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Biocomplexity Faculty Search Committee
c/o Prof. Rob de Ruyter
Department of Physics
Swain West 117
727 East Third Street
Indiana University
Bloomington, IN 47405-7105
USA

Re.: Application for the position of Assistant Professor in the field of biocomplexity at Indiana University at Bloomington.

Dear Prof. Rob de Ruyter,

I am applying for the Assistant Professor position in the field of biocomplexity at Indiana University at Bloomington. My detailed experience in research and teaching, as well as a list of references, are provided in my curriculum vitae. Also, included are my statements of research, teaching and vision. I have a strong interest in pursuing a research and teaching career in a university environment, and therefore hope to be considered for the above position.

During the past three and a half years of my postdoctoral academic career, I have worked towards the application of chaos theory tools and nonlinear signal processing techniques to neurological and physiological systems. I am currently an Assistant Research Scientist in the Department of Bioengineering at Arizona State University, where I am involved in exploring plasticity of neuronal interactions due to learning and adaptation in primates, and also working towards prediction of epileptic seizures and epileptic foci localization through chaos theory tools. Moreover, I am also involved in guiding and supervising graduate and undergraduate students from the disciplines of Bioengineering, Electrical Engineering, and Neuroscience.

Prior to my current position, I had a postdoctoral fellowship at Boston University/Harvard Medical School, where I completed a project on the relationship between arterial pressure and cerebral blood flow velocity and its possible alterations with aging. I also investigated the mechanisms of postural control in groups of young and elderly adults and elderly fallers.

My doctorate program, from Indian Institute of Technology, Madras, India, concentrated in nonlinear time series analysis and its applications to Human Cardiac, Human Brain and coupled chaotic chemical oscillators. After my doctorate, I also undertook a project involving nonlinear dynamical analysis of physiological data in the Department of Physics at University of Potsdam, Potsdam, Germany.

I sincerely believe that I meet the specific skills required for the above position with respect to the application of computational and theoretical techniques to real world data with my expertise in the application of sophisticated mathematical methods from chaos and information theory towards exploring mechanism of complex biological systems through experimental data.

I also strongly feel that with my above experience in research and guiding students from different disciplines, I can significantly contribute to the active research and teaching activities at Indiana University at Bloomington.

I will be glad to provide you with any additional materials of support upon request. Thank you for your time and consideration.

Sincerely yours,

K. Narayanan

Enclosures:

1. Curriculum Vitae
2. Statement of Research Interests
3. Statement of Teaching Interests
4. Statement of Vision

STATEMENT OF RESEARCH INTERESTS

My research interests revolve around understanding functionality of physiological systems through nonlinear and linear signal processing techniques especially through chaos theory tools. The recent development in nonlinear signal processing techniques opened the gates for a very new way of investigating biological systems, and most of the techniques developed are based on the theory of chaos. These techniques provide an opportunity to study a system from its actual measurements and enable one to considerably reduce the number of assumptions usually involved in studying biological systems.

My doctorate study involved the application of different techniques from nonlinear signal processing to human cardiac and brain systems with the aim of distinguishing normal state from other pathological states in respective systems. During my postdoctoral program IREP (*Integrated Rehabilitation and Engineering Program*), which was in collaboration between Boston University and Harvard Medical School, I had ample opportunities to interact with specialists from different fields of medicine, which considerably increased my interests in understanding physiological problems through a mathematical approach.

In that period of time, I investigated the relationship between arterial pressure and cerebral blood flow velocity through transfer function analysis and the effect of aging on this relationship. Our findings suggest that various regulatory responses to transient hypotension during standing blunt the transmission of arterial pressure changes onto cerebral blood flow. Secondly, our analysis suggests that low-frequency cerebral autoregulation remains intact, but higher frequency regulatory mechanisms affecting cerebral blood flow velocity are altered in healthy elderly subjects. In addition to the above study, the alterations in the balance control due to aging and in the case of persons who fall were identified through a nonlinear technique namely, Detrended Fluctuation Analysis. This study may be used to identify a person who is at the risk of falling and therefore can be developed as a tool to prevent such falls.

Currently, I am investigating the mechanisms of learning and adaptation in primates through the analysis of multi-unit neural recordings. Neuronal interactions within a cortex and across different cortices of brain are quantified through the estimation of mutual information between neurons. This will give insight about importance of synchrony among neurons for any learning and adapting to a new task. This may also shed some light whether synchrony among neurons is more important than just an increase in the average firing rate of neurons to carry out a specific task successfully.

Moreover, I am also working on the detection of direction of information flow between observed EEG traces (measured from different locations of the brain) using the transfer of entropy between them. In addition, another nonlinear dynamical technique is being developed for the above detection of direction of information flow; this involves estimation of dynamical correlation between different EEG traces through the modeling of local linear neighborhood of the state spaces constructed from EEG measurements.

