

### LNAI Series Editors

Randy Goebel

*University of Alberta, Edmonton, Canada*

Yuzuru Tanaka

*Hokkaido University, Sapporo, Japan*

Wolfgang Wahlster

*DFKI and Saarland University, Saarbrücken, Germany*

### LNAI Founding Series Editor

Joerg Siekmann

*DFKI and Saarland University, Saarbrücken, Germany*

More information about this series at <http://www.springer.com/series/1244>

Vasiliki Vouloutsi · José Halloy  
Anna Mura · Michael Mangan  
Nathan Lepora · Tony J. Prescott  
Paul F. M. J. Verschure (Eds.)

# Biomimetic and Biohybrid Systems

7th International Conference, Living Machines 2018  
Paris, France, July 17–20, 2018  
Proceedings

*Editors*

Vasiliki Vouloutsis  
SPECS, Institute for Bioengineering  
of Catalonia  
Barcelona  
Spain

José Halloy  
Laboratoire Interdisciplinaire des  
Université Paris Diderot  
Paris Cedex 13  
France

Anna Mura  
SPECS, Institute for Bioengineering  
of Catalonia  
Barcelona  
Spain

Michael Mangan  
University of Sheffield  
Sheffield  
UK

Nathan Lepora  
Bristol University  
Bristol  
UK

Tony J. Prescott  
University of Sheffield  
Sheffield  
UK

Paul F. M. J. Verschure  
SPECS, Institute for Bioengineering  
of Catalonia  
Barcelona  
Spain

ISSN 0302-9743                      ISSN 1611-3349 (electronic)  
Lecture Notes in Artificial Intelligence  
ISBN 978-3-319-95971-9              ISBN 978-3-319-95972-6 (eBook)  
<https://doi.org/10.1007/978-3-319-95972-6>

Library of Congress Control Number: 2018948143

LNCS Sublibrary: SL7 – Artificial Intelligence

© Springer International Publishing AG, part of Springer Nature 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

These proceedings contain the papers presented at Living Machines 2018: the 7th International Conference on Biomimetic and Biohybrid Systems, held in Paris, France, July 17–20, 2018. The international conferences in the Living Machines series are targeted at the intersection of research on novel life-like technologies inspired by the scientific investigation of biological systems, *biomimetics*, and research that seeks to interface biological and artificial systems to create biohybrid systems. The conference aim is to highlight the most exciting international research in both of these fields united by the theme of “Living Machines.”

The Living Machines conference series was first organized by the Convergent Science Network (CSN) of biomimetic and biohybrid systems to provide a focal point for the gathering of world-leading researchers and the presentation and discussion of cutting-edge research in this rapidly emerging field. The modern definition of biomimetics is the development of novel technologies through the distillation of principles from the study of biological systems. The investigation of biomimetic systems can serve two complementary goals. First, a suitably designed and configured biomimetic artifact can be used to test theories about the natural system of interest. Second, biomimetic technologies can provide useful, elegant, and efficient solutions to unsolved challenges in science and engineering. Biohybrid systems are formed by combining at least one biological component — an existing living system — and at least one artificial, newly engineered component. By passing information in one or both directions, such a system forms a new hybrid bio-artificial entity.

Although one may consider this approach to be modern, the underlying principles are centuries old. More specifically, after the European Renaissance, we observe the usage of automata to imitate the functionality of both animals and humans. Such endeavors not only served to entertain but can also be considered as philosophical experiments that allowed for the reproduction of aspects of living organisms in machines, while revealing important information regarding their nature. What initially started as a philosophical idea turned into a mechanical revolution as most of the automata of the 18th century were not only imitating the external appearance of an organism but also simulated the organism’s functionalities or behaviors. An example of linking human kinesiology and anatomy is Leonardo da Vinci’s “Knight” in 1495, where an elaborate system of pulleys and cables moved the knight’s armor to produce various human-like independent motions. This compelling artifact has endowed modern robotics with scaffolds for kinematics and structural design.

