Abstract: Identifying and eliminating bugs in software systems early in the development process has many advantages. A traditional means of achieving this objective is to do rigorous testing including writing unit tests and end-to-end scenario tests. However, in practice, testing has been found to be inadequate in ensuring software reliability because of its strong dependence on code coverage and the value of test inputs used. Sophisticated program analysis techniques have been designed to address these limitations. These techniques work by analyzing the source code or the program execution and subsequently detecting bugs. In this talk, I will present the challenges of scaling analysis techniques to large code bases and present our recent attempts at addressing these challenges.

Brief Bio: Murali Krishna Ramanathan is an Assistant Professor in the Department of Computer Science and Automation at Indian Institute of Science, Bangalore. His research interests broadly span the areas of software engineering, programming languages and scalable system design. Previously, he was a Principal Engineer in the core analysis team at Coverity Inc. building static and dynamic analysis tools for bug detection in industrial codebases. He holds M.S. and PhD degrees in Computer Science from Purdue University and a B.E. in Computer Science and Engineering from College of Engineering, Guindy, Anna University, Chennai.

Session 2

Contributed Session: Networks and Graphs

Session Chair: L Sunil Chandran

2.1 Epsilon nets and hitting sets for geometric objects

Speaker: Pradeesha Ashok

Affiliation: Department of Computer Science and Automation

Advisor: Satish Govindarajan

Contact: pradeesha@csa.iisc.ernet.in

Abstract: Let (P, S) be a range space consisting of a set P of n elements and a collection $S = \{S_1, S_2, ..., S_m\}$ of subsets of P. A *hitting set* for this range space refers to a subset H of P such that every S_i in S contains at least one element of H. Finding the minimum hitting set is an NP-complete problem. ϵ-nets are hitting sets for a special range space (P, S) where P is any set and S contains all subsets of P that contain more than ϵn elements of P, where $0 \leq \epsilon \leq 1$. ϵ-nets were introduced by Haussler and Welzl and it has been proved that ϵ-nets of size independent of n exist for range spaces with finite VC-Dimension. Bronniman and Goodrich showed that the existence of smaller-sized ϵ-nets implies better approximation algorithm for hitting set problem.

We have studied about ϵ-nets and hitting sets for geometric range spaces where P is a set of n points in $\mathbb{R}^2$ and the subsets are defined by intersection of P with geometric objects. In particular, we have investigated the following questions.

- Small strong epsilon nets: Here we fix the size of strong ϵ-net as some small integer and investigate bounds on the minimum value of ϵ. We show an optimal strong centerpoint

theorem for rectangles and prove lower and upper bounds for geometric range spaces defined by families of axis-parallel rectangles, disks and half spaces.

- Hitting many induced objects with an input point : Here the range space is defined by geometric objects induced by points in P. We investigate how many of them can be hit by a single input point. This is a variant of a classic theorem in combinatorial geometry called First Selection Lemma. We study this problem for rectangles and circles.
- Epsilon nets for grids: Here P is fixed as a $\sqrt{n} \times \sqrt{n}$ grid and subsets are defined by intersection of P with geometric objects. We try to bound the size of the ϵ-nets for a fixed value of ϵ when the range space is defined by geometric objects like lines, strips, rectangles and convex objects. In this setting, the size of the ϵ-net is substantially smaller than a general pointset. For example, while it is known that linear sized ϵ-nets do not exist for lines and axis-parallel rectangles for general pointsets, we show that linear-sized ϵ-nets exist for lines and axis-parallel rectangles for a grid pointset.

2.2 Rainbow colouring of graphs

Speaker: Deepak Rajendraprasad

Affiliation: Department of Computer Science and Automation

Advisor: L. Sunil Chandran

Contact: `deepakr@csa.iisc.ernet.in`

Abstract: An edge colouring of a graph is called a rainbow colouring if between any two vertices in the graph there exists at least one path in which no two edges are coloured the same. Any connected graph can be rainbow coloured by giving a different colour to each of its edges. One way to save on the number of colours is to give distinct colours only to the edges of a spanning tree in the graph. But there are graphs like complete graphs which can be rainbow coloured with a single colour. The rainbow connection number of a graph is the minimum number of colours needed to rainbow colour the graph.

This relatively new problem in the area of graph colouring was introduced by Chartrand *et al.* in 2008. It has got considerable attention from the international graph theory community. The problem invites many structural, algorithmic, and complexity theoretic investigations. On the structural side, the rainbow connection number for many special graphs have been exactly determined, and many upper bounds have been discovered based on other graph parameters. On the complexity side, it has been shown that computing rainbow connection number of an arbitrary graph is NP-hard. In the random setting, sharp thresholds for jumps in rainbow connection number have been computed for the Erdős-Rényi model of random graphs.

We will report some constructive upper bounding techniques for the rainbow connection number which will lead to some approximation algorithms for the same.

2.3 Geometric proximity graphs

Speaker: Abhijeet Khopkar

Affiliation: Department of Computer Science and Automation

Advisor: Satish Govindarajan

Contact: abhijit@csa.iisc.ernet.in

Abstract: A geometric proximity graph $G = (V, E)$ is an embedding of the set V as the points in the plane and the set E as the line segments joining two points in V. An edge exists between two points if some geometric proximity condition is satisfied. Delaunay graphs, Gabriel graphs and Relative Neighborhood Graphs (RNGs) are classic examples of geometric proximity graphs. We study several classes of geometric proximity graphs for various computational and combinatorial problems.

- **Locally Gabriel graphs:** Delaunay and Gabriel graphs are widely studied geometric proximity structures. Motivated by applications in wireless routing, relaxed versions of these graphs known as *Locally Delaunay Graphs* ($LDGs$) and *Locally Gabriel Graphs* ($LGGs$) were proposed. We propose another generalization of $LGGs$ called *Generalized Locally Gabriel Graphs* ($GLGGs$). We prove that computing an edge maximum $GLGG$ is APX-hard and computing a minimum dilation LGG is NP-hard.
- **Unit distance graphs:** A unit distance graph is a geometric graph in plane where an edge exists between two points if and only if they are unit distance apart. The study of these graphs was initiated by Erdős in 1948. These graphs have been studied for various point sets. We study various properties of unit distance graphs when all the points are in convex position.
- **Witness graphs:** Witness graphs are special kind of proximity graphs that are generalization of Delaunay graphs. Given a point set V, an edge exists between two points if there exists a witness point (different from V) in a vicinity region defined by the two points. We study piercing and hitting problems for witness graphs when the vicinity region defined by two points is an axis parallel rectangle.

