LIVING MACHINES

19-22 July 2022
Online

livingmachinesconference.eu/2022/

The 11th International Conference on Biomimetic and Biohybrid Systems

Workshop by

Dr. Roger Quinn and Dr. Hillel Chiel
Case Western Reserve University

Featuring Talks by
Dr. Gregory Sutton
Dr. Matthew Tresch
Dr. Matthieu Chardon
Dr. Ansgar Büschges
Dr. Gesa Dinges

Plenary Speakers

Dr. Hillel J. Chiel
Case Western Reserve University

Dr. Mirko Kovac
Imperial College, London

Dr. Victoria Webster-Wood
Carnegie Mellon University

livingmachinesconference.eu/2022/

WORKSHOP 12:45 - 17:00 UTC

HOW DO ANIMAL NEUROMECHANICAL SYSTEMS PERFORM COMMUNICATION, COORDINATION, AND CONTROL?

Organizers:

Roger Quinn – Professor, Mechanical and Engineering Department, Case Western Reserve University, rdq@case.edu, http://biorobots.case.edu/

Hillel Chiel – Professor, Biology Department, Case Western Reserve University, hjc@case.edu, https://case.edu/artsci/biology/chiellab/

Speakers:

Gregory Sutton – Professor, Royal Society University Research Fellow, Department of Life Sciences, College of Science, University of Lincoln, U.K.

Matthew Tresch – Professor, Biomedical Engineering, Neuroscience, Physical Medicine and Rehabilitation, Northwestern University

Matthieu Chardon – Research Assistant Professor, Department of Neuroscience, Northwestern University

Ansgar Büschges – Department of Animal Physiology, Institute of Zoology, University of Cologne

Gesa Dinges – Department of Mechanical and Aerospace Engineering, West Virginia University

Contact: Roger Quinn, rdq@case.edu

Abstract:

The purpose of this workshop is to compare and contrast how neuromechanical systems in animals from different phyla allow them to perform functions essential to their survival. The workshop first focuses on an overview on how the frequency of movement and size of libs can affect the control of locomotion (Dr. Gregory Sutton). The role of joint stresses and strains on control of limbed locomotion is then discussed (Dr. Matthew Tresch). A discussion of how to fit multiple parameters that are necessary for neuromechanical models provides useful guidance for others who are working in this area (Dr. Matthieu Chardon). New insights on insect walking will bridge between single neuron function and system performance of six-legged walking (Dr. Ansgar Büschges). To further understand sensory inputs to the insect leg, biomechanical and morphological studies of strain sensors (campaniform sensilla) clarify how sensors are integrated and can affect both control within and between legs (Dr. Gesa Dinges). The workshop should be of broad general interest to those studying the neural and mechanical basis of behavior and those interested in creating autonomous artificial devices inspired by animals.

Program:

(12:45 - 13:00 UTC) **Introduction – Roger Quinn and Hillel Chiel**

(13:00 - 13:25 UTC) **“Limb Control Parameters are Determined by Size and Frequency of Movement” – Gregory Sutton**

Studies of motor control usually examine how the CNS activates muscles to achieve task performance – grasping an object or walking to a target. However, to achieve task performance, muscles must act through joints and so different control strategies, each achieving the same task performance, might result in aberrant stresses and strains within our joints. We show how consideration of these internal joint stresses and strains leads to better understanding of neural control strategies and might help guide investigations into neural circuitry underlying movement.

(13:25 - 13:35 UTC) **Questions for Gregory Sutton**

(13:35 - 13:45 UTC) **Break**

(13:45 - 14:10 UTC) **“The Importance of Internal Joint Mechanics for Understanding Neural Coordination Strategies” – Matthew Tresch**

Studies of motor control usually examine how the CNS activates muscles to achieve task performance – grasping an object or walking to a target. However, to achieve task performance, muscles must act through joints and so different control strategies, each achieving the same task performance, might result in aberrant stresses and strains within our joints. We show how consideration of these internal joint stresses and strains leads to better understanding of neural control strategies and might help guide investigations into neural circuitry underlying movement.

