Varun Joshi

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Education

Ph.D. The Ohio State University, 2012 – 2018
Department: Mechanical Engineering
Dissertation: Understanding the control of human walking using perturbation experiments.
Advisor: Dr. Manoj Srinivasan

B. Tech. and M. Tech Indian Institute of Technology, Madras, 2007 - 2012
Major: Mechanical Engineering
Specialization: Product Design
Thesis: A MATLAB based kinematic synthesis and analysis package.
Advisor: Dr. Sujatha Srinivasan

Research interests

- Dynamics and control in human, animal, and robot locomotion
- Model-based design of robotic prostheses, exoskeletons and assistive devices
- Kinematic design of mechanisms and machines
- Machine learning

Journal publications

1. V. Joshi and M. Srinivasan. Walking on a moving surface: Energy-optimal walking motions on a shaky bridge and a shaking treadmill can reduce energy costs below normal, *Proceedings of the Royal Society A 471:* 20140662, 2015
2. V. Joshi and M. Srinivasan. Walking crowds on a shaky surface: The mechanics of stable walking predict Millennium bridge oscillations with and without pedestrian synchrony, *Biology Letters 14: 20180564, 2018*
3. V. Joshi and M. Srinivasan. A controller for inverted pendulum biped control inferred from human walking dynamics, *In revision after review for Journal of the Royal Society Interface (draft available on request)*
4. V. Joshi and M. Srinivasan. Human response to large perturbations during walking: Foot placement, center of pressure and ground reaction forces, *In preparation for IEEE Journal of Biomedical Engineering*

Press and media publicity

Article 1. Walking on a moving surface: Energy-optimal walking motions on a shaky bridge and a shaking treadmill can reduce energy costs below normal (2015):

- Science Daily article "To save your energy while strolling, walk this sway", Feb 2 2015

Article 2. Walking crowds on a shaky surface: The mechanics of stable walking predict Millennium bridge oscillations with and without pedestrian synchrony (2018):

- Ars Technica article “New study sheds more light on what caused Millennium Bridge to wobble”, Oct 30 2018
- Tech Xplore article “New model offers more specifics about the swaying of the Millennium Bridge”, Oct 31 2018
- The Wall Street Journal article "Swing Shift: A Bridge Wobbled and Robotics Benefited”, Nov 9, 2018

Conference presentations

1. V. Joshi and M. Srinivasan. A full-state controller for the simple inverted pendulum biped derived from human perturbation experiments. American Society of Biomechanics, Rochester, MN, Aug 2018. (Finalist for ASB doctoral student presentation competition, top 36 of nearly 250 submissions)
2. V. Joshi and M. Srinivasan. Using perturbation experiments to infer how humans control walking. American Society of Biomechanics, Boulder, CO, Aug 2017
3. V. Joshi and M. Srinivasan. Finding the human walking controller from perturbed walking + Human-structure interaction: The Millennium Bridge. Conference on Dynamic Walking, Finland, June 2017
4. V. Joshi and M. Srinivasan. Is human walking behavior better predicted by energetics or stability: a case-study involving human-structure interactions. International Society of Electrophysiology and Kinesiology Congress, Chicago, IL, July 2016
5. V. Joshi and M. Srinivasan. Understanding foot placement and leg-force generation in humans using perturbation experiments. Conference on Dynamic Walking, Holly, MI, June, 2016
6. B. Clark, V. Joshi, Y. Wang, and M. Srinivasan. On human walking foot placement + Energy-optimal perturbation recovery for a walking biped. Conference on Dynamic Walking, Columbus, OH, July 2015
7. V. Joshi and M. Srinivasan. Walking on a shaky bridge and shaken treadmill: optimal walking motions predict metabolic costs below normal. Conference on Dynamic Walking, Columbus, OH, July 2015
8. V. Joshi and M. Srinivasan. Humans walking on shaky and shaking surfaces: application to oscillating treadmills and the London Millennium Bridge. World Congress of Biomechanics, Boston, MA, July 2014

Research projects

Deriving the human walking controller through perturbation experiments

Motivation: Understanding the human controller would allow us to predict human response to perturbations, develop metrics for walking stability and design controllers for bipedal robots, exoskeletons and prostheses

Contributions:

1. Human subject experiments: I collected kinematic and kinetic data from human subjects as they walked on a treadmill while being intermittently pulled sideways or backwards. 12 subjects, over 2000 perturbed steps for each experiment
2. System Identification: I used the collected experimental data to derive simple linear controllers which could explain how foot-position, center-of-pressure and ground reaction forces are used to stabilize walking

3. Model-specific fitting: I derived a model-specific controller which could make a simple inverted pendulum model respond to perturbations in a manner that approximates human response
4. Controller analysis: I determined the basin of attraction and robustness of the model-specific controller

Using simple models of walking to explain human-structure interaction for footbridges and walkways

Motivation: Large scale lateral oscillations have been observed on bridges and walkways when large crowds walk on them. The mechanism for the onset of these oscillations is poorly understood. We would like to see if simple models of walking using the principle of energy-minimization or a linear controller can explain these events

Contributions:

1. Energy optimal biped simulations: I simulated a simple point-mass model of a biped walking on a bridge and used trajectory optimization to determine the energy-optimal motion for the coupled biped-bridge system
2. Forward simulation of a crowd of stable bipeds: I simulated multiple simple inverted pendulum biped models, each with a once-per-step linear controller walking on a bridge
3. Analyzing synchronization: I used the Kuramoto model to determine if synchronization between bipeds is an important factor in the onset of large lateral oscillations of the pedestrian-bridge system

Relevant coursework

Graduate coursework:

Advanced topics in the dynamics and control of human and animal movement
Advanced dynamics
Advanced kinematics
Control systems laboratory
Nonlinear dynamics
Linear systems theory
Mechanics and control of robots

Online coursework:

Programming a robotic car (Udacity, 2012)
Machine Learning (Coursera, 2017)
Robotics software engineering nanodegree term 1 (Udacity 2018)

Technical skills

Programming languages. Python, MATLAB, C, C++

Libraries and packages. Real-time control: dSPACE, Simulink, Robot Operating System (ROS)
Deep learning and AI: Keras with TensorFlow.
Motion capture and data collection: Vicon Nexus
CAD and Multi-body dynamics: MSC Adams, COMSOL, Solidworks, AutoCAD

Teaching experience

1. Teaching assistant, First half of Spring 2015, “System Dynamic and Vibrations”, The Ohio State University
2. Teaching assistant, Fall 2013, “Design and Analysis of Machine Elements I”, The Ohio State University
3. Teaching assistant, Spring 2013, “Introduction to Fluid Mechanics”, The Ohio State University
4. Teaching assistant, Spring, 2012, “Theory of Mechanisms”, Indian Institute of Technology, Madras
5. Teaching assistant, Fall, 2011, “CAD and Machine Elements”, Indian Institute of Technology, Madras