WeRob 2016

# The International Symposium on Wearable Robotics

La Granja de San Ildefonso (Segovia)
18-21 October, 2016

NRG · INSTITUTO CAJAL · CSIC · UNIVERSITY of HOUSTON CULLEN COLLEGE of ENGINEERING · Tecnológico de Monterrey · UNIVERSITY OF TWENTE.

# TABLE OF CONTENTS



# ABOUT WeRob

In this second edition of the International Symposium on Wearable Robotics, researchers and innovators from all around the world will discuss novel approaches, challenges and potential solutions in technologies for wearable robots.

International speakers from academia, government, industry, medical centres and end users are encouraged to participate in this biannual event. WeRob provides an international forum for researchers and practitioners to report the latest innovations, discuss state-of-the-art techniques, and exchange ideas and advances in all aspects of wearable robotics.

Moreover, the symposium will be held in parallel with the 2016 International Conference on Neurorehabilitation, which will bring together researchers and students from the fields of Clinical Rehabilitation, Applied Neurophysiology, and Biomedical Engineering to promote, feed and encourage this therapeutic global shift.

# LETTER FROM THE WeRob2016 SYMPOSIUM CHAIRS

Dear Colleagues,

With great pleasure we would like to welcome you to the 2nd International Symposium on Wearable Robotics (WeRob2016), which is to be held in 'La Granja de San Ildefonso', Segovia (Spain) from October 18th until 21st, 2016. After the success of WeRob2014 (Baiona, Spain), WeRob2016 gathers researchers and innovators from all around the world to discuss novel approaches, challenges and potential solutions in the field of wearable robotics.

The WeRob2016 program includes oral and poster presentations and discussions in various fields such as: supporting solutions for healthy ageing, advanced therapeutic treatments of neurological diseases, space applications or assistive technologies in the industry. Demonstrations and exhibitions of reference technologies in the field will also take place, with a special focus on research prototypes.

The scientific program will start on October 18th with more than 10 Special Session covering all areas of research in this field and addressing key challenges related to standardisation, benchmarking, regulatory and funding aspects. This program in complemented by Plenary talks by world-class experts in the field and by plenary demonstrations of these technologies. We really hope that you will be able of attending many of these exciting presentations and have stimulating discussions with your colleagues.

We would like to thank all the members of the steering committee, the organizing committee and the scientific program committee. We are especially grateful to all authors, reviewers and sponsors for their effort and valuable support to make WeRob 2016 a reality.

Finally, note that WeRob2016 Proceedings will be published by Springer. Digital copies can be downloaded (as of October, 16th for 1 month) from the Springer website with your personal code(see instructions in page 6).

Once again, welcome to WeRob2016!

José L. Pons, PhD
Conference Chair

Herman van der Kooij, PhD
Conference Co-Chair

José L. Contreras-Vidal, PhD
Conference Co-Chair

# PROGRAM AT A GLANCE

| | Tuesday 18 | Wednesday 19 | Thursday 20 | Friday 21 |
|---|---|---|---|---|
| 8:30-9:00 | | Plenary - C. Walsh | Plenary - D. Farina | S11 - Funding oportunities & challenges in WRs |
| 9:00-9:20 | Opening session | | | |
| 9:20-9:40 | Ekso Bionics demonstration | Neuroelectrics demonstration | Technoconcept demonstration | BioMot demonstration |
| 9:40-11:10 | S1 - Clinical focus in rehabilitation and assistive wearable robots | S3 - Soft wearable robotics<br>Robomate Project demonstration | S6 - New developments in wearable rehabilitation robotic<br>Symbitron Project demonstration | S9 - Symbiotic control of wearable robots. The Biomot Project |
| 11:10-11:30 | Coffee break | | | |
| 11:30-13:00 | S1 - Clinical focus in rehabilitation and assistive wearable robots | S3 - Soft wearable robotics (ICNR T3-W-S2) | S6 - New developments in wearable rehabilitation robotic (ICNR T3-T-S6) | S9 - Symbiotic control of wearable robots. The Biomot Project (ICNR T3-F-S8) |
| 13:00-14:30 | Lunch break | | Lunch break | Lunch break |
| 14:30-14:45 | | | S4 - Legal framework, standardization and ethical issues in wearable robots<br>BALANCE Project demonstration | |
| 14:45 - 15:00 | | Technaid demonstration | Gogoa demonstration | |
| 15:00-16:30 | S2 - Emerging technologies in wearable robots<br>MiRAD Project Demonstration | S7 - Neural interfacing with wearable robots<br>Spring-Clutch ankle demonstration (G. Sawicky) | Poster Session & Coffee break | S10 - Emerging application domains for wearble robots |
| 16:30-17:00 | Coffee break | | | Coffee break |
| 17:00-18:-30 | S2 - Emerging technologies in wearable robots | S8 - Biomechanics and neurophysiological studies with wearable robots | S5 - Benchmarking in wearable robots and related communities | S10 - Emerging application domains for wearble robots |
| 18:30-20:00 | | Segovia Tour | | |
| 20:00 | Opening Reception<br>Parador de La Granja | | Conference Banquet<br>Glass Museum | |