A way to appreciate the early simulation of living beings is the central idea of “moving anatomy” in the creations of Jacques de Vaucanson (1709–1782), a French inventor and artist. One of his first biomechanical automata was the “Flute Player,” a life-sized wooden statue of a man who played the flute by emitting air through its mouth. This design resulted from the extensive study of human flute players and was used to validate Vaucanson’s hypothesis that the consequent pitch of a note was

affected by the blowing pressure, aperture, and sounding length. Notably, his most famous creation was the “Digesting Duck” (1739) a mechanical artifact modeled upon thorough studies of real ducks that was conceptualized to teach the animal’s anatomy. Both the “Flute Player” and the “Digesting Duck,” although used for entertainment, are good examples that intended to approximate their biological counterparts.

Attention to anatomical, physiological, and behavioral simulations started with Vaucanson and climaxed with the creations of Pierre Jaquet-Droz (1721–1790). The father-and-son team of Pierre and Henri-Louis Jaquet-Droz produced three automata: “the Writer,” “the Draughtsman,” and “the Musician.” Their hands were modeled after real human hands that later constituted the basis for constructing prosthetic limbs. The tendency of that period was to use mechanical artifacts to approximate nature and, through modeling, experimentation, and observation, draw conclusions about their biological counterparts. Nowadays, the study and modeling of biological systems has led to the acquisition of insights into a plethora of domains ranging from architecture to materials, sensors, and control systems and even robotics. Advances in each of these areas were presented in detail at the conference.

The main conference, July 18–20, took the form of a three-day single-track oral and poster presentation program that included five plenary lectures from leading international researchers in biomimetic and biohybrid systems: Jérôme Casas (University of Tours) on insect-inspired mechatronics; Metin Sitti (Max Planck Institute) on bio-inspired and bio-hybrid miniature mobile robots; Stéphane Viollet (Aix-Marseille University) on the application of insect perception models to robots; Simon Thorpe (University of Toulouse) on memory storage and retrieval in both humans and machines; and Pascal Brioist (University of Tours) on the machines of Leonardo Da Vinci. There were also 22 regular talks and one poster session and poster spotlight (featuring approximately 36 posters). Session themes included: advances in soft robotics; 3D-printed bio-machines; robots and society; biomimetic vision and control; utility and limits of deep learning for bio-robotics; collective and emergent behaviors in animals and robots; and bioinspired flight. The conference was complemented by workshops on July 17, 2018, held at the École Normale Supérieure in Paris. More specifically, “Sapiens 5.0: Augmenting Humanity to Overcome the Challenges of the Anthropocene” was organized by professor Paul F. M. J. Verschure and Tony Prescott.

The main conference was hosted at the Muséum national d’Histoire Naturelle, MNHN (Paris, France), a place built initially for medicinal and educational purposes. Surrounded by the botanical garden and next to the Seine, for more than four centuries, the MNHN hosted revolutionary discoveries in the field of natural sciences held by prodigious minds, such as Buffon, Lamarck, or Cuvier. Today, the MNHN is one of the most highly considered places in Europe with regard to scientific dissemination, education, and integration of multiple areas of expertise, ranging from molecular biology to applied technology. Hosting the Living Machines conference in such a place reinforces the aim of MNHN in the exploration and promotion of nature to protect it and understand it. This year, Living Machines was held in Paris after successful previous editions in Stanford, USA in 2017; Edinburgh, UK in 2016; Barcelona, Spain in 2015; Milan Italy in 2014; London, UK in 2013; and Barcelona, Spain in 2012.

We would like to thank our hosts at the National History Museum of Paris, Emmanuelle Pouydebat DR CNRS, and Vincent Bels, our hosts for the poster session

that was held at the Pierre and Marie Curie University, on the Jussieu Campus, in collaboration with Stéphane Doncieux UMPC, ISIR, and Benoît Girard DR CNRS, UPMC, ISIR.