2.4 Belief propagation for optimal edge-cover in the random complete graph

Speaker: Mustafa Khandwawala

Affiliation: Department of Electrical Communication Engineering

Advisor: Rajesh Sundaresan

Contact: mustafa@ece.iisc.ernet.in

Abstract: We apply the objective method of Aldous to the problem of finding the minimum cost edge-cover of the complete graph with random independent and identically distributed edge-costs. The limit, as the number of vertices goes to infinity, of the expected minimum cost for this problem was determined by Hessler and Wastlund using a combinatorial approach. Wastlund has also presented a different proof for this. We provide a proof of this result using the machinery of the objective method and local weak convergence. This approach was used to prove the $\zeta(2)$ limit of the random assignment problem. We further show that a belief propagation algorithm converges to the optimal solution asymptotically. Our work guides the construction of a program which can be used to solve other such optimization problems.

Session 3

Contributed Session: Game Theory and Image Analysis

Session Chair: Venu Madhav Govindu

3.1 Strategy-proof crowdsourcing over networks

Speaker: Swaprava Nath

Affiliation: Department of Computer Science and Automation

Advisor: Y. Narahari

Contact: swaprava@gmail.com, swaprava@csa.iisc.ernet.in

Abstract: Individuals and organizations often face the challenge of executing tasks for which they do not have enough resources or expertise. Outsourcing to experts at a cost helps them execute the task without procuring any extra resources. With the advent of the Internet, outsourcing has become more convenient, and in particular, online social networks have given access to a huge crowd with plenty of expertise. Today it is easy to find a group of people to collectively solve a problem or to generate a content by aggregating knowledge. This phenomenon of harvesting information from the crowd is known as *crowdsourcing*. However it poses a challenge in terms of reliability and authenticity of the solutions, contents, and also the individuals. The group of people to whom the task has been outsourced are human, and hence they are strategic and seek to maximize their own payoffs. In this thesis, we investigate different types of strategic behavior that arise in application specific task outsourcing problems and present creative solutions. We also discuss some challenging future questions in solving the optimal outsourcing problem.

3.2 Morse-Smale complexes: computations and applications

Speaker: Nithin Shivashankar

Affiliation: Department of Computer Science and Automation

Advisor: Vijay Natarajan

Contact: nithin19484@gmail.com, nithin@csa.iisc.ernet.in

Abstract: The Morse-Smale complex is a useful topological data structure for the analysis and visualization of scalar fields. For a given scalar function, it is defined as a partition based on the sources and sinks of lines that track its gradient. This thesis describes efficient parallel algorithms to compute the Morse-Smale complex in two and three dimensions. The first part of the thesis describes a parallel algorithm to compute the Morse-Smale complex for two-dimensional meshes. A divide and conquer technique which allows the algorithm to scale to large datasets is also described. This algorithm is implemented and evaluated for 2D structured grids. The Morse-Smale complex possesses additional structural complexity in 3D, thereby requiring better algorithms to compute it. The second part of the thesis describes scalable techniques to compute the MS complex in 3D. The last part of this thesis looks to apply the Morse-Smale complex for the study of the structure of the cosmic web simulations. Due to the need to understand the large-scale structure, the Morse-Smale complex can be used to efficiently encode this structure. Furthermore, due the large-number of data points, efficient analysis is of importance. Hence we look to apply our Morse-Smale complex algorithms for this analysis. This part of the work for the thesis is in progress.

3.3 Novel computational techniques for image reconstruction in diffuse optical tomography

Speaker: Ravi Prasad Jagannath

Affiliation: Supercomputer Education and Research Centre

Advisors: Phaneendra K. Yalavarthy, R. M. Vasu

Contact: raviprasad@rishi.serc.iisc.ernet.in,
k.j.raviprasad@gmail.com

Abstract: Diffuse Optical Tomography (DOT) is an emerging medical imaging modality that is capable of providing functional images of tissue under investigation. The image reconstruction problem, also known as inverse problem, in the diffuse optical tomography is known to be non-linear, ill-posed, and some times under-determined, requiring regularization to obtain meaningful results. Among the traditional methods, Tikhonov type regularization

is the most popular one for solving the inverse problem. The choice of this regularization parameter dictates the reconstructed optical image quality and is typically chosen empirically or based on prior experience. In the first part, an automated method for optimal selection of regularization parameter that is based on regularized Minimal Residual Method (MRM) is attempted and the same is compared with the traditional Generalized Cross-Validation(GCV) method. The results obtained using numerical and gelatin phantom data indicate that the MRM based method is capable of providing optimal regularization parameter. In the second part of the work, we have investigated the effective usage of image guidance by incorporating the refractive index (RI) variation in computational modeling of light propagation in tissue to assess its impact on optical-property estimation. With the aid of realistic patient breast three-dimensional models, the variation in RI for different regions of tissue under investigation is shown to influence the estimation of optical properties in image-guided diffuse optical tomography (IG-DOT) using numerical simulations. It is also shown that by assuming identical RI for all regions of tissue would lead to erroneous estimation of optical properties. The a priori knowledge of the RI for the segmented regions of tissue in IG-DOT, which is difficult to obtain for the in vivo cases, leads to more accurate estimates of optical properties. Even inclusion of approximated RI values, obtained from the literature, for the regions of tissue resulted in better estimates of optical properties, with values comparable to that of having the correct knowledge of RI for different regions of tissue.

3.4 Segmenting image for text (SIFT) algorithms

Speaker: Deepak Kumar

Affiliation: Department of Electrical Engineering

Advisor: A. G. Ramakrishnan

Contact: deepak@ee.iisc.ernet.in

Abstract: Our primary focus is on extraction of text from born-digital or scenic images. Applications of text extraction are transliteration of detected text to a language known to the user, product label processing, map tagging and visual aid for the blind. These applications require algorithms that perform the task of robust reading. This task is broken into multiple sub-tasks such as text detection, text localization, and word recognition. Each of these sub-tasks is complex, thus increasing the complexity of robust reading. Otsu-Canny minimum spanning tree algorithm for text segmentation, A new algorithm called the was adjudged the best in ICDAR 2011 robust reading competition. A text localization methodology was built on the result of text segmentation.