All WeRob2016 sessions will be held in Room D. Please note that Prof. Farina's talk will be held in Room A and Plenary demonstrations will be held in Hall -1 (see Floor Plans in page 7)

# GENERAL CONFERENCE INFORMATION

**Conference venue:**

Centro de Congresos y Convenciones Guardia de Corps

C/ Alameda, 2. 40100 – La Granja de San Ildefonso (SEGOVIA)

All conference sessions will take place in this location. The opening reception and the conference banquet will be held offsite. For further details on these social events, please visit page 9.

**Getting there:**

The **fly-in airport is Adolfo Suarez Madrid Barajas Airport**. From the airport you will need to go:

Route 1– To Madrid Chamartin train station (**recommended option**). Chamartin station can be reached by metro (line 10), by train (if you landed in Terminal 4) or by taxi (flat fare, 30 EUR).

OR

Route 2– To Madrid Moncloa bus station (if you plan to take the bus to Segovia). You can take the metro (line 3) or a taxi (flat fare, 30 EUR).

*If you arrived in Madrid Chamartin train station from the airport (Recommended option) – Route 1*

Take a high-speed train (25 minutes) to Segovia train station (called Segovia Av. or Segovia Guiomar). To check the schedule and timetables please visit Renfe website. It is recommended to book in advance.

Then, transportation by shuttle bus will be provided to 'Parador de La Granja' on the first day and last day of the conference (if you are travelling any other day, please take a taxi to 'Parador de La Granja'). Timetable of the shuttles will be the following:

*October 18: Segovia train station -> 'Parador de La Granja': 10am, 12pm, 2pm, 4pm, 6pm, 8pm, 10pm*

*October 21: 'Parador de La Granja' -> Segovia train station -> 8am, 10am, 12pm, 1pm, 3pm, 5pm, 7pm*
These buses will have signs to be easily recognized. They are free and you do not need to book a place before.

*If you arrived in Madrid Moncloa bus station from the airport – Route 2*

Take a public bus from to Segovia (and back). They take around 75 minutes to Segovia and arrive at Segovia bus station where it is possible to take another bus to La Granja de San Ildefonso. They depart every 45 minutes approximately.

The bus company is the same for both trips. Please visit La Sepulvedana website to check the schedule and timetables.

*From Segovia to La Granja de San Ildefonso (conference venue)*

If you are in Segovia by any other means you can take a taxi to the conference venue (it will take around 15 minutes and will cost around 20€) OR a public bus to La Granja de San Ildefonso.

The bus company is called La Sepulvedana. Please visit the website to check the schedule and timetables.

**Registration fees:**

WeRob registration fees include access to all sessions including full access to activities in the International Symposium on Wearable Robotics. Registration also includes daily coffee breaks, lunches, the Opening Reception and the Gala Dinner.

**Additional tickets:**

Tickets can be purchased separately for your guests for the Opening Reception, and Gala Dinner. These additional tickets can be purchased from the staff at WeRob's Registration Desk.

**Name Badges:**

Your name badge is your admission ticket to the conference sessions and coffee breaks. Please wear it at all times. For the meals, opening reception and gala dinner you will find a ticket inside your badge. At the end of the Conference we ask that you recycle your name badge leaving it at the Registration Desk.

**Registration and Information Desk Hours**

If you need assistance during the Conference, please visit the Registration Desk.
The WeRob Registration and Information Desk, located in Floor 1, will be open during the following dates and times:

Tuesday, October 18 08:00 – 18:00
Wednesday, October 19 08:00 – 18:00
Thursday, October 20 08:00 – 18:00
Friday, October 21 08:00 – 18:00

**Conference Proceedings:**

For a complete copy of the Proceedings, digital copies can be downloaded from the Springer website with your personal code (see page 2).

This code will be valid as of October, 16th for 1 month.

When the ebooks are available you need to do the following steps to get access to the ebooks
1) an account on http://link.springer.com
2) activate the token
3) have access to the ebook

**Poster Information**

There will be one Poster Session during the Conference. Poster should be printed considering the recommended poster size: 70 (width) x 90 (height) cm. Authors are free to create their own poster design, there are no particular style requirements.

It will be held on Thursday, October 20 from 15:30 to 17:00. Poster presenters must set-up and remove their posters during the following times:

Set-up: Thursday, October 20, between 08:30 and 15:30
Remove: Thursday, October 20, between 17:00 and 19:00

Fixation material will be provided on site. Information on Poster Authors, Poster Numbers and Poster Titles begins on page 19.