We also wish to thank the many people that were involved in making the seventh edition of *Living Machines* possible: José Halloy and Paul Verschure co-chaired the meeting; Vasiliki Vouloutsi and Michael Mangan chaired the Program Committee and edited the conference proceedings; Tony Prescott chaired the international Steering Committee; Nathan Lepora was involved in the conference communication; Anna Mura was the general organization chair and also coordinated the website and communications; José Halloy and his group provided administrative and local organizational support in Paris. We are grateful to the SPECS lab and the Communication Unit at the Institute for Bioengineering of Catalonia (IBEC) in Barcelona for the assistance in the organization and for technical support. We would also like to thank the authors and speakers who contributed their work, and the members of the Program Committee for their detailed and considered reviews. We are grateful to the five keynote speakers who shared with us their vision of the future.

Finally, we wish to thank the organizers and sponsors of LM 2018: The Convergence Science Network for Biomimetic and Neurotechnology (CSNII; ICT-601167); the Institute for Bioengineering of Catalonia IBEC, and the Catalan Institution for Research and Advanced Studies (ICREA). Additional support was also provided by Springer. *Living Machines 2018* was further supported by: the IOP physics journal *Bioinspiration & Biomimetics*, which will publish a special issue of articles based on the best conference papers, and *Biomimetics*, an Open Access journal, which will publish a special issue of articles based on the best conference posters, and by Eodyne SL (neuro-rehabilitation solutions) with an award for best paper with a social impact.

July 2018

Vasiliki Vouloutsi  
José Halloy  
Anna Mura  
Michael Mangan  
Nathan Lepora  
Tony J. Prescott  
Paul F. M. J. Verschure

# Organization

## Conference Chairs

|                         |   |
|-------------------------|---|
| José Halloy             | Université Paris Diderot, France  |
| Tony J. Prescott        | University of Sheffield, UK   |
| Paul F. M. J. Verschure | Institute for Bioengineering of Catalonia (IBEC),<br>Barcelona<br>Institute of Science and Technology (BIST), Catalan<br>Institution for Research and Advanced Studies<br>(ICREA), Barcelona, Spain |

## Program Chairs

|                    |   |
|--------------------|---|
| Vasiliki Vouloutsi | Institute for Bioengineering of Catalonia (IBEC),<br>Barcelona<br>Institute of Science and Technology (BIST), Barcelona,<br>Spain |
| Michael Mangan     | University of Lincoln, UK   |

## Local Organizers

|                      |  |
|----------------------|--|
| José Halloy          | Université Paris Diderot, France             |
| Stéphane Doncieux    | UMPC, ISIR, France                           |
| Benoît Girard        | DR CNRS, UPMC, ISIR, France                  |
| Emmanuelle Pouydebat | DR CNRS, Muséum d'Histoire Naturelle, France |
| Vincent Bels         | Muséum d'Histoire Naturelle, France          |

## Communications

|               |   |
|---------------|---|
| Anna Mura     | Institute for Bioengineering of Catalonia (IBEC),<br>Barcelona<br>Institute of Science and Technology (BIST), Barcelona,<br>Spain |
| Nathan Lepora | University of Bristol, UK   |

## Conference Website

|           |   |
|-----------|---|
| Anna Mura | Institute for Bioengineering of Catalonia (IBEC),<br>Barcelona<br>Institute of Science and Technology (BIST), Barcelona,<br>Spain |
|-----------|---|



## Workshop Organizers

|                         |   |
|-------------------------|---|
| Tony J. Prescott        | University of Sheffield, UK   |
| Paul F. M. J. Verschure | Institute for Bioengineering of Catalonia (IBEC),<br>Barcelona<br>Institute of Science and Technology (BIST), Catalan<br>Institution for Research and Advanced Studies<br>(ICREA), Barcelona, Spain |