(14:10 - 14:20 UTC) **Questions for Matthew Tresch**

(14:20 - 14:45 UTC) **"Algorithmic Parameter Estimation and Uncertainty Quantification for Hodgkin-Huxley Neuron Models" – Matthieu Chardon**

Neuromechanical models often rely on Hodgkin-Huxley (H-H) formulations for their neuron models. A challenge with H-H models is that many different sets of ion channel conductances can produce the same response from the model. This makes computational approaches for inferring ion channel parameters from observations of voltage data difficult or intractable. We show that by framing the inference in a Bayesian setting, which naturally allows multiple solutions, and employing a specific algorithm from the Markov chain Monte Carlo family allows us to successfully reconstruct ``landscapes'' or ``maps'' of possible parameter sets. The visualization of these solution maps (i.e., posteriors) enables physiologists to inspect and reason about the vast possibilities, sensitivities, and uncertainties of ion channel parameters. We will cover how this algorithm is being used to reverse engineer a locomotion circuit.

(14:45 - 14:55 UTC) **Questions for Matthieu Chardon**

(14:55 - 15:20 UTC) **Break**

(15:20 - 15:45 UTC) **"Task-specificity in the Control of Insect Walking" – Ansgar Büschges**

Recent methodological advances in high-resolution-high-speed video analysis of locomotor behavior combined with new neurogenetic tools allows for studying the neural control of six-legged insect walking from the systems level, i.e. interleg coordination, to the single leg level and to the level of single neuron function in generating a stepping cycle. The talk will report recent advances in unravelling the neural basis of six-legged walking with specific focus on the generation of task-specific modifications.

(15:45 - 15:55 UTC) **Questions for Ansgar Büschges**

(15:55 - 16:20 UTC) **"Comprehensive Study of Leg Strain Sensors" – Gesa Dinges**

Using interdisciplinary approaches, we characterized Drosophila leg campaniform sensilla morphologically and biomechanically. Further, we monitored single and group sensor effects on motor output during optogenetic manipulation. Our work highlights interindividual and interleg differences, how individual sensor morphology within a field can affect strain dynamics, and that optogenetic manipulation effects both intra- and interleg coordination.

(16:20 - 16:30 UTC) **Questions for Gesa Dinges**

(16:30 - 17:00 UTC) **Discussion**

(12:45 - 13:00 UTC) **WELCOME**

(13:00 – 14:00 UTC) **PLENARY TALK**

Dr. HILLEL J. CHIEL

FROM LIVING ORGANISMS TO LIVING MACHINES

What characteristics would a machine have to be considered alive? Are living organisms machines? These questions are a focus for active research as scientists and engineers attempt to bridge the gap between artificial and natural devices.

Defining what is alive and what is not is difficult. Lists of characteristics to define life such as organization, metabolism, homeostasis, growth, reproduction and responsiveness, always have exceptions. A more abstract definition, autopeoisis – a network of processes producing key components necessary to maintain the operation of the network as a unit – has intriguing implications but has been more difficult to test empirically. A key to answering this question comes from understanding the unique characteristics of living cells: their internal self-description that encodes three dimensional components that maintain the network of cell processes, their ability to replicate, and their ability to respond adaptively to changing environmental conditions, avoiding damage and finding nutrients.

A complementary approach to the question is to understand the way in which living organisms and non-living organisms are created and modified. Most human-made machines are designed, manufactured, and controlled. In living organisms, the roughly corresponding processes are evolution, development, and plasticity, all of which emerge from and act upon the properties of cells and multi-cellular organisms. Moreover, manufacturers of artificial devices work hard to reduce variation and noise; in contrast, variation and noise are essential to the function of biological organisms.

The areas of artificial life, synthetic biology, and bio-hybrid robotics are actively exploring and expanding the borders of what is alive and what is not. Describing examples of some of the recent work in these and related areas, and descriptions of some of the open questions that need to be addressed for the future, will suggest exciting areas for future research that could lead to novel Living Machines.