Application of power-law transform on the gray scale image resulted in superior binarization, which in turn resulted in higher word recognition rate than existing methods. An objective criterion based on discrimination power was proposed to choose the best color plane after

power-law transform based enhancement to increase word recognition. Another binarization technique has been proposed, based on a novel concept of middle line analysis and propagation of segmentation.

The algorithms have been experimented on five publicly available standard datasets (totaling 3600 images) containing English words in camera captured, born-digital images and video frames. These datasets have also been benchmarked by us.

Session 4

Invited Talk: Department of Electrical Communication Engineering

High frequency system modeling aided by the cloud

Speaker: Dipanjan Gope

Abstract: With the increasing bit rates for communication, chip-package-system level challenges like signal integrity (SI), power integrity (PI), and electromagnetic interference (EMI) play a crucial role in circuit design. RLGC parasitics or S-parameter extraction tools have been used for modeling system level electrical integrity using different flavors of solution methodology: 2D, 2.5D, 3D. However, the complexity of analyzing full systems particularly with Maxwell accuracy presents a time and memory bottleneck. The fast solver algorithms of the last two decades have alleviated the problem to an extent, but the quick turn-around time required for design has been elusive. This seminar will discuss the recent trends in fast simulation and modeling techniques and the emergence of cloud computing as a unique opportunity to enter simulation-in-a-coffee-break paradigm.

Brief Bio: Dipanjan Gope, PhD, is Assistant Professor in Electrical Communication Engineering at Indian Institute of Science, Bangalore. His research interests include computational electromagnetics with applications in signal integrity, power integrity, EMI for high speed chip-package-systems, antenna analysis and design, parallel programming for many-core and cloud computing. Dr. Gope is a founding member at Nimbic where he served as Vice President, R&D from 2007-2011. Dr. Gope received his PhD and M.S. degrees in Electrical Engineering from the University of Washington, Seattle and BTech in Electronics and Electrical Communication Engineering from the Indian Institute of Technology, Kharagpur.

Session 5

Contributed Session: Signal Processing and Power Systems

Session Chair: A. G. Ramakrishnan

5.1 Robust symbol segmentation in degraded Indic printed documents

Speaker: Shiva Kumar H. R.

Affiliation: Department of Electrical Engineering

Advisor: A. G. Ramakrishnan

Contact: shivahr@ee.iisc.ernet.in

Abstract: Robust segmentation of a document page into lines, words and characters/symbols is the crucial step that can boost the performance of Indic OCRs to a very high level. This is especially important in the processing of old books/documents, only for which OCRs are especially needed, where there could be many degradations because of low contrast, ageing of the document and/or poor quality paper/printing. Such degradations cause splitting of characters, merging of characters and/or even bridging of adjacent text lines. Even though such problems can occur with Roman script documents, the type and occurrence of such problems get accentuated in Indic script documents due to the addition of vowel and consonant modifiers above and/or below the base characters. Traditional approaches to segmentation have not sufficiently addressed these issues. We have come up with a new approach to line segmentation based on interval-trees which has given promising results across Kannada, Tamil, Telugu and Gujarati documents. We have also proposed a novel technique, which puts together binarization, segmentation, recognition and language-models in a closed loop that significantly boosts the character/symbol segmentation accuracy, thereby resulting in increased overall text recognition accuracy. The performance of these approaches have been

evaluated on a huge corpus of 5000 pages taken from books printed from 1950-2000.

5.2 OASIS: Optimal avionics systems based on intelligent sampling

Speaker: J. V. Satyanarayana

Affiliation: Department of Electrical Engineering

Advisor: A. G. Ramakrishnan

Contact: jvsat29@yahoo.co.in, satya@ee.iisc.ernet.in

Abstract: Over the past several decades, avionics systems have tremendously evolved with respect to complexity, performance, power consumption and functionality. Data acquisition with the help of multiple analog-to-digital converters is one of the most important functions in these systems. The presence of many ADCs along with the associated circuitry makes typical avionics embedded designs highly complex, thereby, in many cases, not being able to meet the requirements of compactness, low power consumption and cost. A smarter design comprising lesser number of components would go well with the increasing demand for miniaturization. The signals that are acquired and processed by most of the embedded electronics are well characterized. The focus of this research is to exploit the information redundancy in signals for their acquisition and reconstruction at sub-Nyquist sampling rates, thereby reducing the number of ADCs required. Compressed sensing (CS) is an elegant undersampling method, that has shown promising results in several engineering and science applications. CS has generated tremendous excitement in the recent past and is the backbone of the undersampling schemes proposed in this research. This research seeks to evolve embedded designs, in which multiple signals are acquired in a multiplexed fashion, so as to utilize all the unutilized sampling instants in a compressed sampling scheme. The ultimate goal is to identify and provide solutions to all candidate data acquisition domains with information redundancy in the total avionics and to consolidate the individual solutions into a single optimal avionics system based on intelligent sampling (OASIS).

5.3 Energy efficient legged vehicle - modeling, implementation and control

Speaker: Lalit Patnaik

Affiliation: Department of Electronic Systems Engineering

Advisor: L. Umanand

Contact: lalit.patnaik@gmail.com, plalit@cedt.iisc.ernet.in

Abstract: Wheels are very efficient in presence of a hard and even surface to travel on. But if either of the two criteria is not met i.e. the surface is either soft and/or uneven leading to a poor coefficient of rolling friction, wheels are not the best solution. In such cases, it might be beneficial, from an energy perspective, to resort to legged locomotion using dynamic gaits that takes advantage of the tipping moments due to gravity to achieve motion, with minimal amount of actuation from within the system. The objective of the research is to move a specified amount of mass from point A to point B with the minimum amount of energy consumption in normal off-road terrain, in applications where speed is not of primary importance. Earlier works have shown passive walking achieved in certain mechanical systems, while moving down a gentle incline. The present work focuses on suitable control approaches for achieving under-actuated locomotion for a rimless spoked wheel in the absence of such a friendly downward slope. Simplifying the problem to an inverted pendulum model, for a given average forward velocity and a factor of loss in kinetic energy (on the collision of foot with ground), optimal initial velocity and angle of fall have been proposed. Braking will have to take care of bringing the system to a halt only at the point of highest potential energy (and lowest kinetic energy). Modeling and simulation results are presented here; hardware implementation is in progress.