## International Steering Committee

|                    |   |
|--------------------|---|
| Joseph Ayers       | Northeastern University, USA  |
| Mark Cutkosky      | Stanford University, USA  |
| Marc Desmulliez    | Heriot-Watt University, UK  |
| José Halloy        | Université Paris Diderot, France  |
| Nathan Lepora      | University of Bristol, UK   |
| Barbara Mazzolai   | Istituto Italiano di Tecnologia, Italy  |
| Anna Mura          | Catalan Institution for Research and Advanced Studies<br>(IBEC-BIST), Barcelona, Spain  |
| Tony Prescott      | University of Sheffield, UK   |
| Roger Quinn Case   | Western Reserve University, USA   |
| Paul Verschure     | Catalan Institution for Research and Advanced Studies<br>(IBEC-BIST) and Catalan Institution for Research<br>and Advanced Studies, Barcelona, Spain |
| Vasiliki Vouloutsi | Catalan Institution for Research and Advanced Studies<br>(IBEC-BIST), Barcelona, Spain  |
| Stuart Wilson      | University of Sheffield, UK   |

## Program Committee

|                           |   |
|---------------------------|---|
| Andrew Adamatzky          | UWE, Bristol, UK  |
| Xerxes Arsiwalla          | Institute for Bioengineering of Catalonia (IBEC), Spain                     |
| Farshad Arvin             | University of Manchester, UK  |
| Farshad Arvin Tareq Assaf | BRL, UK   |
| Pankaja Bagul             | Symbiosis School of Architecture, Urban<br>Development, and Planning, India |
| Yoseph Bar-Cohen          | JPL, USA  |
| Josh Bongard              | University of Vermont, USA  |
| Jorg Conradt              | TU München, Germany   |
| Federico Corradi          | University of Zurich and ETH, Switzerland                                   |
| Heriberto Cuayáhuatl      | University of Lincoln, UK   |
| Mark Cutkosky             | Stanford University, USA  |
| Vassilis Cutsuridis       | University of Lincoln, UK   |
| Kathryn Daltorio          | Case Western Reserve University, USA  |

|                          |   |
|--------------------------|---|
| Marc Desmulliez          | Heriot-Watt University, UK  |
| Alex Dewar               | University of Sussex, UK  |
| Christian Dondrup        | Heriot-Watt University, UK  |
| Volker Dürr              | Bielefeld University, Germany                                     |
| Wolfgang Eberle          | IMEC, Belgium   |
| Benoît Girard            | Sorbonne Université, CNRS, France                                 |
| José Halloy              | Université Paris Diderot, France                                  |
| Helmut Hauser            | University of Bristol, UK   |
| Ivan Herreros            | Universitat Pompeu Fabra, Spain                                   |
| J. Michael Herrmann      | University of Edinburgh, UK                                       |
| Toby Howison             | University of Cambridge, UK                                       |
| David Hu                 | Gatech, USA   |
| Ioannis Ieropoulos       | University of the West of England, Bristol, UK                    |
| Jesung Koh               | Ajou University, South Korea                                      |
| Nathan Lepora            | University of Bristol, UK   |
| Alexis Lussier Desbiens  | University of Sherbrooke, Canada                                  |
| Michael Mangan           | University of Sheffield, UK                                       |
| Uriel Martinez-Hernandez | University of Bath, UK  |
| Stefano Mintchev         | EPFL, Switzerland   |
| Ben Mitchinson           | TUOS, UK  |
| Vishwanathan Mohan       | University of Essex, UK   |
| Clément Moulin-Frier     | Universitat Pompeu Fabra, Spain                                   |
| Anna Mura                | Institute for Bioengineering of Catalonia (IBEC), Spain           |
| John Murray              | University of Lincoln, UK   |
| Iordanka Panayotova      | Christopher Newport University, USA                               |
| Diogo Pata               | Institute for Bioengineering of Catalonia (IBEC), Spain           |
| Martin Pearson           | Bristol Robotics Laboratory, UK                                   |
| Andrew Philippides       | University of Sussex, UK  |
| Tony Prescott            | University of Sheffield, UK                                       |
| Roger Quinn              | Case Western Reserve University, USA                              |
| Guillaume Rieucan        | LUMCON, USA   |
| Hannes Saal              | University of Sheffield, UK                                       |
| Sebastian Schneider      | Bielefeld University, CITEC, Applied Informatics,<br>Germany      |
| Charlie Sullivan         | University of the West of England, UK                             |
| Nicholas Szczecinski     | Case Western Reserve University, USA                              |
| Pablo Varona             | Universidad Autonoma de Madrid, Spain                             |
| Paul Verschure           | ICREA, Institute for Bioengineering of Catalonia<br>(IBEC), Spain |
| Vasiliki Vouloutsi       | Institute for Bioengineering of Catalonia (IBEC), Spain           |
| Benjamin Ward-Cherrier   | University of Bristol, UK   |
| Victoria Webster-Wood    | Case Western Reserve University, USA                              |