**Staff**

WeRob2016 staff can be identified by t-shirts with the logo. Feel free to ask anyone of our staff for assistance. For immediate assistance please visit us at the Registration Desk.

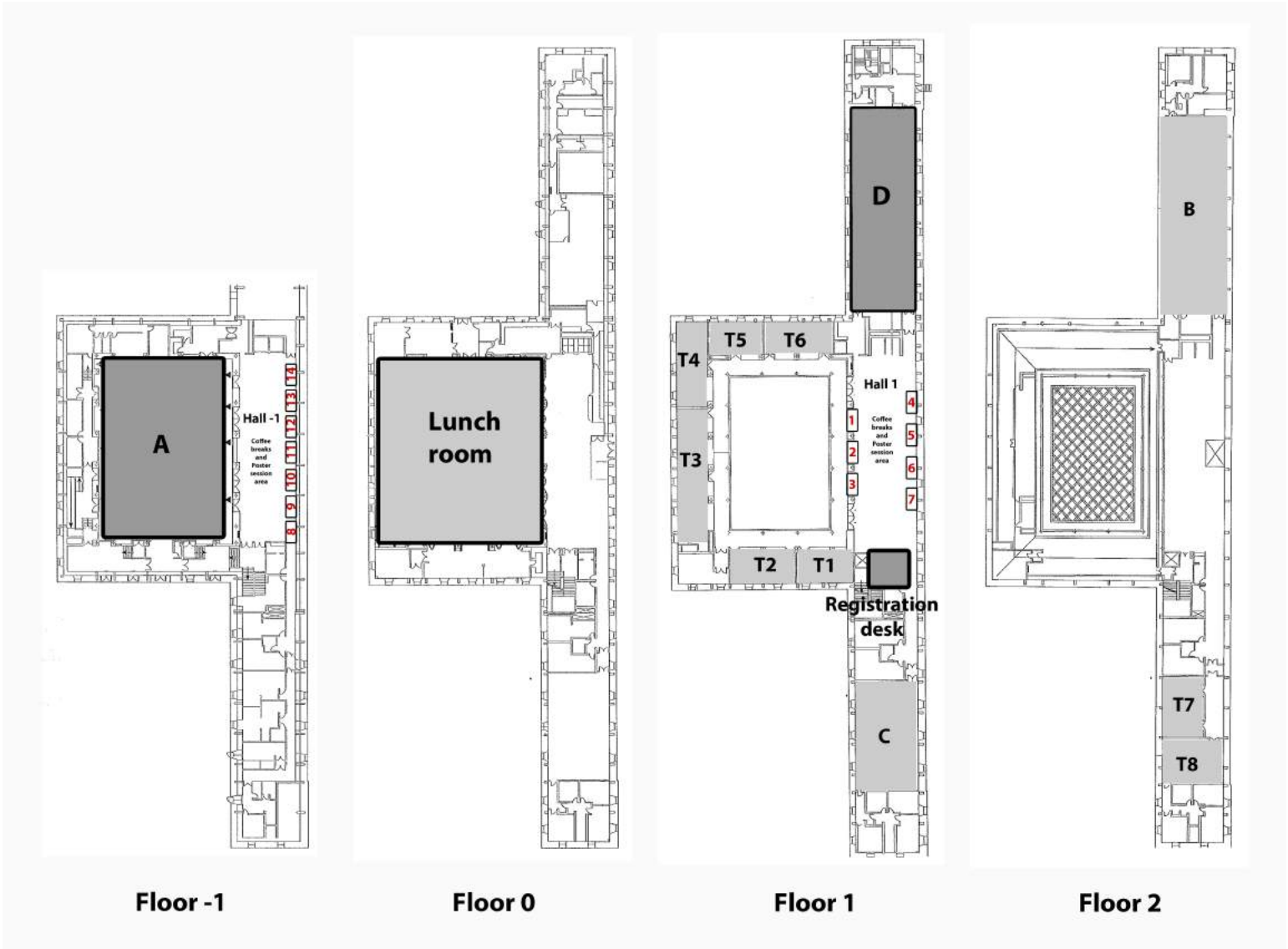
**Internet Services**

WeRob2016 is providing Internet access as part of the 2016 conference registration. The wireless code for the duration of the conference is

Network name: parador
Password: A123450116

If you require assistance, please visit the registration desk.