5.4 Variable speed micro-hydel power generation

Speaker: Rex Joseph

Affiliation: Department of Electronic Systems Engineering

Advisor: L. Umanand

Contact: rexjoseph@hotmail.com, rjoseph@cedt.iisc.ernet.in

Abstract: The generation of electricity from renewable sources has gained importance in recent years due to the limited availability of fossil fuels and the increasing concerns about the environmental impact due to their use. Hydro-electric power is amongst the most economical and reliable sources of electrical energy. However, large hydro-power sources have almost been fully tapped, and there are concerns about adverse effects on the environment that stand in the way of commissioning of new large scale projects. This is where micro-hydel power plants have gained significance. Sources of micro-hydro power have been only minimally exploited thus far and there exists considerable potential for their increased usage. Such plants do not raise concerns about environmental impact since they do not need large storage reservoirs. Further, they are suitable for stand-alone systems in many remote locations where providing grid access would be non-viable both economically and in terms of energy spent in setting up the necessary infrastructure. Traditionally such systems are based on constant turbine speed operation using ballast loads that are switched to compensate for changes

in consumer load. This leads to additional cost for the ballast loads and their enclosures, power switching devices and the controllers. The objective of this research is to develop a generation scheme that dispenses with ballast loads and instead relies on the power-speed characteristics of the hydraulic turbine to extract only the required power. This would result in a more economical, reliable, energy efficient and quick-to-commission power plant.

Session 6

Contributed Session: Networks and Coding

Session Chair: Neelesh B. Mehta

6.1 Codes with locality and local regeneration for distributed data storage

Speaker: Prakash Narayana Moorthy

Affiliation: Department of Electrical Communication Engineering

Advisor: P. Vijay Kumar

Contact: prakashn@ece.iisc.ernet.in,
prakashnarayanamoorthy@gmail.com

Abstract: The talk focuses on codes for reliably and efficiently storing data across nodes in a distributed data storage system. The distributed storage system will consist of multiple nodes, in which every file to be stored is broken into k fragments, encoded by an appropriate code into n fragments and each of these n fragments is stored in a distinct node. It is desirable that such a distributed storage system has good storage efficiency and permits multiple options for reconstruction of the original file, i.e., there are multiple k-subsets of the n nodes from which the entire file can be reconstructed. A second desirable property of the distributed storage system is its ability to repair a failed node with minimal network cost. Two key parameters which affect the repair cost and time are 1)the amount of data downloaded (download bandwidth) during repair 2)number of nodes accessed during the repair (locality of repair).

Two classes of codes will presented in this talk, the first of which addresses the issue of locality of repair. These codes permit repair of a failed node by accessing a fraction of

the total number of nodes and such a repair could be performed even in the presence of other failed nodes in the system. Upper bounds on the possible minimum distance (overall reliability) of codes with locality are derived and the codes presented will be optimal with respect to these bounds. The second class of codes combines the notion of locality with the existing notion of regenerating codes. Regenerating codes themselves are a new paradigm for distributed data storage which efficiently trades-off the download bandwidth during repair with the overall storage efficiency. Thus these second class of codes will offer the dual advantages of decreased download bandwidth and locality during repair.

A framework where theoretical performance of various coding solutions for distributed storage could be compared with each other will also be presented.

6.2 Linear coding schemes for the distributed computation of subspaces

Speaker: Lalitha Vadlamani

Affiliation: Department of Electrical Communication Engineering

Advisor: P. Vijay Kumar

Contact: `lalitha@ece.iisc.ernet.in`,
`lalitha.teegavarapu@gmail.com`

Abstract: This talk focuses on distributed function computation problem. A simple example of the problem is where there are two binary sources X_1 and X_2 and a receiver is interested in recovering their modulo-two sum $Z = X_1 + X_2 \bmod 2$. It is well known that using a suitably chosen common linear encoder is often advantageous in terms of sum-rate than doing the naive approach of decoding both the sources at the receiver. We consider a generalization of this problem to arbitrary number of sources where there are m statistically dependent sources $X_1, ..., X_m$ and a receiver that is interested in the lossless computation of the elements of an s-dimensional subspace W generated by $[X_1, \ldots, X_m]\Gamma$ for some $(m \times s)$ matrix Γ of rank s.

A sequence of three increasingly refined approaches are presented, all based on linear encoders. The first uses a common matrix to encode all the sources and a suitably designed receiver to directly compute W. The second improves upon the first by showing that it often more efficient to compute a carefully chosen superspace W' of W. The superspace is identified by showing that the joint distribution of the $\{X_i\}$ induces a unique decomposition of the set of all linear combinations of the $\{X_i\}$, into a chain of subspaces identified by a normalized measure of entropy. This subspace chain also suggests a third approach, one that employs nested codes. For any joint distribution of the $\{X_i\}$ and any W, the sum-rate of the nested-code approach is no larger than that under the Slepian-Wolf (SW) approach. Under

the SW approach, W is computed by first recovering each of the $\{X_i\}$. For a large class of joint distributions and subspaces W, the nested-code scheme is shown to improve upon SW. Additionally, a class of source distributions and subspaces are identified, for which the nested-code approach is sum-rate optimal.

6.3 First spike latency codes in neuronal networks, their applications and relation to network structure

Speaker: Mohan Raghavan

Affiliation: Department of Electrical Communication Engineering

Advisors: Bharadwaj Amrutur, Sujit K. Sikdar

Contact: `mohanr@ece.iisc.ernet.in`

Abstract: The means by which the brain represents and stores information has been a prime area of research for the neuroscience community. Historically, the brain is known to encode information by modulating the rate of firing of a neuron. But over the last decode or two, a huge corpus of evidence has been presented to show that the time at which a neuron spikes too encodes information. We focus on a class of spike time codes called the latency codes which are essentially spike timings measured at the time of spiking onset. In this work we look at the possible genesis of first spike times and the relation between spike latency patterns and the underlying network structure using biophysically realistic simulations. Using recordings from hippocampal cultures, we also show how studying the pattern of first spike times can help detect disruptions and modifications in neuronal network structure.

