

NARAYANAN KRISHNAMURTHI

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CAREER OBJECTIVES

Conduct challenging research in the field of biomedical engineering. Apply sophisticated methods in nonlinear dynamics, information theory and classical signal processing to investigate the mechanism underlying electro- and neurophysiological systems. Establish the importance of multidisciplinary approach to understand biological systems through teaching.

EDUCATION

- Ph.D., Indian Institute of Technology, Madras, India (1999)
Fields of specialty: Nonlinear dynamics and its applications to biomedical systems, nonlinear time series analysis
- M. Sc., RamaKrishnaMission Vivekananda College, Chennai, India (1992)
Fields of specialty: Chemistry
- B. Sc., RamaKrishnaMission Vivekananda College, Chennai, India (1990)
Fields of specialty: Chemistry

ACADEMIC POSITIONS

Assistant Research Scientist (10/01 – present)

Brain Dynamics Laboratory, Harrington Department of Bioengineering, Arizona State University, Tempe, AZ, USA.

Advisor: Leon D. Iasemidis, Department of Bioengineering, Arizona State University

- Responsible for proposing and carrying out new research projects involving analysis of biomedical signals using nonlinear and linear signal processing techniques with a goal of its application in clinical medicine and rehabilitation.
- Guiding and supervising graduate and undergraduate students from the disciplines of Bioengineering, Electrical engineering and Neuroscience etc.

Projects Undertaken

- Understanding the mechanism of learning and adaptation involved in task-reaching in primates, from the multi-unit neural recordings using techniques from information theory. From preliminary study, the presence of increasing and decreasing trends of interactions (plasticity) across days between neurons in different cortical regions or within a same cortical region is observed. The analysis of shuffled spike-time data indicates towards spatial firing patterns of neurons as a possible mechanism for the plasticity observed.
- The detection of direction of information of flow between observed EEG traces (measured from different locations of the brain) is being carried out, for better predictability of epileptic seizure and

identification of epileptic focus using nonlinear and linear dynamical techniques. This includes development of a new technique based on state-space approach and methodology for the proper selection of critical parameters involved in the estimation of transfer of entropy.

Projects Proposed

- Understanding the mechanism of Parkinson's disease based on the information exchange within basal ganglia and between basal ganglia and other areas of the brain. The information exchange will be estimated from the individual neuronal discharges or from in-depth EEG recordings using sophisticated techniques from nonlinear dynamics and information theory.

Post Doctoral Fellow, *Integrated Rehabilitation Engineering Program (02/00 – 09/01)*

Boston University and Harvard Medical School

Advisors: Lewis A. Lipsitz, Hebrew Rehabilitation Center for Aged, Harvard Medical School;
James J. Collins, Department of Biomedical Engineering, Boston University

Major projects

- Study of relationship between arterial pressure and cerebral blood flow and their possible changes due to healthy aging and hypertension was carried out through transfer function analysis. The results suggest that various regulatory responses to transient hypotension during standing blunt the transmission of arterial pressure changes onto cerebral blood flow. It is also found that low-frequency cerebral autoregulation remains intact, but higher frequency regulatory mechanisms affecting cerebral blood flow velocity are altered in healthy elderly subjects.
- Investigation of mechanism of posture control in different groups of people such as young, elderly and fallers. A nonlinear statistical approach was used to quantify the short-term and long-term correlations in center-of-pressure data collected from all the three groups. It was observed that the tendency to drift away from the equilibrium in short-term is higher for healthy elderly and fallers than that of the healthy young.

Project Assistant (10/99 – 01/00)

Department of Physics, Indian Institute of Technology, Madras, Chennai, India.

Developed user-friendly software modules in Visual Basic. These modules are used for educational purposes to explain basic concepts of chaos theory, a branch of nonlinear dynamics. This experience enabled me to learn Visual Basic and importance of concept presentation.

Visiting Post Doctoral Fellow (03/99 - 07/99)

University of Potsdam, Potsdam, Germany.

Estimated algorithmic entropy through symbolic encoding of ECG data of normal and pathological subjects. The algorithmic entropy represents complexity of the dynamics involved in the different conditions of cardiac system.

Research Assistant (10/93 – 02/99)

Indian Institute of Technology, Madras, Chennai, India.

Advisor: Prof. M.S. Gopinathan, Indian Institute of Technology, Madras, Chennai, India

Thesis Referee: Prof. A.M. Albano, Ph.D, Department of Physics, Bryn Mawr College, Bryn Mawr, PA.