# FLOOR PLANS


A
Hall -1
Coffee breaks and Poster session area
Lunch room
D
T4
T5
T6
T3
Hall 1
Coffee breaks and Poster session area
T2
T1
Registration desk
C
B
T7
T8
Floor -1
Floor 0
Floor 1
Floor 2

# CONFERENCE COMMITTEES

Conference Steering Committee:

*Prof. José L. Pons*, Cajal Institute, CSIC, Spain (Chair)
*Prof. José L. Contreras-Vidal*, University of Houston, USA (Co-Chair & Coordinator for US and Canada)
*Prof. Herman van der Kooij*, University of Twente, The Netherlands (Co-Chair & Coordinator for Europe)

*Prof. Rogelio Soto*, Tecnológico de Monterrey, Mexico (Coordinator for South and Central America)
*Prof. Changsoo Han,* Hanyang University, Seoul, Korea (Coordinator for Asia)

Organizing Program Committee

*José L. Pons*, Cajal Institute, CSIC, Spain
*Jose González*, Cajal Institute, Spain
*Jaime Ibáñez*, Cajal Institute, Spain
*Luis Barrios*, Cajal Institute, Spain
*Magdo Bortole*, Cajal Institute, Spain
*Juan C. Moreno*, Cajal Institute, Spain
*Diego Torricellli*, Cajal Institute, Spain

# SPECIAL EVENTS & MEETINGS

**Opening Reception**
Tuesday, October 18
7.30pm
Location: Parador de La Granja

The opening reception will be held at the Parador de La Granja. This event is included in your Registration fee. If you plan to bring an accompanying guest to the reception, you can purchase an additional ticket at the registration desk for 30€. If you require assistance getting to the venue, please come and see us at the registration desk.
Dress Code: Casual

**Conference Banquet**
Thursday, October 20
8pm
Location: Glass Museum
'Real Fábrica de Cristales de la Granja'

This dinner is included in your registration. If you plan to bring an accompanying guest to the dinner, you can purchase an additional ticket at the registration desk for 70€.
Dress Code: Casual

# CONFERENCE EXCURSION

**Segovia Tour**

Segovia is a city full of history, with its origins dating back to Celtiberian tribes. From the 16th century, Segovia's skyline has been compared to a ship made of stone.

World Heritage Route: It is, perhaps, the most representative route of the city. It takes the visitor along the main streets of the ancient city. The route starts at the feet of the Aqueduct, with a walk along Calle Real - the main street of the city -. The first stop is the sightseeing point of La Canaleja (also close to the surprising Casa de los Picos). Leaving behind the Medina del Campo square and the Romanesque church of San Martin, we will reach the Corpus Square with the former Main Synagogue, converted nowadays into the Catholic Church of Corpus Christi. Later on, we will visit the Main Square and the Cathedral. The guide ends with an explanation of the Alcázar.

AQUEDUCT OF SEGOVIA: Located in Azoguejo Square, this unique and magnificent Roman construction from the 2nd century was aimed to carry the water from the mountains to the city. It is built with huge blocks of granite stone from Guadarrama Mountains, and there is no concrete or mortar between the stones. Its equilibrium is maintained by using an ingenious weight balance. Water ran on the channel at its top, and crossed the city underground until it reached the Alcázar. Its original total length, from its origin in the Sierra de Guadarrama Mountains, is 14.965 m. Its highest point is 29 meters and total number of arches of the construction is 166. This place is a protected National Monument since 1884 and World Heritage Monument since 1985.

CASA DE LOS PICOS: This ancient palace was built in the 15th century decorated with diamond points and with a Renaissance style.

SAINT MARTIN CHURCH: The magnificent temple is an actual sample of Castilian Romanesque art from the 12th century.

CATHEDRAL: Following the late Gothic Style, the construction begun in 1525 under the direction of the architect Rodrigo Gil de Hontañón and it was finished in 1768. It has a three-nave floor with a transept covered by a dome. Facing north, we may find the Door of San Frutos, built in honour of the patron saint of the city. The grandeur and harmony on dimensions defines the inside spaces, with its beautiful glass stained windows from the 14th century and 18 chapels on the inside, decorated with important paintings and sculptures.

ALCÁZAR: Its silhouette appears as an imaginary ship over the confluence of the rivers Eresma and Clamores. The Castle, built on the remains of a Roman fortress, was successively transformed. A deep moat with a drawbridge gives us entrance to a fortress situated in a privileged place. Inside the monument, we must pay attention to the Ajimeces Room, the Chimney Room, The Throne Room -with an outstanding mudéjar ceiling-, The Pineapples Room, and the Kings Chamber containing an extraordinary coffered ceiling made of golden hexagons and rhomboids, and a curious frieze displaying 52 sitting images of the Kings and Queens of Asturias, León and Castilla. The Alcázar became Royal College of Artillery in 1764.

