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Center for Adaptive Neural Systems

School of Biological and Health Systems Engineering

Arizona State University

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Education

- 1999 Ph.D. Indian Institute of Technology, Madras, India
Field: Biomedical signal analysis
- 1992 M. Sc. Rama Krishna Mission Vivekananda College, Chennai, India
Field: Chemistry
- 1990 B. Sc. Rama Krishna Mission Vivekananda College, Chennai, India
Field: Chemistry

Professional Interests

Neurorehabilitation; Neural plasticity; Bioengineering; Parkinson's disease; Spinal cord injury; Exercise training; Neuromuscular electrical stimulation; Biomedical signal analysis; Nonlinear dynamics.

Positions

- 02/07 – present *Assistant Professor, Research*, Center for Adaptive Neural Systems, School of Biological and Health Systems Engineering, Ira A. Fulton Schools of Engineering, Arizona State University, Tempe, Arizona
- 07/11 – present *Program Manager Parkinson Research*, Muhammad Ali Parkinson Center, Barrow Neurological Institute, St. Joseph's Hospital and Medical Center, Phoenix, Arizona
- 05/05 – 02/07 *Research Scientist*, Center for Adaptive Neural Systems, Ira A. Fulton School of Engineering, Arizona State University, Tempe, Arizona
- 10/01 – 04/05 *Research Scientist*, Brain Dynamics Laboratory, Department of Bioengineering, Arizona State University, Tempe, Arizona
- 02/00 – 09/01 *Postdoctoral Fellow*, Integrated Rehabilitation Engineering Program, Boston University/Harvard Medical School, Massachusetts
- 10/99 – 01/00 *Project Assistant*, Department of Physics, Indian Institute of Technology, Madras, India
- 03/99 – 07/99 *Visiting Postdoctoral Fellow*, Center for Nonlinear Dynamics, Department of Physics, University of Potsdam, Potsdam, Germany

Sponsored Research**Active***Exercise training in Parkinson's disease: Neural and functional benefits*

NIH-NICHD-National Center for Medical Rehabilitation Research

1R21HD060315-01A2 09/23/08 – 08/31/12 \$495,525

Role: PI

The study investigates the benefits of a physical exercise program in persons with Parkinson's disease. Specifically, this study quantifies functional benefits and document changes in brain function through the use of ¹⁸F-FDG PET imaging techniques.

Collaborators: James Abbas, PhD and Wayne Willis, PhD (Arizona State University), Holly Shill, MD (Sun Health Research Institute), Abraham Lieberman, MD (Barrow Neurological Institute), Kewei Chen, PhD, Padma Mahant, MD, and Johan Samanta, MD (Banner Good Samaritan Medical Center).

Exercise training in Parkinson's disease: Neural and functional benefits (Supplement)

NIH-NICHD-National Center for Medical Rehabilitation Research

3R21HD060315-02S1 (ARRA) 09/01/2010-08/31/2012 \$114,116

Role: PI

The goal is to extend the FDG-PET imaging aspect of the parent study to all the 16 participants. This will enable to obtain more definitive conclusions on the ability of regular exercise training to produce beneficial alterations in brain metabolic activity patterns.

Improving mobility in Parkinson's disease: Effects of a dance-based movement program

Arizona State University – Mayo Seed Grant Program 01/01/2011 – 12/31/2011 \$40,000

Role: Co-PI

This study will explore the effects of a dance-based movement program called Movement and Motion specifically designed to improve mobility (balance, gait, and range of motion) in people with Parkinson's disease.

Collaborators: Claudia Murphey, MA (Arizona State University) and Erika Driver-Dunckley, MD (Mayo Clinic)

The effect of whole body periodic acceleration (WBPA) on the disorders of balance, gait, and freezing of gait in Parkinson's disease: A clinical study

St. Joseph's Hospital and Medical Center – funded by Non-Invasive Medical Systems

Role: Co-I

The goal of this study is to investigate whether WBPA provide a means of managing the symptoms of impaired balance and secondarily the symptoms of freezing of gait in Parkinson's disease individuals

Pending

Biomarkers of brain health after spinal cord injury

Christopher and Dana Reeve Foundation (\$150,000)

Role: PI

The main aim of this study is to investigate whether people with chronic spinal cord injury also exhibit unfavorable alterations in brain anatomy, may be due to dysfunction of autonomic nervous system.