Session 7

Invited Talk: Supercomputer Education and Research Centre

Recent Computational Advances in Diffuse Optical Tomographic Image Reconstruction

Speaker: Phaneendra Yalavarthy

Abstract: Diffuse optical tomography has a potential to become an adjunct imaging modality for cancer diagnosis/prognosis. This uses near infra red light between 600 to 1000 nm to probe the tissue and is capable of providing functional images when multi-wavelength data is available. Due to the dominance of scattering, modeling of light propagation in tissue requires use of advanced computational models. One of the main bottlenecks for making diffuse optical imaging a clinical imaging modality is the computational complexity associated with it.

This seminar will give an over view of these computational models, including the recent developments at medical imaging group, SERC. These include automated way of finding the regularization parameter and data-resolution based automated choice of optimizing the minimal required measurements for reconstructing the diffuse optical images. The emphasis of this talk is going to be on open problems and associate challenges in computational aspects of diffuse optical tomography.

Brief Bio: Phaneendra K. Yalavarthy received B.Sc. and M.Sc. degrees in physics from Sri Sathya Sai University, Prasanthi Nilayam, India in 1999 and 2001 respectively. He also obtained a M.Sc. degree in engineering from Indian Institute of Science, Bangalore, India in 2004. He received a Ph.D., working as a U.S. Department of Defense Breast Cancer Predoctoral Fellow, in biomedical computation from Dartmouth College, Hanover, USA in 2007.

He worked as a post-doctoral research associate in the Department of Radiation Oncology, School of Medicine, Washington University in St. Louis, USA from 2007-2008. Currently he is working as an assistant professor in Supercomputer Education and Research Centre (SERC), Indian Institute of Science, Bangalore, India. He is a recipient of the Apple Laureate award in the year 2009. He also received Department of Atomic Energy young scientist research award in 2010 and coauthor of the work chosen for ISMRM Merit Award (Summa Cum Laude) in 2012. He serves as an associate editor for Medical Physics, which is an official scientific journal of American Association of Physicists in Medicine (AAPM). His research interests include Computational methods in medical imaging, medical image processing (reconstruction/analysis), physiological signal processing, and diffuse optical tomography.

Session 8

Invited Talk: Department of Electronic Systems Engineering

Updates on indDG Compact Model

Speaker: Santanu Mahapatra

Abstract: This talk will first give an overview of the science of compact modeling and its importance in integrated circuit design. In this context several related topics e.g., compact modeling methodologies, types of compact models, compact modeling council (CMC), standardisation etc. will be discussed. The talk will then outline the core of indDG compact model for double gate MOSFETs, which is being developed by the speaker's research team over last three years.

Brief Bio: Santanu Mahapatra received the Ph.D. degree from the Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland, in 2005. He is currently an associate professor with the Department of Electronic Systems Engineering. His research activities are focused on 2D material based MOS transistors, electro-thermal effects in Graphene/CNT and compact modeling of multi-gate MOSFETs.

Session 9

Contributed Session: Electron Devices and MEMS - I

Session Chair: Navakanta Bhat

9.1 Atomically thin tunnel field effect transistor

Speaker: Ramkrishna Ghosh

Affiliation: Department of Electronic Systems Engineering

Advisor: Santanu Mahapatra

Contact: ramkrishna@cedt.iisc.ernet.in,
rams.ramkrishna@gmail.com

Abstract: Tunnel field effect transistor (TFET) has emerged as a strong candidate for next generation low-standby power (LSTP) applications due to its sub-60mV/dec subthreshold slope (SS). As the direct band-to-band tunneling (BTBT) is improbable in Silicon (either its bulk or nanowire form), it is difficult to achieve superior TFET characteristics (i.e., very low SS and high ON current) from the Silicon TFETs. As a result alternative channel materials for TFET are being investigated. After the discovery of Graphene, atomically thin layered materials have found great significance as alternate MOSFET channel materials due to their excellent electrostatic integrity, planner structure and mechanical flexibility. However the band gap of intrinsic Graphene Nano-Ribbon (GNR) decreases very rapidly as its width increases and thus the practical application of GNR as TFET channel material are questionable as the very small band gap might result in an increase of OFF-state leakage, which is a major concern for LSTP applications. In this presentation, we explore different two-dimensional materials in their sheet and nano-ribbon form for their potential application as the channel material of TFET. We first explain the concept of complex bandstructure and least action integral (LEA), which is important tool to access the direct BTBT possibilities in

any channel material. We then use quasi-abinitio simulation to study complex bandstructure of different transition-metal dichalcogenide nanoribbons and hybrid GNRs (e.g. Graphane-Graphene, BN-Graphene etc.) and to calculate LEA for the materials where direct BTBT is highly probable under strained and relaxed conditions. We then use those LEA values in the analytical drain current models of TFTs to compute the ON current. Reasonably high tunneling current in these nanoribbon based TFET shows that it can take advantage over Silicon in future TFET applications.

9.2 High-k dielectrics for MIM capacitors

Speaker: Revathy Padmanabhan

Affiliation: Department of Electrical Communication Engineering

Advisors: Navakanta Bhat, S. Mohan

Contact: `revathyp@ece.iisc.ernet.in`

Abstract: Metal-insulator-metal (MIM) capacitors are used for analog, RF, and DRAM applications in ICs. The technology roadmap for semiconductors (ITRS) specifies continuing increase in the capacitance density ($> 7fF/\mu m^2$), lower leakage current density ($< 10nA/cm^2$), sub-nm effective oxide thickness (EOT), and better capacitancevoltage linearity ($< 100ppm/V^2$). In addition, the maximum fabrication temperature should not be greater than 400°C in order to be compatible with back-end fabrication steps. Low dielectric constants of conventional SiO_2 and Si_3N_4 capacitors limit the capacitance densities of these devices. Although scaling down of dielectric thickness increases the capacitance density, it results in large leakage current density and poor capacitance density-voltage linearity.