# WeRob 2016 PROGRAM – OCT 18-21

## Tuesday 18

| Tu-S1 | Clinical Focus on Rehabilitation and Assistive WRs (M. Molinari, J.L. Pons) | Day | Time |
|---|---|---|---|
| | | Tu18 | 9.40-13.00 |
| **Paper ID** | **Title** | **Authors** | |
| 55 | Clinical evaluation of a socket-ready naturally controlled multichannel upper limb prosthetic system | Ivan Vujaklija, Sebastian Amsuess, Aidan Roche, Dario Farina and Oskar Aszmann | |
| 34 | Evaluation of a Robotic Exoskeleton for Gait Training in Acute Stroke: A case study | Ghaith Androwis and Karen J. Nolan | |
| 36 | Wearable exoskeleton assisted rehabilitation in Multiple Sclerosis: Feasibility and Experience | Shuo-Hsiu Chang, Marcie Kern, Taimoor Afzal, Shih-Chiao Tseng, John Lincoln and Gerard Francisco | |
| 45 | Using Robotic Exoskeletons for Over-Ground Locomotor Training | Arun Jayaraman and William Rymer | |
| 67 | Lower limb wearable systems for mobility and rehabilitation challenges: clinical focus | Federica Tamburella, Marcella Masciullo, Iolanda Pisotta, Nevio Luigi Tagliamonte and Marco Molinari | |
| | On Lessons learned from pilot clinical trials with WR and future prospects | Gerard Francisco | |
| | Powered exoskeletons for bipedal locomotion after spinal cord injury: Challenges and Opportunities | Jose Contreras | |

| Tu-S2 | Emerging Technologies in WRs (D. Lefeber, J. Gonzalez) | Day | Time |
|---|---|---|---|
| | | Tu18 | 15.00-18.30 |
| **Paper ID** | **Title** | **Authors** | |
| 7 | Impedance Control of Series Elastic Actuators Using Acceleration Feedback | Andrea Calanca, Riccardo Muradore and Paolo Fiorini | |
| 12 | Kinetic energy recovery in human joints: the Flywheel-Infinitely Variable Transmission actuator | Roberta Alò, Francesco Bottiglione and Giacomo Mandritta | |
| 17 | A Compliant Lightweight and Adaptable Active Ankle Foot Orthosis for Robotic Rehabilitation | Marta Moltedo, Tomislav Bacek, Kevin Langlois, Karen Junius, Bram Vanderborght and Dirk Lefeber | |
| 25 | A Novel Shoulder Mechanism with a Double Parallelogram Linkage for Upper-Body Exoskeletons | Simon Christensen and Shaoping Bai | |
| 28 | A Soft Robotic Extra-Finger and Arm Support to Recover Grasp Capabilities in Chronic Stroke Patients | Irfan Hussain, Gionata Salvietti, Giovanni Spagnoletti, David Cioncoloni, Simone Rossi and Domenico Prattichizzo | |
| 39 | A Quasi-Passive Knee Exoskeleton to Assist During Descent | Emily Rogers, Panagiotis Polygerinos, Stephen Allen, Fausto Panizzolo, Conor Walsh and Donal Holland | |
| 48 | Wearable sensory apparatus for multi-segment system orientation estimation with long-term drift and magnetic disturbance compensation | Sebastjan Šlajpah, Roman Kamnik and Marko Munih | |
| 78 | A portable Active Pelvis Orthosis for ambulatory movement assistance | Andrea Parri, Tingfang Yan, Francesco Giovacchini, Mario Cortese, Marco Muscolo, Matteo Fantozzi, Raffaele Molino Lova and Nicola Vitiello | |

# Wednesday 19

| W-S3 | Soft Wearable Robotics (C. Walsh, Jesus Ortiz) | Day | Time |
|---|---|---|---|
| | | We19 | 9.40-13.00 |
| Paper ID | Title | Authors | |
| 6 | XoSoft - A vision for a soft modular lower limb exoskeleton | Jesus Ortiz, Eduardo Rocon, Valerie Power, Adam De Eyto, Leonard O'Sullivan, Markus Wirz, Christoph Bauer, Samuel Schülein, Konrad S. Stadler, Barbara Mazzolai, Wouter Teeuw, Chris Baten, Corien Nikamp, Jaap Buurke, Freygardur Thorsteinsson and Jeanette Müller | |
| 57 | On the Efficacy of Isolating Shoulder and Elbow Movements with a Soft, Portable, and Wearable Robotic Device | Zahra Kadivar, Christopher Beck, Roger Rovekamp, Marcia O'Malley and Charles Joyce | |
| 74 | Design Improvement of a Polymer-Based Tendon-Driven Wearable Robotic Hand (Exo-Glove Poly) | Haemin Lee, Brian Byunghyun Kang, Hyunki In and Kyu-Jin Cho | |
| 75 | Affective touch and low power artificial muscles for rehabilitative and assistive wearable soft robotics | Jonathan Rossiter, Espen Knoop and Yuichi Nakamura | |
| ICNR-102* | MAXX: Mobility Assisting teXtile eXoskeleton that Exploits Neural Control Synergies | Kai Schmidt and Robert Riener | |
| ICNR-161* | Soft Printable Pneumatics for Wrist Rehabilitation | Hong Kai Yap, Hui Yong Ng and Chen Hua Yeow | |
| ICNR-175* | Use of an Actuated Glove to Facilitate Hand Rehabilitation after Stroke | Ning Yuan, Kelly Theilbar, Li-Qun Zhang and Derek Kamper | |
| ICNR-212* | Design and Preliminary Testing of a Soft Exosuit for Assisting Elbow Movements and Hand Grasping | Michele Xiloyannis, Leonardo Cappello, Khan Dinh Binh, Chris Wilson Antuvan and Lorenzo Masia | |