Unfunded:

Training that uses real-time feedback to improve gait in Parkinson's disease

National Institutes of Health (R21 proposal) (\$428,680) – will be resubmitted

Role: PI

The goal of the study is to improve gait in people with Parkinson's disease by providing feedback of gait parameters in real-time.

Improving cardiorespiratory function in persons with cervical spinal cord injury

Paralyzed Veterans of America (\$150,000)

The main aim of this study is to improve cardiorespiratory function by regular deep breathing training in people with spinal cord injury.

Selected in the list of top 16 projects for two consecutive years by Paralyzed Veterans of America Research Foundation (2004, 2005) but not funded due to insufficient funds. This proposal will be resubmitted to NIH and other funding agencies.

Completed

Improving orthostatic tolerance after spinal cord injury

Paralyzed Veterans of America Research Foundation

2546

\$150,000

Role: PI

The major goal of this project is to investigate the use of neuromuscular electrical stimulation to alleviate orthostatic hypotension in people with complete spinal cord injury.

Collaborators: James Abbas (Arizona State University), Denise Campagnolo, MD, and Candyce Williams, MD (Barrow Neurological Institute).

Adaptive electrical stimulation for locomotor retraining

NIH-NICHD-National Center for Medical Rehabilitation Research

R01-HD049773

07/01/05-04/30/11

\$868,573

Role: Research Scientist (PI: James Abbas, Ph.D.)

The goal of this project is to develop and evaluate an adaptive control system to generate gait movements using electrical stimulation during treadmill locomotion in individuals with spinal cord injury.

Adaptive Stimulator for Exercise and Rehabilitation

NIH-NICHD-National Center for Medical Rehabilitation Research

R44

7/1/04 - 06/30/08

\$234,885

Role: Research Scientist (PI on subcontract to ASU: James Abbas, Ph.D.)

In this Phase II SBIR grant, an electrical stimulator with adaptive capabilities that could be for exercise by individuals with spinal cord injury was developed.

Stimulation-Augmented Exercise and Neuromotor Therapy

NIH-NICHD-National Center for Medical Rehabilitation Research

R43

4/1/06-10/31/07

\$32,630

Role: Research Scientist (PI on subcontract to ASU: James Abbas, Ph.D.)

This Phase I SBIR grant demonstrated the feasibility of an exercise and therapeutic device to promote functional recovery after spinal cord injury.

Teaching

Ad-hoc lectures for courses such as Biodynamics, Computational Neuroscience, and Biosignals and Systems

Ability to teach courses in the field of Physiology, Rehabilitation, and Statistics.

Academic Service

Invited Reviewer for Journal of Neural Engineering; Journal of Neurology, Neurosurgery & Psychiatry; Medical Engineering & Physics; IEEE Transactions on Biomedical Engineering; IEEE Transactions on Neural Systems and Rehabilitation Engineering; Medical & Biological Engineering & Computing; American Institute of Biological Sciences.

Program Committee Member for Program Committee Member - First International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC-2008); International Conference on Bio-inspired Systems and Signal Processing (BIOSIGNALS 2011, BIOSIGNALS 2010, BIOSIGNALS 2009).

Invited Talks

“Improving Health and Function by Multidisciplinary Neurorehabilitative Approach”, at Kansas City University of Medicine and Biosciences, Kansas City, MO, 5th November, 2010.