In this work, we have studied the effects of high-k materials (Eu_2O_3, Gd_2O_3, TiO_2) on the device performance of MIM capacitors. We have also investigated the performance of single and multi-dielectric stack devices. We have evaluated the effects of anneal temperature, anneal ambient, anneal mode, metal electrodes, and dielectric thickness on device performance. Capacitance densityvoltage, current densityvoltage, and reliability measurements were performed to benchmark the electrical performance, and this was correlated to the structural and material properties of the films. Schottky and Poole-Frenkel conduction were found to be the dominant leakage current mechanisms at low and high electric fields, respectively. Density of defects and barrier/trap heights were extracted, and correlated with the device characteristics. Device data obtained for the fabricated capacitors were found to be better than the reported data in recent literature, and meet the ITRS specifications.

9.3 Low temperature hetero-junction photovoltaic devices

Speaker: Sindhuja Sridharan

Affiliation: Department of Electrical Communication Engineering

Advisors: Navakanta Bhat, K. N. Bhat

Contact: sindhujasri@ece.iisc.ernet.in, sindhuja.sri@gmail.com

Abstract: The demand to develop economic photovoltaic cells to meet the global energy requirements have been on the rise. In recent developments, hetero-junctions are becoming quite popular and are extensively investigated due to their low processing temperature conditions. This work focuses on developing a low temperature fabrication processes and achieving higher cell efficiencies. In the first part of the thesis, a low cost solution based sol-gel technique for doped ZnO thin film deposition was developed to study Silicon-ZnO junctions. By varying the film thickness (4 nm to 180 m) and the process temperature, device responses under different illumination conditions were examined. An odd behaviour of increased Voc under low intensity illumination conditions was observed. The reason for this phenomenon was due to increased recombination at the junction due to the bad interface quality. To validate this hypothesis, TCAD device simulator SILVACO was employed and we observed similar results when the devices had a large defect density.

Second part involved the study of textured surfaces and its impact on the electrical characteristics. A two step texturing process involving KOH etching followed by a short time of TMAH treatment on Silicon surfaces, resulted in modified surfaces topographically as well as in the electrical aspects. Increase in reflectance, reduced flat band voltage and lower interface trap density was observed when compared to the conventional single step KOH or TMAH texturing technique.

The final part is the ongoing work, developing heterojunctions between amorphous SiGe and c-Silicon using low temperature PECVD. This work involves studying the junction properties and the photovoltaic response by varying Si to Ge ratio during deposition and the process temperature less than 200°C is maintained.

9.4 Analysis of electro-thermal effects in CNT/Graphene interconnects

Speaker: Rekha Verma

Affiliation: Department of Electronic Systems Engineering

Advisor: Santanu Mahapatra

Contact: rekha@cedt.iisc.ernet.in, rekha.verma26@gmail.com

Abstract: Efficient heat removal from integrated circuits while on operation has become a crucial issue for the semiconductor industry due to increased levels of dissipated power as a result of Joule-heating. Conventional inter- connect materials like Cu and Al has limited current carrying capacity of about 10^6 Acm^{-2} and thermal conductivity (κ) of 401 and 237 $Wm^{-1}K^{-1}$ at room temperature respectively. Metallic single walled carbon nanotube (SWCNT) and single layer graphene (SLG) have been found to possess an extremely high lattice thermal conductivity and current density of the order of 2000-7000 $Wm^{-1}K^{-1}$ and 10^8-10^9 Acm^{-2} at room temperature respectively which makes them potential candidates for interconnects over Cu/Al. It is therefore important to understand heat transport mechanism in CNT/ Graphene and analyze effects like hot-spot creation, electro migration etc., which might occur due to Joule heating.

In this talk we develop analytical model for the temperature dependent thermal conductivity and electronic resistivity of CNT/Graphene. Using those models we find a closed form analytical solution of Joule-heat equation. This solution is then used to estimate the electromigration effects and life-time of such carbon based system. The result obtained in this work could be useful to develop CAD tools for full-chip electro-thermal analysis for next-generation interconnects system.

Session 10

Contributed Session: Electron Devices and MEMS - II

Session Chair: Manoj Varma

10.1 Displacement sensing mechanisms for MEMS devices

Speaker: Thejas

Affiliation: Department of Electrical Communication Engineering

Advisors: Navakanta Bhat, Rudra Pratap

Contact: thejas@ece.iisc.ernet.in

Abstract: The displacements arising out of acceleration / force based detection in high resolution MEMS sensors are in the range of $< 5nm$. This work investigates the realization of high resolution MEMS inertial sensors classified under the popular categories (1) Hybrid and (2) Direct integration approaches.

In hybrid integration approach, MEMS sensor is interfaced with a capacitance sensing ASIC. The capacitance sensor circuit, based on Continuous Time Voltage sensing with Coherent Demodulation scheme, is prototyped on AMS $0.35\mu m$ technology. 50milli-g acceleration over an input frequency of 50Hz was sensed in this approach.

Under the Direct integration approach 'Sub-threshold based sensing' technique is explored.

In Sub-threshold based sensing technique, the exponential modulation of drain current for a change in displacement of 1nm is evaluated using TCAD. The influence of 1nm displacement on the sensitivity factor ($\Delta ID/ID$) is evaluated assuming a forced plate motion. It is seen that 1% change in displacement translates to nearly 1050% change in drain current sensitivity for an initial gap of 100nm. Post processing feasibility of this device using a commercial bulk-fet is explored as proof of validation. It is seen that for 59% change in

displacement (or equivalently for 370aF change in capacitance), 114% change in drain current(Id) is observed. The performance estimate is carried out considering specific Equivalent Gap Thickness(EGT)of 573nm and 235nm, to help overcome the role of coupled electrostatics in influencing the sensitivity metric.