* These contributions are shared with ICNR session T3-W-S2: “Soft wearable robotics: potential for neurorehabilitation”

| T-S7 | Neural Interfacing of WRs (J.L. Contreras-Vidal, Lee Kyuhwa) | Day | Time |
|---|---|---|---|
| | | We19 | 15.00-16.30 |
| Paper ID | Title | Authors | |
| 30 | Endogenous Control of Powered Lower-limb Exoskeleton | Kyuhwa Lee, Dong Liu, Laetitia Perroud, Ricardo Chavarriaga and José Millán | |
| 31 | Natural User-Controlled Ambulation of Lower Extremity Exoskeletons for Individuals with Spinal Cord Injury | Kiran Karunakaran, Ghaith Androwis and Richard Foulds | |
| 62 | Real-Time Modeling for Lower Limb Exoskeletons | Guillaume Durandau, Massimo Sartori, Magdo Bortole, Juan Moreno, José Pons and Dario Farina | |
| 71 | Analysis of Steady State Visual Evoked Potentials for Lower Limb Exoskeleton Control based on Brain-Computer Interface | No-Sang Kwak, Klaus-Robert Müller and Seong-Whan Lee | |
| 81 | Towards Everyday Shared Control of Lower Limb Exoskeletons | Tom Carlson | |

| T-S8 | Biomechanics and Neurophysiological studies with WRs (G. Sawicki, H. Van der Kooij) | Day | Time |
|---|---|---|---|
| | | We19 | 17.00-18.30 |
| Paper ID | Title | Authors | |
| 19 | Joint-level responses to counteract perturbations scale with perturbation magnitude and direction | Mark Vlutters, Edwin H. F. van Asseldonk and Herman van der Kooij | |
| 26 | Metabolic Energy Consumption in a Box-Lifting Task: A Parametric Study on the Assistive Torque | Mohammad Sharif Shourijeh, Moonki Jung and Michael Damsgaard | |
| 44 | Analysis of the Movement Variability in Dance Activities using Wearable Sensors | Miguel Xochicale, Chris Baber and Mourad Oussalah | |

# Thursday 20

| T-S6 | New developments in Wearable Rehabilitation Robotics (H. van der Kooij, M. Sartori) | Day | Time |
|---|---|---|---|
| | | Th20 | 9.40-13.00 |
| Paper ID | Title | Authors | |
| 8 | Real time computation of Centroidal Momentum for the use as a stability index applicable to human walking with exoskeleton | Je Hyung Jung, Lidwine Van Opheusden, Pierre Barralon and Jan Veneman | |
| 35 | A versatile neuromuscular exoskeleton controller for gait assistance: a preliminary study on spinal cord injury patients | Amy Wu, Florin Dzeladini, Tycho Brug, Federica Tamburella, Nevio Tagliamonte, Edwin van Asseldonk, Herman van der Kooij and Auke Ijspeert | |
| 51 | Introducing a Modular, Personalized Exoskeleton for Ankle and Knee Support of Individuals with a Spinal Cord Injury | Cory Meijneke, Herman van der Kooij, Shiqian Wang and Victor Sluiter | |
| 54 | Towards exoskeletons with balance capacities | Herman van der Kooij, Edwin van Asseldonk and Mark Vlutters | |
| 79 | EMG-based detection of user's intentions for human-machine shared control of an assistive upper-limb exoskeleton | Alessandro Accogli, Lorenzo Grazi, Simona Crea, Alessandro Panarese, Jacopo Carpaneto, Nicola Vitiello and Silvestro Micera | |
| ICNR-30* | A model of human non-stepping postural responses as the basis for a biomimetic control strategy for robot-assisted balance | Maarten Afschrift, Joris De Schutter, Ilse Jonkers and Friedl De Groote | |
| ICNR-67* | Optimal control of neuromuscular human models for the design of wearable assistive devices | Manish Sreenivasa, Matthew Millard, Paul Manns and Katja Mombaur | |
| ICNR-170* | Combining a 3D reflex based neuromuscular model with a state estimator based on central pattern generators | Tycho Brug, Florin Dzeladini, Amy Wu and Auke Ijspeert | |
| ICNR-214* | Neuromusculoskeletal Modeling using Subject-Specific Muscle Parameters | Massimo Sartori, Jonas Rubenson, David Lloyd, Dario Farina and Fausto Panizzolo | |
| ICNR-263* | An In Vitro Approach for Directly Observing Muscle-Tendon Dynamics with Parallel Elastic Mechanical Assistance | Gregory Sawicki and Benjamin Robertson | |
| ICNR-282* | Toward Balance Recovery with Active Leg Prostheses using Neuromuscular Model Control | Hartmut Geyer, Nitish Thatte and Helei Duan | |