(14:00 – 14:20 UTC) **BREAK**

(14:20 – 14:40 UTC) **Unit Cell Based Artificial Venus Flytrap.**
Falk J. Tauber, Laura Riechert, Joscha Teichmann, Nivedya Poovathody, Uwe Jonas, Stefan Schiller, and Thomas Speck

(14:40 – 15:00 UTC) **Conversion of Elastic Energy Stored in the Legs of a Hexapod Robot into Propulsive Force.**
Atusushi Kaneko, Masahiro Shimizu, and Takuya Umedachi

(15:00 – 15:20 UTC) **SLUGBOT, an Aplysia-inspired Robotic Grasper for Studying Control.**
Kevin Dai, Ravesh Sukhnandan, Michael Bennington, Karen Whirley, Ryan Bao, Lu Li, Jeffrey P. Gill, Hillel J. Chiel, and Victoria A. Webster-Wood

(15:20 – 15:40 UTC) **BREAK**

(15:40 – 16:10 UTC) **SHORT TALKS A**

1) Multi-Material FDM 3D Printed Arm with Integrated Pneumatic Actuator.
2) The Shaker: A Platform for Active Perturbations in Neuromechanical Studies of Small Animals.
3) The Modelling of Different Dog Breeds on the Basis of a Validated Model.
4) Gut Feelings: Towards Robotic Personality Generation with Microbial Fuel Cells.
5) Development and Characterization of a Soft Bending Actuator.
6) Robotic Platform for Testing a Simple Stereopsis Network.
7) SNS-Toolbox: A Tool for Efficient Simulation of Synthetic Nervous Systems.
8) Animal Acceptance of an Autonomous Pasture Sanitation Robot.
9) Quasi-static Modeling of Feeding Behavior in Aplysia Californica.
10) Using DeepLabCut to Predict Locations of Subdermal Landmarks from Video.

(16:10 – 16:40 UTC) **SHORT TALKS Q&A**

(16:40 – 17:00 UTC) **BREAK**

(17:00 – 17:20 UTC) **Direct Assembly and Tuning of Dynamical Neural Networks for Kinematics.**
Chloe K. Guie, Nicholas S. Szczecinski

(17:20 – 17:40 UTC) **A Synthetic Nervous System with Coupled Oscillators Controls Peristaltic Locomotion.**
Shane Riddle, William Nourse, Zhuojun Yu, Peter J. Thomas, and Roger D. Quinn

(17:40 – 18:00 UTC) **Ten Years of Living Machines Conferences: Transformers-based Automated Topic Grouping.**
Théophile Carniel, Leo Cazenille, Jean-Michel Dalle, and José Halloy

(12:45 - 13:00 UTC) **WELCOME**

(13:00 – 14:00 UTC) **PLENARY TALK**

Dr. MIRKO KOVAC

BIOLOGICALLY INSPIRED FLYING ROBOTS (TBC)

Environmental sciences rely heavily on accurate, timely and complete data sets which are often collected manually at significant risks and costs. Robotics and mobile sensor networks can collect data more effectively and with higher spatial-temporal resolution compared to manual methods while benefiting from expanded operational envelopes and added data collection capabilities. In future, robotics and AI will be an indispensable tool for data collection in complex environments, enabling the digitalization of forests, lakes, off-shore energy systems, cities and the polar environment. However, such future robot solutions will need to operate more flexibly, robustly and efficiently than they do today.

This talk will present how animal-inspired robot design methods can integrate adaptive morphologies, functional materials and energy-efficient locomotion principles to enable this new class of sustainability robotics. The talk will also include application examples, such as flying robots that can place sensors in forests, aerial-aquatic drones for autonomous water sampling, drones for aerial construction and repair, and impact-resilient drones for safe operations in underground and tunnel systems.

Webpages:
https://www.robotics.empa.ch
http://www.imperial.ac.uk/aerialrobotics
LinkedIn: https://www.linkedin.com/in/mirkokovac/
Twitter: @MKovacRobotics

(14:00 – 14:20 UTC) **BREAK**

(14:20 – 14:40 UTC) **A Synthetic Nervous System Controls a Biomechanical Model of Aplysia Feeding.**
Yanjun Li, Victoria A. Webster-Wood, Jeffrey P. Gill, Gregory P. Sutton, Hillel J. Chiel, and Roger D. Quinn

(14:40 – 15:00 UTC) **Scaling a Hippocampus Model with GPU Parallelization and Test-driven Refactoring.**
Jack Stevenson and Charles Fox