These above analyses are used in the context of entrainment behavior between different areas of the brain during epileptic seizure. These analyses will also be of tremendous utility in identification of epileptic focus and for further control of seizures. It is widely believed that there is a strong entrainment between all the areas of the brain with the epileptic foci area during seizure. By identifying the focus, it is possible to perturb the optimal site of the brain to hinder the above process of entrainment and that in turn may prevent the occurrence of seizure. There are also plans to apply these methods to detect the direction of information flow between neurons that may enhance our knowledge significantly about the path of information flow among different areas of the brain for learning and adaptation.

From the experience and knowledge that I gained from my above research work, I would like to move forward in the direction of application of mathematical techniques in understanding the functionality of physiological systems in general. Specifically, I would like to probe in detail the cardiac and brain systems and the possible control of events like cardiac arrest and epileptic seizure. Moreover, I am very interested in the investigation of how the interaction of different areas of the brain differs for a particular neurological disease compared to that of the normal brain functioning, such as in Parkinson's disease (PD). Recently, I have also proposed a study to understand the mechanism of PD in terms of information exchange within the basal ganglia and between the basal ganglia and other areas of the brain. This type of study can also be extended to the cases of brain and spinal cord injury, which may be successful in the evaluation of rehabilitation programs.

STATEMENT OF TEACHING INTERESTS

Teaching is one of the highly noble professions by which one can build a responsible society and thereby an entire nation. Even from my school days, I had an intuitive sense of teaching and helped my friends in their lessons. One of the reasons may be that I hail from a family of teachers, and that provided a perfect atmosphere to understand the importance of learning and teaching. By teaching, I can evaluate myself, the knowledge and the degree of understanding I have in the subject. Teaching helps me to better grasp basic knowledge especially from inputs received from different perspectives. The experience of learning new things and of imparting knowledge to others always carries with it a special sense of gratification and satisfaction for me.

I possess multidisciplinary knowledge in the areas of Nonlinear Dynamics, Chaos theory, Information theory, Signal Processing, Chemistry, Physiology and Computer languages. I have experience in handling tutorials and classes for the courses on Signals and Systems, and Nonlinear and Linear signal processing techniques. I am also involved in guiding and supervising graduate and undergraduate students from the disciplines of Bioengineering, Electrical engineering and Neuroscience etc., towards their accomplishment of research projects at Arizona State University.

The above exciting experience of teaching and research made me to realize the importance of integrated aspects of communication skills, commitment towards teaching and undertaking research. It also made me feel strongly that teaching and research are complementary and each is exciting and fun.

My research along the development of novel signal processing techniques that take into account the latest discoveries in nonlinear dynamics, information theory and control theory provided me with opportunities to publish my work in prestigious international journals and to attend and present my work in international meetings. This in turn significantly improved my writing and presentation skills and willingness to interact with professionals in my field of research.

My postdoctoral work in Boston University/Harvard Medical School, gave me a unique opportunity to collaborate with medical doctors; and in that process I learned the importance of conveying my research interests and results to scientists in others areas of science and unlimited benefits of interdisciplinary research.

Based on my above knowledge and experience, I am confident in my ability to teach courses along the lines of the following:

- Nonlinear Dynamics and Chaos Theory
- Nonlinear Signal Processing
- Application of nonlinear techniques to biomedical signals
- Signals and Systems

In addition to the above, I will be happy to get involved in teaching computer languages namely FORTRAN, C, C++, and MATLAB with their applications to numerical techniques and simulations.

STATEMENT OF VISION

The recently developed sophisticated mathematical methods in the field of nonlinear time series analysis and information theory, together with breathtaking advances in technology for recording high quality biomedical signals can certainly play a major role towards our understanding of complex biological systems. I sincerely envision that

- The application of the nonlinear time series techniques can be of immense help in understanding the mechanism of epileptic seizure and cardiac arrest in respective systems. The knowledge about mechanistic aspects of the system can be fruitfully implemented, not only for prediction, but also for further prevention of abnormal functionalities.

- Moreover, as an example, the interaction among different areas of the basal ganglia of the brain can be captured from high quality neural recordings (single neuron spike trains or in-depth EEG recordings) through nonlinear dynamical methods. This will enable one to understand about functional aspects of basal ganglia, with respect to its normal information transfer with other areas of the brain and within itself, and to identify the abnormal interactions at the onset and during Parkinson disease. The above research can also be directed to other neurological disorders as well.

- With respect to control studies, the techniques from the above fields can be beneficial in identifying the neurons that are more important for any specific motor functioning (based on their interactions with other neurons). This information can be used to achieve preplanned motor movements.

- Other than the above, nonlinear dynamical techniques can be of great utility in assessing the level of one's balance (through center of pressure data obtained from under the feet). Any deterioration from normal levels of balance can be identified and used to prevent falls in the elderly or diseased. Also, the effect of drug and rehabilitation exercises can be quantified that will help us in altering the course of a drug or redesigning of an exercise with respect to the improvement obtained in patients.

I am very optimistic that my expertise in nonlinear dynamics, information theory, signal processing techniques, and software development and my experience and growing interest in studying different biological systems will enable me to accomplish the above mentioned goals and more.