* These contributions are shared with ICNR session T3-T-S6: “Neuromechanical Modeling for Wearable Assistive Technologies”

| W-S4 | Legal Framework, standardization and ethical issues in WRs (J. Veneman, D. Torriceli) | Day | Time |
|---|---|---|---|
| | | Th20 | 15.00-16.30 |
| Paper ID | Title | Authors | |
| 64 | Safety standardization of Wearable Robots – the need for testing methods | Jan F. Veneman | |
| 65 | The potential and acceptance of exoskeletonis in industry | Michiel de Looze, Frank Krause and Leonard O'Sullivan | |
| 82 | Wearable Robots: a Legal Analysis | Andrea Bertolini | |
| 83 | A Verification Method for Testing Abrasion in The Use of Restraint Type Personal Care Robots | Yoji Yamada | |

| W-S5 | Benchmarking in WRs and related communities (D. Torricelli, J. Veneman) | Day | Time |
|---|---|---|---|
| | | Th20 | 17.00-18.30 |
| Paper ID | Title | Authors | |
| 4 | Kinematic Comparison of Gait Rehabilitation with Exoskeleton and End-effector Devices | Byung-Woo Ko and Won-Kyung Song | |
| 41 | Evaluating the Gait of Lower Limb Prosthesis Users | Stephanie Carey, Kyle B. Reed, Amanda Martori, Tyagi Ramakrishnan and Rajiv Dubey | |
| 69 | Some considerations on benchmarking of Wearable Robots for Mobility | Jan Veneman | |
| 73 | Benchmarking data for human walking in different scenarios | Katja Mombaur, Debora Clever and Alexander Schubert | |
| 77 | Clinical gait assessment in relation to benchmarking robot locomotion | Jaap Buurke, Jan Veneman and Diego Torricelli | |

# Friday 21

| F-S9 | Symbiotic Control of WRs (J.C. Moreno, A. del Ama) | Day | Time |
|---|---|---|---|
| | | Fr21 | 9.40-13.00 |
| **Paper ID** | **Title** | **Authors** | |
| 1 | Attention level measurement during exoskeleton rehabilitation through a BMI system | Álvaro Costa, Guillermo Asín, José González-Vargas, Eduardo Iáñez, Juan C. Moreno, Jose M. Azorin, Antonio J. Del-Ama and Ángel Gil-Agudo | |
| 11 | Detection of subject's intention to trigger transitions between seat, stand and walk with a lower limb exoskeleton | Fernando Trincado-Alonso, Antonio J. Del Ama-Espinosa, Elisa Piñuela-Martín, Soraya Pérez-Nombela, Ángel Gil-Agudo, Guillermo Asín-Prieto, Jose Luis Pons and Juan C. Moreno | |
| 13 | The New Generation of Compliant Actuators for Use in Controllable Bio-Inspired Wearable Robots | Tomislav Bacek, Marta Moltedo, Jose Gonzalez-Vargas, Guillermo Asin Prieto, Maria Del Carmen Sanchez-Villamanan, Juan C Moreno and Dirk Lefeber | |
| 43 | An EMG-informed Model to Evaluate Assistance of the Biomot Compliant Ankle Actuator | Elena Ceseracciu, Luca Tagliapietra, Juan C. Moreno, Guillermo Asin, Antonio J. Del-Ama, Soraya Pérez, Elisa Piñuela, Ángel Gil and Monica Reggiani | |
| 56 | Tacit adaptability of a mechanically adjustable compliance and controllable equilibrium position actuator, a preliminary study | Guillermo Asín-Prieto, Shingo Shimoda, Jose Gonzalez, María Del Carmen Sánchez Villamñán, José L. Pons and Juan C. Moreno | |
| ICNR-90* | Dynamic Optimization of A Hybrid Gait Neuroprosthesis to Improve Efficiency and Walking Duration: A Simulation Study | Nicholas Kirsch, Naji Alibeji and Nitin Sharma | |
| ICNR-97* | Preliminary Experiments of an Adaptive Low-Dimensional Control for a Hybrid Neuroprosthesis | Naji Alibeji, Nicholas Kirsch and Nitin Sharma | |
| ICNR-125* | The potential of inertial sensors in posture, gait and cycling FES-assistance | Christine Azevedo Coste, Benoit Sijobert, Christian Geny, Jérôme Froger and Charles Fattal | |
| ICNR-155* | Online Monitoring of Muscle Activity during Walking for Bio-Feedback and for Observing the Effects of Transcutaneous Electrical Stimulation | Nathan Bunt, Juan Moreno, Philipp Müller, Thomas Seel and Thomas Schauer | |
| ICNR-190* | Walking Assistance through Impedance Control of a Lower-limb Exoskeleton | Weiguang Huo and Samer Mohammed | |