|                |   |
|----------------|---|
| Stuart Wilson  | University of Sheffield, UK                                     |
| Daniel Withey  | Council for Scientific and Industrial Research, South<br>Africa |
| Hartmut Witte  | Technische Universität Ilmenau, Germany                         |
| Jiawei Xu      | University of Newcastle, UK                                     |
| Shigang Yue    | University of Lincoln, UK                                       |
| Ketao Zhang    | Imperial College London, UK                                     |
| Riccardo Zucca | Institute for Bioengineering of Catalonia (IBEC), Spain         |

# Contents

|  |    |
|--|----|
| Undulatory Swimming Locomotion Driven by CPG with Multimodal Local Sensory Feedback . . . . .  | 1  |
| <i>Kyoichi Akiyama, Kotaro Yasui, Jonathan Arreguit, Laura Paez, Kamilo Melo, Takeshi Kano, Auke Jan Ijspeert, and Akio Ishiguro</i>                     |    |
| A Nitinol-Actuated Worm Robot Bends for Turning and Climbing Obstacles . . . . .   | 6  |
| <i>Kayla B. Andersen, Akhil Kandhari, Hillel J. Chiel, Roger D. Quinn, and Kathryn A. Daltorio</i>   |    |
| Are Brains Computers, Emulators or Simulators? . . . . .   | 11 |
| <i>Xerxes D. Arsiwalla, Camilo M. Signorelli, Jordi-Ysard Puigbo, Ismael T. Freire, and Paul F. M. J. Verschure</i>                                      |    |
| Prioritized Sweeping Neural DynaQ with Multiple Predecessors, and Hippocampal Replays . . . . .  | 16 |
| <i>Lise Aubin, Mehdi Khamassi, and Benoît Girard</i>   |    |
| Should Mobile Robots Have a Head? A Rationale Based on Behavior, Automatic Control and Signal Processing . . . . .                                       | 28 |
| <i>François Bailly, Emmanuelle Pouydebat, Bruno Watier, Vincent Bels, and Philippe Souères</i>   |    |
| The Neck of Pinobo, A Low-Cost Compliant Robot . . . . .   | 40 |
| <i>Arnaud Blanchard and Djamel Mebarki</i>   |    |
| Artificial Compound Eye and Synthetic Neural System for Motion Recognition . . . . .   | 52 |
| <i>Drago Bračun, Nicholas S. Szczecinski, Gašper Škulj, Alexander J. Hunt, and Roger D. Quinn</i>  |    |
| Living in a Machine: Experiencing the World Through a Robotic Avatar. . . . .  | 64 |
| <i>Daniel Camilleri and Tony Prescott</i>  |    |
| How to Blend a Robot Within a Group of Zebrafish: Achieving Social Acceptance Through Real-Time Calibration of a Multi-level Behavioural Model . . . . . | 73 |
| <i>Leo Cazenille, Yohann Chemtob, Frank Bonnet, Alexey Gribovskiy, Francesco Mondada, Nicolas Bredeche, and José Halloy</i>                              |    |