“Analysis of Electrocardiogram: Calculation of Heart Rate Variability”, at Speed School of Engineering, University of Louisville, KY, 20th July, 2010

“Improving Health and Function by Neurorehabilitative Approach”, at Health Sciences Campus, University of Louisville, KY, 19th July, 2010

“Neurorehabilitative interventions to improve health and function”, at Division of Physical Therapy, School of Medicine, West Virginia University, WV, 11th March, 2010

“Effects of Deep Brain Stimulation on Dynamic Posture Shifts in Parkinson’s Disease”, IEEE International Conference on Complex Medical Engineering, April 9-11, 2009, Tempe, AZ

“Deep brain stimulation as a treatment for Parkinson’s disease”, at A.T. Still University, Arizona School of Health Sciences, Mesa, AZ, 2nd November, 2006

“Computational Analysis of Neurological Disorders”, at State University of New York, Binghamton, NY, 11th August, 2005

“Parkinson’s disease: Effects of DBS settings on posture control”, Brown Bag Seminar at Biodesign Institute representing the Center for Adaptive Neural Systems, 19th September, 2004.

“Investigation of Motor and Sensory Cortical Interactions during Learning and Adaptation”, at National Brain Research Institute, Gurgaon, India, June, 2003

“Analysis of Neuronal Interactions during Adaptation and Learning in Motor Control of Primates: A Model Independent Approach using Information Theory”, at the 2nd Joint EMBS/BMES Conference, Houston, TX, USA, Oct 23-26, 2002

“Nonlinear and linear dynamical analyses of human ECG, EEG, and cerebral blood flow” at the Department of Bioengineering, Arizona State University, 1st June, 2001

Invention Disclosure

June 25, 2009, AzTE Case #M9-162L, *“Real-Time Feedback System to Improve Gait”*, Narayanan Krishnamurthi & James Abbas

Media Exposure

Arizona Republic, July 3, 2010 - *Disease victims step up for study: Effects of exercise on Parkinson's measured*

<http://www.azcentral.com/news/articles/2010/07/03/20100703arizona-parkinsons-disease-study.html?source=nletter-news>

EurekAlert, December 3, 2009 – *Can exercise reduce the symptoms of Parkinson's disease?*

http://www.eurekalert.org/pub_releases/2009-12/sjha-map120309.php

Paraplegic News, February 2008 – *Innovative Research for a Better life*

Continuing Education/Training

Strategies for Creating Successful NIH Proposals – Research Strategy Group and College of Nursing and Health Innovation, February 16, 2011, Arizona State University, Tempe, AZ, USA

Co-Adaptive Learning: Adaptive Technology for the Aging – The Center for Adaptive Neural Systems, January 8-9, 2009, Arizona State University, Tempe, AZ, USA.

Promoting Neural Plasticity - The Center for Adaptive Neural Systems, February 15, 2008, Arizona State University, Tempe, AZ, USA.

Mentoring Strategies - funded by Howard Hughes Medical Institute to Arizona State University, October 19, 2007, Arizona State University, Tempe, AZ, USA.

Proposal Budgets, April 12, 2007, Arizona State University, Tempe, AZ, USA

Adaptation and Learning in Neuro-biomechatronic Systems - The Center for Adaptive Neural Systems, March 22-23, 2007, Arizona State University, Tempe, AZ, USA.

Locating Funding, March 14, 2007, Arizona State University, Tempe, AZ, USA

The Fundamentals of Research Administration for the Investigator, January 2007, Arizona State University, Tempe, AZ, USA

Successful Grant writing and Collaborative Projects, February 24, 2005, Arizona State University, Tempe, AZ, USA

International IEEE EMBS Summer School on *Biocomplexity, Bioscaling and Biosignal Interpretation*, June 24 – July 1, 2001, Dartmouth College, Hanover, NH, USA

Montreal 2000 Summer school on *Nonlinear Dynamics in Biology and Medicine*, May 22 – June 2, 2000, Montreal, Quebec, Canada

Awards & Scholarships

2010: Arizona State University - Mayo Clinic Seed Grant Award

2010: ARRA Supplement Research Grant Award from National Institutes of Health

2008: Exploratory Research Grant Award from National Institutes of Health

2008: Clinical Study Research Grant Award from Paralyzed Veterans of America

2006: First World Parkinson Congress – Junior Scholarship Award

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: Max-Planck Institute Visiting Post Doctoral Fellowship, 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

