Midhun Parakkal Unni

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Technical Skills

Mathematical modelling and Machine Learning: Dynamical systems, physiological systems modelling, hybrid-dynamical systems, supervised and unsupervised learning, and optimization algorithms.

Signal Processing: Time-frequency analysis and compressive sensing and sparse signal processing.

Software Skills

Languages: Python, MATLAB, Mathematica

Packages: Numpy, Scipy, matplotlib, scikit-learn, Keras, L1-Magic (MATLAB), Optimization Toolbox (MATLAB)

Design: SolidWorks

Version Control: Git

Standards Used: IEC 60812, 62366, ISO 13485, 14971

Honors & Awards

- One of the recipients of the International Excellence Scholarship for PhD, University of Exeter, UK, 2017
- 3 Journal articles, 3 Conference proceedings and 2 Patent grants (Details are provided in Appendix).
- Half Time Research Assistantship, Department of Biotechnology, India, 2010
- Scholarship and a travel grant to attend Summer School on Cognitive and Computational Neuroscience, CSHL-Asia by Department of Bio-Technology, India, 2010
- Multiple awards for outstanding performance, HCL Technlogies

Education

Univerity of Exeter — **Exeter, UK**
Ph.D. Mathematics — *2017-Ongoing*

Indian Institute of Technology Madras — **Chennai, India**
Master of Technology, Clinical Engineering — *2008-2011*

Government Engineering college, Kerala University — **Kerala, India**
Bachelor of Technology, Mechanical Engineering — *2004-2008*

Work Experience

University of Exeter - Mathematical Modelling and Data Analysis for Freezing of Gait in Parkinson's Disease

Mathematical modelling — *2017-Ongoing*

- Developed a hybrid inverted-pendulum mathematical model and simulated neurally controlled walking dynamics in Parkinson's Disease. Captured rich behaviours such as chaos and periodic orbits. Authored a peer-reviewed journal article that points to management solutions for patients with movement difficulties.
- Effectively integrated the inverted pendulum system with a feedback-controlled central pattern generator. Demonstrated this hybrid dynamical model's ability to understand the effect of augmented feedback in alleviating freezing of gait, potentially be used in conjunction with wearable devices.
- Developed a phase-reset-curve based discrete model of gait to study freezing in Parkinson's considering the change in the different neuronal characteristics and neuronal inputs. A highly modular approach with potential to integrate with other systems was implemented leveraging the functional programming strengths of Mathematica.

Machine Learning and Data Analysis *2017-Ongoing*

- Developed a pre-processing technique to be used in a time series forecasting/predictive modelling scenario specific to the stepping force data. Converted the forecasting problem into a classification problem by appropriately segmenting the data.
- Built a pipeline and systematically evaluated and implemented different machine learning approaches (Neural Networks, Naïve Bayes, Random Forest) to predict freezing of gait in Parkinson's disease. The project was implemented using python packages such as scikit-learn and Keras.
- Used statistical approaches to validate the significance of the different conclusions made using the machine learning algorithms. Part of the machine learning work has been published as a journal article

Researcher, TCS Research & Innovation, India

Mathematical Modelling, Machine Learning and Signal processing *2014-2017*

- Developed an innovative technique to estimate stress from photoplethysmograph signal using a mathematical model. Neural network-based learning and numerical simulations were used to extract parameters from the model. Validated the conclusions derived from the algorithm using healthy participants' data. Authored an IEEE conference proceedings paper to communicate the results and generated a US patent grant for this invention
- Developed an early screening technique for Motor Disorders using a neuromuscular model of the human arm using rigid body mechanics. Using Kinect data, the model's cost functionals were estimated using inverse optimal control and optimization methods in Python. Authored a peer-reviewed journal article and generated a patent filing for this work
- Developed a non-invasive blood pressure (BP) estimation algorithm. Employed genetic algorithms, Neural networks and maximum likelihood estimation techniques for estimating the blood pressure from the displacement signals measured using a piezoelectric sensor from the wrist. Generated a European and Chinese patent grant for this project.
- Reduced the memory requirement of a numerical method in solving differential equations using compressive sensing. The algorithm has the potential to be used in embedded devices with memory constraints. This work resulted in a peer reviewed IEEE conference proceedings publication.
- Developed a time-frequency analysis based algorithm using Photoplethysmograph data to understand the effect of stress on heart rate variability. Presented the work in IEEE - EMBC conference.