|  |     |
|--|-----|
| Evolutionary Optimisation of Neural Network Models for Fish<br>Collective Behaviours in Mixed Groups of Robots and Zebrafish . . . . .                     | 85  |
| <i>Leo Cazenille, Nicolas Bredeche, and José Halloy</i>  |     |
| The Impact of Nature Inspired Algorithms on Biomimetic<br>Approach in Architectural and Urban Design . . . . .   | 97  |
| <i>Natasha Chayaamor-Heil</i>  |     |
| Spiders' Ballooning Flight as a Model for the Exploration<br>of Hazardous Atmospheric Weather Conditions. . . . .  | 110 |
| <i>Moonsung Cho, Klaus Affeld, Peter Neubauer,<br/>and Ingo Rechenberg</i>   |     |
| Insect-Inspired Elementary Motion Detection Embracing Resistive<br>Memory and Spiking Neural Networks . . . . .  | 115 |
| <i>Thomas Dalgaty, Elisa Vianello, Denys Ly, Giacomo Indiveri,<br/>Barbara De Salvo, Etienne Nowak, and Jerome Casas</i>                                   |     |
| Understanding Interstate Competitiveness and International<br>Security in European Dual-Use Research . . . . .   | 129 |
| <i>Saheli Datta Burton, Christine Aicardi, Tara Mahfoud,<br/>and Nikolas Rose</i>  |     |
| Neuromechanical Model of Rat Hind Limb Walking<br>with Two Layer CPGs and Muscle Synergies . . . . .   | 134 |
| <i>Kaiyu Deng, Nicholas S. Szczecinski, Dirk Arnold,<br/>Emanuel Andrada, Martin Fischer, Roger D. Quinn,<br/>and Alexander J. Hunt</i>                    |     |
| A Hexapod Walking Robot Mimicking Navigation Strategies<br>of Desert Ants Cataglyphis. . . . .   | 145 |
| <i>Julien Dupeyroux, Julien Serres, and Stéphane Viollet</i>   |     |
| Development and Characterization of a Novel Biomimetic Peristaltic<br>Pumping System with Flexible Silicone-Based Soft<br>Robotic Ring Actuators . . . . . | 157 |
| <i>Falk Esser, Friederike Krüger, Tom Masselter,<br/>and Thomas Speck</i>  |     |
| Artificial System Inspired by Climbing Mechanism of Galium<br>Aparine Fabricated via 3D Laser Lithography. . . . .   | 168 |
| <i>Isabella Fiorello, Omar Tricinci, Anand Kumar Mishra,<br/>Francesca Tramacere, Carlo Filippeschi, and Barbara Mazzolai</i>                              |     |
| Modeling the Opponent's Action Using Control-Based<br>Reinforcement Learning. . . . .  | 179 |
| <i>Ismael T. Freire, Jordi-Ysard Puigbò, Xerxes D. Arsiwalla,<br/>and Paul F. M. J. Verschure</i>  |     |