10.2 Differential reflectance modulation sensing with diffractive microstructures

Speaker: Nityanand Kumawat

Affiliation: Department of Electrical Communication Engineering

Advisors: Manoj Varma, V. Venkataraman

Contact: `nits@ece.iisc.ernet.in`

Abstract: Micro-electromechanical systems (MEMS) are micro scale devices with feature size of the order of microns (10-6) and are fabricated using micro fabrication technology which is widely used in integrated circuit (IC) industry. Due to its outstanding performance at RF over the existing semiconductor switches such as PIN diode and FETs, MEMS switches show immense potential for commercial (telecommunication) and defense (radar, satellite etc.) applications. Although, many important developments on MEMS switches have been reported by various research communities over the last 20 years, MEMS switches have not made an impact on the market because of packaging as well as reliability issues.

This thesis presents theoretical as well as experimental investigation on the switching and release times of an electrostatically actuated micromachined switches. Switching dynamics is investigated with and without squeeze-film damping and tests were performed on SOI (silicon-on-insulator) based parallel beams of various dimensions. Experimental data as well as finite- element simulations of electrostatically actuated beams used in radio frequency microelectromechanical systems (RF-MEMS) switches show that the pull-in time is generally more than the pull-up time at voltages comparable to the pull-in voltage of the beam. This issue is investigated analytically and numerically for various forcing conditions and this is attributed to the softening of the overall effective stiffness of the electromechanical system. In this context, this thesis also addresses about methods to improve reliability of MEMS switches. High impact velocity can leads to the mechanical failure of the switch. Reliability of a switch can be improved by providing an actuation voltage in such a way that during the contact it has near-zero velocity by shaping the applied voltage waveform instead of step input or square waves. It is planned to evaluate these approaches on RF switches fabricated in-house.

10.3 A time-based all-digital technique for analog built-in-self-test

Speaker: Rajath Vasudevamurthy

Affiliation: Department of Electrical Communication Engineering

Advisor: Bharadwaj Amrutur

Contact: rajath@ece.iisc.ernet.in

Abstract: The strive for nearly-minimum energy operation is pushing the design of integrated circuits and systems towards reduced supply voltages. The design of analog and data conversion circuits is thus getting increasingly difficult due to reducing supply voltages and increasing process variations during manufacturing. However, in such technology nodes, the time domain resolution of a digital signal edge transition is superior to voltage resolution of analog signals. Hence, a lot of recent research activity has focused on using digitally assisted techniques for analog and data converter designs, especially the use of time-domain signal processing as against the conventional voltage/current-domain processing. This thesis presents the use of a unique method of time-delay measurement, especially tailored for the application of testing analog IP modules distributed all over a chip. An architecture is presented to measure analog voltages in a distributed manner all-digitally, thus reducing the routing of analog signals over long paths. A sampling head present at each test node locally converts the voltage information to delay information between a pair of sub-sampled signals, giving rise to as many sub-sampled pair of signals as there are test nodes. To measure a certain voltage, the corresponding sub-sampled signal pair is fed to a delay measurement unit to measure the delay and convert it to voltage information using previously computed calibration data. The thesis also talks about techniques of reducing the measurement time and the generation of the pair of clocks needed for delay measurement.

10.4 Theoretical and experimental investigations on the switching dynamics and reliability improvement of an RF MEMS switch

Speaker: Sudhanshu Shekhar

Affiliation: Department of Electrical Communication Engineering

Advisors: K. J. Vinoy, G. K. Ananthasuresh

Contact: sshekhar@ece.iisc.ernet.in

Abstract: Micro-electromechanical systems (MEMS) are micro scale devices with feature size of the order of microns (10-6) and are fabricated using micro fabrication technology which

is widely used in integrated circuit (IC) industry. Due to its outstanding performance at RF over the existing semiconductor switches such as PIN diode and FETs, MEMS switches show immense potential for commercial (telecommunication) and defense (radar, satellite etc.) applications. Although, many important developments on MEMS switches have been reported by various research communities over the last 20 years, MEMS switches have not made an impact on the market because of packaging as well as reliability issues.

This thesis presents theoretical as well as experimental investigation on the switching and release times of an electrostatically actuated micromachined switches. Switching dynamics is investigated with and without squeeze-film damping and tests were performed on SOI (silicon-on-insulator) based parallel beams of various dimensions. Experimental data as well as finite- element simulations of electrostatically actuated beams used in radio frequency microelectromechanical systems (RF-MEMS) switches show that the pull-in time is generally more than the pull-up time at voltages comparable to the pull-in voltage of the beam. This issue is investigated analytically and numerically for various forcing conditions and this is attributed to the softening of the overall effective stiffness of the electromechanical system. In this context, this thesis also addresses about methods to improve reliability of MEMS switches. High impact velocity can leads to the mechanical failure of the switch. Reliability of a switch can be improved by providing an actuation voltage in such a way that during the contact it has near-zero velocity by shaping the applied voltage waveform instead of step input or square waves. It is planned to evaluate these approaches on RF switches fabricated in-house.

Session 11

Invited Talk: Department of Electrical Engineering

Listening to light: Photoacoustic imaging and its future

Speaker: Manojit Pramanik

Abstract: Photoacoustic imaging is a novel imaging techniques combining both optical imaging and ultrasound imaging. A short-pulsed laser source illuminates the tissue to generate sound waves called the photoacoustic waves. These sound waves are used to get high contrast, high resolution deep tissue imaging of various parameters. Photoacoustic imaging like ultrasound imaging a multi-scale multi-depth imaging modality. This talk will give an overview of photoacoustic imaging techniques and their clinical applications such as breast cancer, skin cancer, molecular imaging etc.

Brief Bio: Dr. Manojit Pramanik received his Ph.D. degree (2010) in Biomedical Engineering from Washington University in St. Louis, St. Louis, USA under the tutelage of Dr. Lihong Wang. He joined the Department of Electrical Engineering at Indian Institute of Science (IISc), Bangalore, India as Assistant Professor in July 2012. He obtained his masters (M.Tech.) degree from Department of Instrumentation at Indian Institute of Science, Bangalore in 2004. He did his undergraduate (B.Tech) from the Department of Electrical Engineering at Indian Institute of Technology (IIT), Kharagpur, India in 2002. His industry experiences include two years (2010-12) at General Electric Global Research (GRC), Bangalore, India and one year (2004-05) at Philips Medical System, Bangalore, India. His research interest include development of medical imaging systems, instrumentation for photoacoustic and thermoacoustic imaging systems, development of low-cost ultrasound imaging systems, image reconstruction methods, medical image processing, clinical application areas such as breast cancer imaging, diabetics, molecular imaging, contrast agent development.