(15:00 – 15:20 UTC) **Homeostatic and Allostatic Principles for Behavioral Regulation in Desert Reptiles: A Robotic Evaluation.**
T. Ngo, O. Guerrero, I.T. Freire, and P.F.M.J. Verschure

(15:20 – 15:40 UTC) **BREAK**

(15:40 – 16:10 UTC) **SHORT TALKS B**

1) Application-Oriented Comparison of Two 3D Printing Processes for the Manufacture of Pneumatic Bending Actuators for Bioinspired Macroscopic Soft Gripper Systems.
2) Evaluation of Gait Generation in Quadrupedal Legged Locomotion with Changing Anterior/Posterior Extreme Positions.
3) GymSlug: Deep Reinforcement Learning toward Bio-inspired Control based on Aplysia californica Feeding.
4) Cognitive Architecture as a Service: Scaffolded integration of heterogeneous models through event streams.
5) A Functional Subnetwork Approach to Multistate Central Pattern Generator Phase Difference Control.
6) A Scalable Soft Robotic Cellbot.
7) Simple Reactive Head Motion Control Enhances Adaptability to Rough Terrain in Centipede Walking.
8) Canonical Motor Microcircuit for Control of a Rat Hindlimb.
9) Load Feedback from a Dynamically Scaled Robotic Model of Carausius Morosus Middle Leg.
10) Time-Evolution Characterization of Behavior Class Prototypes

(16:10 – 16:40 UTC) **SHORT TALKS Q&A**

(16:40 – 17:00 UTC) **BREAK**

(17:00 – 17:20 UTC) **Analyzing 3D limb kinematics of Drosophila melanogaster for robotic platform development.**
Clarissa A. Goldsmith, Moritz Haustein, Till Bockemühl, Ansgar Büschges, and Nicholas S. Szczecinski

(17:20 – 17:40 UTC) **A Computational Approach for Contactless Muscle Force and Strain Estimations in Distributed Actuation Biohybrid Mesh Constructs.**
Saul Schaffer, Janic Seungyeon Lee, Lameck Beni, and Victoria A. Webster-Wood

(17:40 – 18:00 UTC) **Surrogate Modeling for Optimizing the Wing Design of a Hawk Moth Inspired Flapping-Wing Micro Air Vehicle.**
Wei Huang, Roger D. Quinn, Bryan E. Schmidt, and Kenneth C. Moses

(12:45 - 13:00 UTC) **WELCOME**

(13:00 – 14:00 UTC) **PLENARY TALK**

Dr. VICTORIA WEBSTER-WOOD

BEYOND BIOINSPIRED: LIVING AND ORGANIC MATERIALS FOR LIVING MACHINES

Bioinspiration and biomimetics have led to tremendous advances in robotics and computing. From high-level abstractions of bioinspired principles in early passive walkers to detailed neural models for robotic control, bioinspired robotics has brought robots from the lab into the real world. However, despite these advances, existing robots still fail to capture the natural compliance, adaptability, and biocompatibility of living organisms. For example, standard materials for robotic fabrication do not exhibit self-healing, adapt in response to changing mechanical load, or have the ability to autonomously generate energy, as is seen in biological systems. Additionally, traditional robotic actuators lack the compliance, energy efficiency, and power-to-weight ratio combinations observed in musculoskeletal systems. Furthermore, these systems rely on many non-renewable and sometimes even hazardous materials. How can living and organic materials be leveraged alongside abiotic components to improve the adaptability and biocompatibility of robots?

Recent advances in tissue engineering and biomaterials have made it possible to consider a new class of robotic systems harnessing living and organic materials directly. But, when should biomaterials be considered over synthetic counterparts? Furthermore, how might we as engineers begin to consider the environmental impact of our creations? Through this talk, I will explore the emerging field of biohybrid robotics, discuss the challenges currently facing the field, and present a long-term vision for the future of biocompatible and even biodegradable robots.