|  |     |
|--|-----|
| Estimating Body Pitch from Distributed Proprioception in a Hexapod . . . . .   | 187 |
| <i>Arne Gollin and Volker Dürr</i>   |     |
| Emulating Balance Control Observed in Human Test Subjects<br>with a Neural Network . . . . .   | 200 |
| <i>Wade W. Hilts, Nicholas S. Szczecinski, Roger D. Quinn,<br/>and Alexander J. Hunt</i>   |     |
| Active Collision Free Closed-Loop Control of a Biohybrid<br>Fly-Robot Interface . . . . .  | 213 |
| <i>Jiaqi V. Huang, Yiran Wei,<br/>and Holger G. Krapp</i>  |     |
| Cognitive Architectures on Discourse . . . . .   | 223 |
| <i>M. Iza</i>  |     |
| Slip Detection on Natural Objects with a Biomimetic Tactile Sensor . . . . .   | 232 |
| <i>Jasper W. James and Nathan F. Lepora</i>  |     |
| Distributed Sensing for Soft Worm Robot Reduces Slip<br>for Locomotion in Confined Environments . . . . .  | 236 |
| <i>Akhil Kandhari, Matthew C. Stover, Prithvi R. Jayachandran,<br/>Alexander Rollins, Hillel J. Chiel, Roger D. Quinn,<br/>and Kathryn A. Daltorio</i> |     |
| Snake-Like Robot that Can Generate Versatile Gait Patterns<br>by Using <i>Tegotae</i> -Based Control. . . . .  | 249 |
| <i>Takeshi Kano, Ryo Yoshizawa, and Akio Ishiguro</i>  |     |
| Observation of Calcium Wave on Physical Stimulus<br>for Realizing Cell Tactile Sensor. . . . .   | 255 |
| <i>Hiroki Kawashima, Umakshi Sajnani, Masahiro Shimizu,<br/>and Koh Hosoda</i>   |     |
| Active Touch with a Biomimetic 3D-Printed Whiskered Robot. . . . .   | 263 |
| <i>Nathan F. Lepora, Niels Burnus, Yilin Tao,<br/>and Luke Cramphorn</i>   |     |
| Implementation of Deep Deterministic Policy Gradients<br>for Controlling Dynamic Bipedal Walking . . . . .   | 276 |
| <i>Chujun Liu, Andrew G. Lonsberry, Mark J. Nandor,<br/>Musa L. Audu, and Roger D. Quinn</i>   |     |
| Investigation of Tip Extrusion as an Additive Manufacturing<br>Strategy for Growing Robots . . . . .   | 288 |
| <i>Dario Lunni, Emanuela Del Dottore, Ali Sadeghi,<br/>Matteo Cianchetti, Edoardo Sinibaldi,<br/>and Barbara Mazzolai</i>                              |     |

|   |     |
|---|-----|
| Platform Selection of a Manta-Inspired Robot for Mitigating<br>Near-Shore Harmful Algal Blooms . . . . .                                    | 300 |
| <i>Lauren Marshall, Adam Schroeder, and Brian Trease</i>  |     |
| Weak DC Motors Generate Earthworm Locomotion<br>Without a Brain . . . . .   | 304 |
| <i>Yoichi Masuda, Masato Ishikawa, and Akio Ishiguro</i>  |     |
| 3D Bioprinted Muscle-Based Bio-Actuators: Force Adaptability<br>Due to Training . . . . .   | 316 |
| <i>Rafael Mestre, Tania Patiño, Xavier Barceló,<br/>and Samuel Sanchez</i>  |     |
| A System to Provide Oculomotor Functions to the User to Control<br>Direction of Gaze and Optical Zoom for both Eyes Independently . . . . . | 321 |
| <i>Fumio Mizuno, Tomoaki Hayasaka, and Takami Yamaguchi</i>   |     |
| Simulating Flapping Wing Mechanisms Inspired<br>by the <i>Manduca sexta</i> Hawkmoth . . . . .  | 326 |
| <i>Kenneth C. Moses, David Prigg, Matthias Weisfeld,<br/>Richard J. Bachmann, Mark Willis, and Roger D. Quinn</i>                           |     |
| A Survival Task for the Design and the Assessment<br>of an Autonomous Agent . . . . .   | 338 |
| <i>Bhargav Teja Nallapu and Frédéric Alexandre</i>  |     |
| Moment Arm Analysis of the Biarticular Actuators<br>in Compliant Robotic Leg CARL . . . . .   | 348 |
| <i>Atabak Nejadfard, Steffen Schütz, Krzysztof Mianowski,<br/>Patrick Vonwirth, and Karsten Berns</i>                                       |     |
| An Adaptive Frequency Central Pattern Generator for Synthetic<br>Nervous Systems . . . . .  | 361 |
| <i>William Nourse, Roger D. Quinn, and Nicholas S. Szczecinski</i>  |     |
| Texture Perception with a Biomimetic Optical Tactile Sensor . . . . .   | 365 |
| <i>Nicholas Pestell and Nathan F. Lepora</i>  |     |
| Simulation of the Arthropod Central Complex: Moving Towards<br>Bioinspired Robotic Navigation Control . . . . .                             | 370 |
| <i>Shanel C. Pickard, Roger D. Quinn,<br/>and Nicholas S. Szczecinski</i>   |     |
| Challenges of Machine Learning for Living Machines . . . . .  | 382 |
| <i>Jordi-Ysard Puigbò, Xerxes D. Arsiwalla,<br/>and Paul F. M. J. Verschure</i>   |     |