Title: Nonlinear time series analysis and its applications to human cardiac system and coupled chemical oscillators

- Applied a spectrum of nonlinear time series tools to human ECG. Specifically, unstable periodic orbits (UPOs) of human cardiac system were extracted. The number and the distribution of UPOs were used to distinguish between normal and different pathological conditions of human cardiac system.

GRANTS PENDING

Co-Principal Investigator

Bioengineering Epilepsy: Dynamical Analysis of Scalp EEG (04/04-04/09)
(NIH; Total amount: \$3,670,000)

PUBLICATIONS

Narayanan, K., Weber, D.J., He, J., and Iasemidis, L.D. "Learning and Adaptation in the Cortex of Primates: Information Analysis of Motor Control Tasks." (To be submitted).

Sabesan, S., Narayanan, K., Prasad, A., Iasemidis, L.D., Spanias, A., and K. Tsakalis, "Improved method to measure the information flow in coupled nonlinear systems." (Submitted to *IEEE Signal Processing Letters*, 2003).

Veeramani, B., Narayanan, K., Prasad, A., Iasemidis, L.D., Spanias, A., and Tsakalis, K. "Measuring the direction and the strength of coupling in nonlinear systems - A modeling approach in the state space." *IEEE Signal Processing Letters*, 2003 (Accepted for publication).

Iasemidis, L.D., Pardalos, P.M., Shiau, D.-S., Chaovalitwongse, W., Narayanan, K., Sabesan, S., Carney P.R., and Sackellares, J.C. "Prediction of Human Epileptic Seizures based on Optimization and Phase changes of brain electrical activity." *J. Optimization Methods and Software*, 18 (1), 81-104 (2003).

Narayanan, K., Collins, J.J., Hamner, J., Mukai, S., and Lipsitz, L.A. "Predicting Cerebral Blood Flow Response to Orthostatic Stress from Resting Dynamics: Effects of healthy aging." *The American Journal of Physiology*, 281, R716-R722 (2001).

Narayanan, K., Govindan, R.B., and Gopinathan, M.S. "Evidence for low dimension chaos in electrically coupled chemical oscillator in batch condition." *Indian J. Chem. A* 39 (1-3) 345-355 (2000).

Narayanan, K., Govindan, R.B., and Gopinathan, M.S. "Unstable Periodic orbits in Human Cardiac Rhythms." *Phys. Rev E* 57, 4594-4603 (1998).

Govindan, R.B., Narayanan, K., and Gopinathan, M.S. "On the evidence of Deterministic Chaos in ECG: Surrogate and Predictability Analysis." *Chaos* 8, 495-502 (1998).

CONFERENCES

Hsiao-Weckslar, E.T., Narayanan, K., Lee, B.S., Laughton, C.A., and Lipsitz, L.A. Does Tai Chi affect postural sway & muscle activity in older adults? To be presented at the *27th Annual Meeting of the American Society of Biomechanics*, Toledo, OH, September 25-27, 2003.

Hsiao-Wecksler, E.T., Narayanan, K., Lee, B.S., Laughton, C.A., and Lipsitz, L.A. Exploring effects of Tai Chi on balance in older adults. Presented at the ASME Summer Bioengineering Conference, Key Biscayne, FL, June 25-29, 2003.

Venugopal, R., Narayanan, K., Prasad, A., Spanias, A., Sackellares, J.C., and Iasemidis, L.D. "A new approach towards predictability of Epileptic Seizures: KLT Dimension." *The Proceedings of 40th Annual Rocky Mountain Bioengineering Symposium 2003*, Mississippi, USA, pp. 123-128.

Sabesan, S., Narayanan, K., Prasad, A., Spanias, A., Sackellares, J.C., and Iasemidis, L.D. "Predictability of Epileptic Seizures: A comparative study using Lyapunov exponent and entropy based measures." *The Proceedings of 40th Annual Rocky Mountain Bioengineering Symposium 2003*, Mississippi, USA, pp. 129-135.

Veeramani, B., Prasad, A., Narayanan, K., Spanias, A., and Iasemidis, L.D. "Measuring information flow in nonlinear systems – A modeling approach in the state space." *The Proceedings of 40th Annual Rocky Mountain Bioengineering Symposium 2003*, Mississippi, USA, pp. 65-70.

Sabesan, S., Narayanan, K., Prasad, A., and Iasemidis, L.D. "Improved Measure of Information Flow in Coupled Non-Linear Systems." *The Proceedings of IASTED International Conference on Modeling and Simulation*, Palm Springs, USA, 2003, pp. 329-333.