Session 12

Contributed Session: Wireless Communication

Session Chair: P. Vijay Kumar

12.1 Relay selection for geographical forwarding in sleep-wake cycling wireless sensor networks

Speaker: Naveen K. P.

Affiliation: Department of Electrical Communication Engineering

Advisor: Anurag Kumar

Contact: naveenkp@ece.iisc.ernet.in

Abstract: Consider a large dense wireless sensor network where the nodes, to conserve energy, are asynchronously sleep-wake cycling so that a node with a packet to forward has to wait until a "good" neighbor (referred to as a relay) wakes up. Thus a packet forwarded through such a network encounters random delay at each hop en route to the sink. The end-to-end objective is to minimize the average end-to-end delay subject to a constraint on an average total cost e.g., hop-count or total transmission power. This end-to-end problem can be considered as a stochastic shortest path problem which can be solved to obtain optimal forwarding rules for each node. However such a global solution requires a pre-configuration phase involving substantial control packets exchange. The focus of our research has been, instead, towards obtaining forwarding solutions which are "locally optimal" and then study their end-to-end performance. Towards this direction we have proposed the local problem at a forwarding node of minimizing one-hop delay subject to a constraint on a suitable reward metric (e.g., progress towards sink or transmission power) of the chosen relay. We have worked on several variants of this problem starting from the simplest case where a forwarding node knows exactly its number of relays, to the one where this information is

unknown and has to be learned as the relays wake-up. We have also worked on the case where the relays, upon waking up, do not reveal their reward metric but instead the forwarding node can probe to learn them. Currently we are working on the problem of forwarding when there are multiple nodes (holding packets from different flows) competing to choose a relay for the next-hop.

12.2 Fast scalable selection algorithms for OFDMA and cooperative wireless networks

Speaker: A. Karthik

Affiliation: Department of Electrical Communication Engineering

Advisor: Neelesh B. Mehta

Contact: karthik_ab@ece.iisc.ernet.in

Abstract: Opportunistic selection algorithms have grown in importance as next generation wireless systems strive towards higher data rates and spectral efficiencies. For example, in orthogonal frequency division multiple access (OFDMA), the system bandwidth is divided into many subchannels. For each subchannel, the user with the highest channel gain is opportunistically assigned to it. Likewise, in a multi-source, multi-destination cooperative relay (MSDR) system, a relay node must be assigned for every source-destination (SD) pair. The assignment decisions must be based only on local channel knowledge and must be fast so as to maximize the time available for data transmission.

We develop novel splitting-based multiple access selection algorithms for OFDMA and MSDR systems. These systems are unique in that the same user and relay can be the most suitable one for multiple subchannels and multiple SD pairs, respectively. For OFDMA systems, we propose an algorithm called SplitSelect that assigns for every subchannel the user with the highest channel gain over it. For MSDR systems, we propose a contention-based en masse assignment (CBEA) algorithm that assigns to each SD pair a relay that is capable of aiding it. Both SplitSelect and CBEA are fast, distributed, and scale well with the number of users or relays. For example, SplitSelect requires just 2.2 slots, on average, to assign a subchannel to its best user even when there are an asymptotically large number of contending users. Likewise, CBEA often takes far less than one slot, on average, to assign an SD pair in a system with many SD pairs.

12.3 Channel dependent reverse channel training in TDD-MIMO systems

Speaker: Bharath Bettagere

Affiliation: Department of Electrical Communication Engineering

Advisor: Chandra R. Murthy

Contact: bharath@ece.iisc.ernet.in

Abstract: Multiple Input Multiple Output (MIMO) communication using multiple antennas has received significant attention in recent years, both in the academia and industry, as they offer spatial dimensions for high-rate, reliable communication without expending valuable bandwidth. However, exploiting these promised benefits of MIMO systems critically depends on fast and accurate acquisition of Channel State Information (CSI) at the Receiver (CSIR) and the Transmitter (CSIT). In Time Division Duplex (TDD) MIMO systems, where the forward channel and the reverse channel are same, it is possible to exploit this reciprocity to reduce the overhead involved in acquiring CSI, both in terms of training duration and power, and this is the focus of this thesis. Further, many popular and efficient transmission schemes such as beamforming, spatial multiplexing over dominant channel modes, etc do not require full CSI at the transmitter. In such cases, it is possible to reduce the Reverse Channel Training (RCT) overhead by only learning the part of the channel that is required for data transmission at the transmitter. In this thesis, we propose and analyze several novel channel-dependent RCT schemes for MIMO systems and analyze their performance in terms of the (a) mean-square error in the channel estimate, (b) lower bounds on the capacity, and (c) the diversity-multiplexing gain trade-off. We show that the proposed training schemes offer significant performance improvement relative to conventional channel-agnostic RCT schemes.

12.4 A family of transitive statistical inference rules

Speaker: M. Ashok Kumar

Affiliation: Department of Electrical Communication Engineering

Advisor: Rajesh Sundaresan

Contact: ashokm@ece.iisc.ernet.in

Abstract: A classic problem in statistical inference is the following. Given a set of probability distributions and a prior, select an appropriate probability distribution from the set that is in some sense "closest" to the prior. For example, the selection rule that chooses

the distribution that minimizes a particular "distance" function from the prior. Such problems arise in statistical physics, finance, signal or image reconstruction, and in many other applications. Csiszar proved that when dealing with sets that are determined by linear constraints, if the inference rule is generated by distance functions of separable form and satisfies a transitivity property, then the distance functions are precisely the Bregman divergences. Kullback-Leibler divergence (or relative entropy) is one common example of such a divergence.

We identify a new class of inference rules which are not of the separable form, but nevertheless satisfy the transitivity property. The new class is a one-parametric family which we term α-relative entropy. It is closely related to, but different from, the family of Renyi divergences. The new class does not belong to the Bregman class.

Our main interest in the above class is the fact that the corresponding inference subject to linear constraints yields a power law. Our work is motivated by a desire to arrive at an axiomatic formulation for inference that leads to a power law, for these power laws are ubiquitous in many natural phenomena such as intensities of earth quakes, word frequencies, income distributions, etc.