|   |     |
|---|-----|
| Quad-Morphing: Towards a New Bio-inspired Autonomous Platform<br>for Obstacle Avoidance at High Speed. . . . .  | 387 |
| <i>Valentin Riviere and Stephane Viollet</i>  |     |
| Toward Computing with Spider Webs: Computational Setup Realization . . . .  | 391 |
| <i>S. M. Hadi Sadati and Thomas Williams</i>  |     |
| Whisker-RatSLAM Applied to 6D Object Identification<br>and Spatial Localisation. . . . .  | 403 |
| <i>Mohammed Salman and Martin J. Pearson</i>  |     |
| Insect Behavioral Evidence of Spatial Memories During<br>Environmental Reconfiguration. . . . .   | 415 |
| <i>Diogo Santos-Pata, Alex Escuredo, Zenon Mathews,<br/>and Paul F. M. J. Verschure</i>   |     |
| Object Localisation with a Highly Compliant Tactile Sensory<br>Probe via Distributed Strain Sensors . . . . .   | 428 |
| <i>Marco Schultz and Volker Dürr</i>  |     |
| How the Sandfish Lizard Filters Particles and What We<br>May Learn from It . . . . .  | 439 |
| <i>Anna Theresia Stadler, Michael Krieger,<br/>and Werner Baumgartner</i>   |     |
| Braided Pneumatic Actuators as a Variable Stiffness<br>Approximation of Synovial Joints . . . . .   | 450 |
| <i>Alexander G. Steele and Alexander J. Hunt</i>  |     |
| An Analysis of a Ring Attractor Model for Cue Integration . . . . .   | 459 |
| <i>Xuelong Sun, Michael Mangan, and Shigang Yue</i>   |     |
| Hide and Seek: Knowledge Search in Biomimicry. . . . .  | 471 |
| <i>Sun-Joong Kim</i>  |     |
| Direction-Specific Footpaths Can Be Predicted by the Motion<br>of a Single Point on the Body of the Fruit Fly<br><i>Drosophila Melanogaster</i> . . . . . | 477 |
| <i>Nicholas S. Szczecinski, Ansgar Büschges,<br/>and Till Bockemühl</i>   |     |
| A Novel Spatially Resolved 3D Force Sensor for Animal Biomechanics<br>and Robotic Grasping Hands . . . . .  | 490 |
| <i>Séverine Toussaint and Artémis Llamasi</i>   |     |



|  |     |
|--|-----|
| Aquatic Swimming of a Multi-functional Pedundulatory<br>Bio-Robotic Locomotor . . . . .                | 494 |
| <i>Dimitris P. Tsakiris, Theodoros Evdaimon,<br/>and Emmanouil Papadakis</i>                           |     |
| Evolution of Neural Networks for Physically Simulated Evolved<br>Virtual Quadruped Creatures . . . . . | 507 |
| <i>Neil Vaughan</i>  |     |
| Evolutionary Robot Swarm Cooperative Retrieval . . . . .   | 517 |
| <i>Neil Vaughan</i>  |     |
| Multi-agent Reinforcement Learning for Swarm Retrieval<br>with Evolving Neural Network . . . . .       | 522 |
| <i>Neil Vaughan</i>  |     |
| A Neuromechanical Rat Model with a Complete Set<br>of Hind Limb Muscles. . . . .                       | 527 |
| <i>Fletcher Young, Alexander J. Hunt, and Roger D. Quinn</i>   |     |
| Guided Growth of Bacterial Cellulose Biofilms. . . . .   | 538 |
| <i>Katia Zolotovskiy, Merav Gazit, and Christine Ortiz</i>   |     |
| <b>Author Index</b> . . . . .  | 549 |