Veeramani, B., Narayanan, K., Prasad, A., and Iasemidis, L.D. "On the use of Directed Transfer Function for Nonlinear systems." *The Proceedings of IASTED International Conference on Modeling and Simulation*, Palm Springs, USA, 2003, pp. 270-274.

Venugopal, R., Prasad, A., Narayanan, K., and Iasemidis, L.D. "Nonlinear Noise Reduction and Predictability of Epileptic Seizures." *The Proceedings of IASTED International Conference on Modeling and Simulation*, Palm Springs, USA, 2003, pp. 240-245.

Iasemidis, L.D., Prasad, A., Narayanan, K., Sackellares, J.C., Pardalos, P.M., Shiau, D.-S., and Chaovalitwongse, W. "Prediction of epileptic seizures by linear and nonlinear methods." *International Nonlinear Sciences Conference on Research and applications in the Life Sciences*, Vienna, Austria, February 7-9, 2003.

Prasad, A., Narayanan, K., Tsakalis, K., and Iasemidis, L.D. "Hysteresis in coupled chaotic oscillators and application to epileptic seizures." *International Nonlinear Sciences Conference on Research and applications in the Life Sciences*, Vienna, Austria, February 7-9, 2003.

Narayanan, K., Weber, D.J., He, J., Prasad, A., and Iasemidis, L.D. "Analysis of Neuronal Interactions during Adaptation and Learning in Motor Control of Primates: A Model Independent Approach using Information Theory." *Proceedings of the Second Joint EMBS/BMES Conference*, Houston, TX, USA, Oct. 23- 26, 2002, pp 2552-2553.

Narayanan, K., and Lipsitz, L.A. “Do resting Cerebral Pressure - Flow dynamics predict Cerebral blood flow responses to Orthostatic Stress? Effects of healthy Aging.” presented in *Experimental Biology 2001*, 31 March – 4 April, 2001, Orlando, FL, USA.

Narayanan, K., Govindan, R.B., Ramasubba Reddy, M., and Gopinathan, M.S. “Dynamics of cardiac system through unstable periodic orbits.” *Proceedings of 19th International Conference - IEEE/EMBS* Oct.30 - Nov. 2 1997, pp 2019-2021.

BOOK CHAPTERS

“Unstable periodic orbit spectra of theoretical and experimental dynamical Systems.” by R.B. Govindan, K. Narayanan, M.S. Gopinathan and N. Pradhan in *Nonlinear Phenomena In Physical And Biological Sciences* edited by S. K. Malik, M. K. Chandrashekharan and N. Pradhan (2000).

“The Spectrum of Unstable Periodic Orbits Of The Human Brain.” by R.B. Govindan, K. Narayanan, and M.S. Gopinathan, N. Pradhan, R. Sreenivasan, and P. Dwivedi in *Nonlinear Dynamics and Brain Functioning* edited by R. Sreenivasan, N. Pradhan and Paul E. Rapp, Nova Science Publishers, Inc, 1999.

JOURNAL REVIEWER

- *IEEE Transactions on Biomedical Engineering*
- *Medical & Biological Engineering & Computing*

WORKSHOPS

- Attended International IEEE EMBS Summer School on **Biocomplexity, Bioscaling and Biosignal Interpretation**, June 24 – July 1, 2001, Dartmouth College, Hanover, NH, USA
- Attended the Montreal 2000 Summer school on **Nonlinear Dynamics in Biology and Medicine**, May 22 – June 2, 2000, Montreal, Quebec, Canada.

AWARDS AND SCHOLARSHIPS

2001: Neural Control and Autonomic Regulation (NCAR) Young Investigator Award Finalist
2000: Integrated Rehabilitation and Engineering Program Fellowship from Center for Applied Bio Dynamics, Boston University.
1999: Visiting Post Doctoral Fellowship from Max-Planck Institute, Germany.
1996: Awarded 'Excellent' performance in Honours Diploma in software Technology and systems Management from NIIT, Madras, India.
1995: Senior Research Fellowship from the University Grants commission, India.
1993: Qualified in the Graduate Aptitude Test in Engineering.
1993: Junior Research Fellowship from the University Grants commission, India.

PERSONAL ATTRIBUTES

- Ability to understand principles underlying the methods.
- Good interpersonal skills as team player.
- Strong communication skills.

REFERENCES

Leon Iasemidis, Ph.D, Associate Professor/Associate Editor IEEE-TBME, Epilepsia, Department of Bioengineering, ECG Building, College of Engineering and Applied Sciences, Arizona State University, Tempe, AZ 85287-9709, P.O. Box 879709, Phone: 480-965-9134, Fax: 480-965-0037, Email: Leon.Iasemidis@asu.edu

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