Publications (My name is listed as "K. Narayanan" in all of my publications)

- K. Narayanan**, H. Shill, J. Stovall, D. O'Donnell, P. Mahant, J. Samanta, A. Lieberman, and J.J. Abbas, "*Polestriding improves gait in Parkinson's disease*" (abstract submitted to 41st Annual Meeting of Society for Neuroscience, Washington, DC, 2011)
- K. Narayanan**, C. Williams, J. Stovall, A. Biemond, M. Raasch, and J.J. Abbas, "*Electrical stimulation training to improve orthostatic tolerance in spinal cord injury*" (abstract submitted to 41st Annual Meeting of Society for Neuroscience, Washington, DC, 2011)
- A. Conovoloff, **K. Narayanan**, P. Mahant, J. Samanta, and J.J. Abbas, "*The effects of deep brain stimulation amplitude on motor performance in Parkinson's disease*" (submitted)
- K. Narayanan**, S. Mulligan, P. Mahant, J. Samanta, and J.J. Abbas, "*Effects of Deep Brain Stimulation on Dynamic Posture Shifts in Parkinson's Disease*", IEEE International Conference on Complex Medical Engineering, April 9-11, 2009, Tempe, AZ (Digital Object Identifier 10.1109/ICCME.2009.4906651)
- K. Narayanan**, A. Conovoloff, P. Mahant, J. Samanta, and J.J. Abbas, "*Effects of Deep Brain Stimulation Amplitude on Gait in Parkinson's Disease*", 37th Annual Meeting of Society for Neuroscience, November, November 3-7, 2007, San Diego, CA.
- A. Downing, **K. Narayanan**, and J.J. Abbas, "*Postural control of self-initiated weight shifts in children and adults*", Annual Conference of American Society for Biomechanics, August 22-25, 2007, Stanford, CA.
- S. Sabesan, **K. Narayanan**, A. Prasad, L.D. Iasemidis, A. Spanias, and K. Tsakalis, "*Information flow in coupled nonlinear systems: Application to the epileptic human brain*", In: Data Mining in Biomedicine, Eds: P. Pardalos, V. Boginski, A. Vazacopoulos, Springer Optimization and its Applications Series, Springer, pp. 483-504 (2007).
- K. Narayanan**, S. Mulligan, P. Mahant, J. Samanta, and J.J. Abbas, "*Deep brain stimulation alters postural control in Parkinson's Disease*", abstract presented at 36th Annual Meeting of Society for Neuroscience, October, October 14-18, 2006, Atlanta, GA
- K. Narayanan**, S. Mulligan, P. Mahant, J. Samanta, and J.J. Abbas, "*Deep Brain Stimulation Effects on Posture Control in Parkinson's Disease*", World Parkinson Congress, February 22-26, 2006, Washington D.C (published in Movement Disorders, Vol. 21, Supp. 13, P209, page S115, 2006)
- S. Mulligan, **K. Narayanan**, P. Mahant, J. Samanta, and J.J. Abbas, "*Effect of deep brain stimulation on posture control in Parkinson's disease*", 9th International Congress of Parkinson's disease and Movement Disorders, March 5-8, 2005, New Orleans, LA (published in Movement Disorders, Vol. 20, Supp. 10, P478, page S141, 2005)
- L.D. Iasemidis, P.M. Pardalos, D-S Shiau, W. Chaovalitwongse, **K. Narayanan**, A. Prasad, K. Tsakalis P. Carney and J.C. Sackellares, "*Long-term prospective on-line real-time seizure prediction*", Clin Neurophysiol., 116, 532-544 (2005)