(14:00 – 14:20 UTC) **BREAK**

(14:20 – 14:40 UTC) **Integrating Spiking Neural Networks and Deep Learning Algorithms on the Neurorobotics Platform.**
Rachael Stentiford, Thomas C. Knowles, Benedikt Feldoto, Deniz Ergene, Fabrice O. Morin, and Martin J. Pearson

(14:40 – 15:00 UTC) **A Novel Multi-Vision Sensor Dataset for Insect-Inspired Outdoor Autonomous Navigation.**
Jan K.N. Verheyen, Julien Dupeyroux, and Guido C.H.E. de Croon

(15:00 – 15:20 UTC) **A Robotic Implementation of Neurally-Based Animal Magnetic Reception and Navigation.**
Andrew Harvey and Brian K. Taylor

(15:20 – 15:40 UTC) **BREAK**

(15:40 – 16:00 UTC) **DISCUSSION SESSION 1 – Jobs and Careers**

(16:00 – 17:20 UTC) **Active Inference for Artificial Touch: A Biologically-Plausible Tactile Control Method.**
Pernilla Craig, Laurence Aitchison, and Nathan F. Lepora

(16:20 – 17:40 UTC) **Design of a Biomolecular Neuristor Circuit for Bioinspired Control.**
Ahmed S. Mohamed, Ashlee S. Liao, Yongjie Jessica Zhang, Victoria A. Webster-Wood, and Joseph S. Najem

(16:40 – 18:00 UTC) **Underwater Light Modulators: Iridescent Structures of the Seagrass Posidonia Oceanica.**
Fabian Meder, Goffredo Giordano, Serena Armiento, and Barbara Mazzolai

(17:00 – 17:20 UTC) **BREAK**

(17:20 – 17:40 UTC) **DISCUSSION SESSION 2 – Equity, Accessibility, and Inclusion**

(17:40 – 18:00 UTC) **CLOSING CEREMONY**

ORGANIZATION & INFORMATION

CONFERENCE COMMITTEE

Workshop Chairs
Roger D. Quinn (Case Western Reserve University, USA)
Hillel J. Chiel (Case Western Reserve University, USA)

Conference Program Chairs
Alexander J. Hunt (Portland State University, USA)
Roger D. Quinn (Case Western Reserve University, USA)

General Organization and Communication
Anna Mura (IBEC, Barcelona, Spain)
Vicky Vouloutsi (Technology Innovation Institute, Abu Dhabi, UAE)

Local Organization
Kenneth C. Moses (Case Western Reserve University, USA)
Roger D. Quinn (Case Western Reserve University, USA)
Hillel J. Chiel (Case Western Reserve University, USA)

INTERNATIONAL STEERING COMMITTEE

Joseph Ayers (Northeastern University, USA)
Minoru Asada (Osaka University, Japan)
Hillel J Chiel (Case Western Reserve University, USA)
Mark Cutkosky (Stanford University, USA)
Marc Desmulliez (Heriot-Watt University, UK)
José Halloy (Université Paris Diderot, France)
Uriel Martinez-Hernandez (University of Bath, UK)
Koh Hosoda (Osaka University, Japan)
Holger G Krapp (Imperial College, UK)
Nathan Lepora (University of Bristol, UK)
Cecilia Laschi (Istituto Italiano di Tecnologia, Italy)
Barbara Mazzolai (Istituto Italiano di Tecnologia, Italy)
Fabian Meder (Istituto Italiano di Tecnologia, Italy)
Anna Mura (IBEC, Barcelona, Spain)

ORGANIZATION & INFORMATION

Tony Prescott (University of Sheffield, UK)
Roger Quinn (Case Western Reserve University, USA)
Masahiro Shimizu (Osaka University, Japan)
Thomas Speck (livMatS @ FIT – University of Freiburg, DE)
Falk Tauber (livMatS @ FIT – University of Freiburg, DE)
Paul Verschure (Radboud University, Netherlands)
Vicky Vouloutsy (Technolgoy Innovation Institute, UAE)
Vickie Webster-Wood (Carnegie Mellon University, USA)

LIVING MACHINES

19-22 July 2022

Online

livingmachinesconference.eu/2022/

The 11th International Conference on Biomimetic and Biohybrid Systems

Thank You!

We hope to see you next year at

Living Machines 2023

The 12th International Conference on Biomimetic and Biohybrid Systems