Lead Engineer, HCL Technologies, India – Engineering and R&D Services

Mathematical Modelling for Device feasibility *2012-2013*

- Numerically simulated a multi-scale model of arterial structure dynamics using MATLAB.
- Demonstrated the feasibility of a blue light device and an electromagnetic device in alleviating erectile dysfunction using mathematical models considering bio-compatibility and manufacturing.

Medical Devices - Idea generation, Concept design, Risk Management and Reverse engineering *2011-2013*

- Devices for erectile dysfunction & urinary incontinence: User research, Material selection, conceptualization and idea generation (in CAD) and authoring design input documents. Modelling and analyzing the physiology and mechanism of erectile dysfunction to assist device development. Design calculation and solutions to avoid catheter-associated urinary tract infection.
- Regulatory/risk management: Authored several risk management documents using the appropriate medical device standards
- Reverse engineering an insulin pump to understand the clinical advantages and disadvantages of the mechanism used.

Other Skills

Organization and Planning:
- Management of a multi-disciplinary project in collaboration with designers, engineers, clinicians and mathematicians concerning technical aspects of the project.
- Initiated Bio-Engineering Group at HCL Technologies, a platform where engineers from various domains can discuss, contribute & innovate solutions to medical problems.
- Assisted senior management in the preparation of project proposal from defining problem statement to risk identification and mitigation plans

Communication:
- Presented the work in international conferences; engaged with audiences from various disciplines.

Independence and Creative Thinking:
- Lead research projects; Identified new areas of research.

Learning New Skills and Outreach: As a hobby I enjoy developing websites, telegram bots, and mobile-apps.

Appendix

Journal Articles

Parakkal Unni, Midhun, Prathyush P Menon, Lorenzo Livi, Mark Wilson, William R Young, Helen M Bronte-Stewart, and Krasimira Tsaneva-Atanasova (2020). "Data-Driven Prediction of Freezing of Gait Events from Stepping Data". In: *Frontiers in Medical Technology* 2, p. 13.

Parakkal Unni, Midhun, Prathyush P Menon, Mark R Wilson, and Krasimira Tsaneva-Atanasova (2020). "Ankle Push-off Based Mathematical Model for Freezing of Gait in Parkinson's Disease". In: *Frontiers in bioengineering and biotechnology* 8, p. 1197.

Unni, Midhun P, Aniruddha Sinha, Kingshuk Chakravarty, Debatri Chatterjee, and Abhijit Das (2017). "Neuromechanical Cost Functionals Governing Motor Control for Early Screening of Motor Disorders". In: *Frontiers in bioengineering and biotechnology* 5, p. 78.

Selected Conference Papers

Unni, Midhun P, M Girish Chandra, and A. Anil Kumar (2017). "Memory Reduction for Numerical Solution of Differential Equations Using Compressive Sensing". In: *13th IEEE Colloquium on Signal Processing and its Applications (CSPA 2017)*.

Unni, Midhun P, Srinivasan Jayaraman, and Balamuralidhar P (2016). "Non-invasive Blood Pressure estimation using constitutive model from the radial artery pulse". In: *2nd International Conference on Biomedical Systems, Signals and Images*, p. 4.

Unni, Midhun Parakkal, Jayaraman Srinivasan, and P. Balamuralidhar (2017). "A Model Based Inference Engine for Stress Estimation". In: *2017 International Conference on Signals and Systems (ICSigSys) (ICSigSys2017)*. IEEE, pp. 234–238.

Invited Talk

Mathematics of Differential Equations and Model Based Estimation in Biomedical Engineering - Model Engineering College, India, Kerala - 2016

Patents

Jayaraman, Srinivasan, Balamuralidhar Purushothaman, Midhun P Unni, Aniruddha Sinha, Arpan Pal, and Ramesh Kumar Ramakrishnan (Mar. 2017). *Method and device for continuous blood pressure monitoring and estimation*. US Patent App. 15/255,643, (The corresponding patent has been granted in EU and China (EP3138482B1 and CN106491108B)).

Unni, Midhun Parakkal, Srinivasan Jayaraman, and Balamuralidhar Purushothaman (Jan. 2021). *Method and system for estimation of stress of a person using photoplethysmography*. US Patent 10,881,345.

Unni, Midhun Parakkal, Aniruddha Sinha, Kingshuk Chakravarty, Debatri Chatterjee, and Abhijit Das (Apr. 2019). *Systems and methods for optimizing a joint cost function and detecting neuro muscular profiles thereof*. US Patent App. 16/159,245.