- B. Veeramani, **K. Narayanan**, A. Prasad, L.D. Iasemidis, A. Spanias, and K. Tsakalis, "*Measuring the direction and the strength of coupling in nonlinear systems - A modeling approach in the state space*", IEEE Signal Processing Letters, 11 (7), 617-620 (2004)
- S. Sabesan, **K. Narayanan**, A. Prasad, A. Spanias, J.C. Sackellares, and L.D. Iasemidis, "*Predictability of Epileptic Seizures: A comparative study using Lyapunov exponent and entropy based measures*", Biomed Sci Instrum., 39, 129-35 (2003)
- B. Veeramani, A. Prasad, **K. Narayanan**, A. Spanias, and L.D. Iasemidis, "*Measuring information flow in nonlinear systems - A modeling approach in the state space*", Biomed Sci Instrum., 39, 65-70 (2003)
- R. Venugopal, **K. Narayanan**, A. Prasad, A. Spanias, J.C. Sackellares, and L.D. Iasemidis, "*A new approach towards predictability of Epileptic Seizures: KLT Dimension*", Biomed Sci Instrum., 39, 123-128 (2003)
- E.T. Hsiao-Wecksler, **K. Narayanan**, B.S. Lee, C.A. Laughton, and L.A. Lipsitz, "*Does Tai Chi affect postural sway & muscle activity in older adults?*" 27th Annual Meeting of the American Society of Biomechanics, Toledo, OH, September 25-27, 2003
- S. Sabesan, **K. Narayanan**, A. Prasad, and L.D. Iasemidis, "*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
- B. Veeramani, **K. Narayanan**, A. Prasad, and L.D. Iasemidis, "*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
- R. Venugopal, A. Prasad, **K. Narayanan**, and L.D. Iasemidis, "*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
- L.D. Iasemidis, A. Prasad, **K. Narayanan**, J.C. Sackellares, P.M. Pardalos, D.S. Shiau, and W. Chaovalitwongse, "*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
- A. Prasad, **K. Narayanan**, K. Tsakalis, and L.D. Iasemidis, "*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
- L.D. Iasemidis, P.M. Pardalos, D-S. Shiau, W. Chaovalitwongse, **K. Narayanan**, S. Sabesan, P.R. Carney, and J.C. Sackellares, "*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)
- K. Narayanan**, D.J. Weber, J. He, A. Prasad, and L.D. Iasemidis, "*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
- K. Narayanan**, J.J. Collins, J. Hamner, S. Mukai, and L.A. Lipsitz, "*Predicting Cerebral Blood Flow Response to Orthostatic Stress from Resting Dynamics: Effects of healthy aging*", The American Journal of Physiology, 281: R716-R722 (2001)

- K. Narayanan** and L.A. Lipsitz, “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
- K. Narayanan**, R.B. Govindan, and M.S. Gopinathan (2000) “Evidence for low dimension chaos in electrically coupled chemical oscillator in batch condition”, Indian J. Chem. A 39: (1-3) 345-355
- R.B. Govindan, **K. Narayanan**, M.S. Gopinathan, and N. Pradhan, “Unstable periodic orbit spectra of theoretical and experimental dynamical Systems”, In: Nonlinear Phenomena In Physical And Biological Sciences edited by S. K. Malik, M. K. Chandrashekhara and N. Pradhan (2000), pp. 153-194.
- R.B. Govindan, **K. Narayanan**, and M.S. Gopinathan, N. Pradhan, R. Sreenivasan, and P. Dwivedi , “The Spectrum of Unstable Periodic Orbits Of The Human Brain”, In: Nonlinear Dynamics and Brain Functioning edited by R. Sreenivasan, N. Pradhan and Paul E. Rapp, Nova Science Publishers, Inc, 1999, pp. 345-377
- K. Narayanan**, R.B. Govindan, and M.S. Gopinathan, “Unstable Periodic orbits in Human Cardiac Rhythms”, Phys. Rev E 57, 4594-4603 (1998)
- Govindan, R.B., **K. Narayanan**, and M.S. Gopinathan, “On the evidence of Deterministic Chaos in ECG: Surrogate and Predictability Analysis”, Chaos 8, 495-502 (1998)
- K. Narayanan**, R.B. Govindan, M. Ramasubba Reddy, and M.S. Gopinathan, “Dynamics of cardiac system through unstable periodic orbits”, Proceedings of 19th International Conference - IEEE/EMBS Oct.30 - Nov. 2 1997, pp 2019-2021