* These contributions are shared with ICNR session T3-F-S8: "FES and wearable robot systems in rehabilitation and assistance of locomotion"

| F-S10 | Emerging Applications Domains of WRs, Emerging Technologies in WRs (P. Letier, Jan Babic) | Day | Time |
|---|---|---|---|
| | | Fr21 | 15.00-18.30 |
| **Paper ID** | **Title** | **Authors** | |
| 3 | Design and Kinematic Analysis of the Hanyang Exoskeleton Assistive Robot (HEXAR) for Human Synchronized Motion | Wansoo Kim, Hojun Kim, Donghwan Lim, Hyungi Moon, and Changsoo Han | |
| 21 | Design and experimental evaluation of a low-cost robotic orthosis for gait assistance in subjects with spinal cord injury | Josep M. Font-Llagunes, Daniel Clos, Urbano Lugrís, F. Javier Alonso and Javier Cuadrado | |
| 24 | A powered low-back exoskeleton for industrial handling: considerations on controls | Stefano Toxiri, Jesús Ortiz, Jawad Masood, Jorge Fernández, Luis A. Mateos and Darwin G. Caldwell | |
| 40 | Efficient Lower Limb Exoskeleton for Human Motion Assistance | Nazim Mir-Nasiri | |
| 50 | Active Safety Functions for Industrial Lower Body Exoskeletons: Concept and Assessment | Jawad Masood, Luis A. Mateos, Jesus Ortiz, Stefano Toxiri, Leonard O'Sullivan and Darwin Caldwell | |
| 53 | SOLEUS: Ankle Foot Orthosis for Space Countermeasure with Immersive Virtual Reality | Pierre Letier, Guillaume Fau, Uwe Mittag, Jochen Zange, Joern Rittweger, Moonki Jung, Joe McIntyre and Arnaud Runge | |
| 63 | SPEXOR: Spinal Exoskeletal Robot for Low Back Pain Prevention and Vocational Reintegration | Jan Babič, Katja Mombaur, Dirk Lefeber, Jaap van Dieën, Bernhard Graimann, Michael Russold, Nejc Šarabon, Han Houdijk | |

# PLENARY LECTURES

**Conor Walsh, Ph.D.pascual_cut**
Founding Core Faculty Member,
Wyss Institute at Harvard University

Associate Professor of Mechanical and Biomedical Engineering,
Harvard John A. Paulson School of Engineering & Applied Sciences

Conor is the founder of the Harvard Biodesign Lab, which brings together researchers from the engineering, industrial design, apparel, clinical and business communities to develop new technologies and translate them to industrial partners. His research focuses on applying disruptive technologies to the development of robotic devices for augmenting and restoring human performance. His current research interests include new approaches to design, manufacture and control of wearable robotic devices and characterizing their performance through biomechanical and physiological studies. He leads a team of researchers on the DARPA Warrior Web project to develop a soft exosuit that can assist with locomotion that can perform small levels of assistance to a wearer. The exosuit's function is based on a detailed understanding of human walking and is soft and pliable, unlike traditional exoskeletons that use rigid components. The long term goal is to develop fully portable wearable robots to assist the disabled and able-bodied and further the scientific understanding of how humans interact with such machines. His group is also working on the modeling and design of fluidic-based soft robotics for cardiac applications and applying emerging meso-scale manufacturing approaches to the design of smart medical tools for the minimally invasive diagnosis and treatment of disease. Given his broad interests in medical devices and robotics, he collaborates closely with Wyss staff in the Bioinspired Robotics and Anticipatory Medical and Cellular Devices platforms. In addition, he is passionate about educating future innovators and he has established the Harvard Medical Device Innovation Initiative that provides students with the opportunity to collaborate with clinicians in Boston and emerging regions such as India.

Conor is Associate Professor of Mechanical and Biomedical Engineering at the Harvard John A. Paulson School of Engineering and Applied Sciences and a Core Faculty Member at the Wyss Institute for Biologically Inspired Engineering at Harvard University. Conor received his B.A.I and B.A. degrees in Mechanical and Manufacturing engineering from Trinity College in Dublin, Ireland, in 2003, and M.S. and Ph.D. degrees in Mechanical Engineering from the Massachusetts Institute of Technology in 2006 and 2010. He has been the recipient of over a dozen invention, entrepreneurship, and student mentoring awards including the MIT $100K business plan competition, Whitaker Health Sciences Fund Fellowship, and the MIT Graduate Student Mentor of the Year.

**Dario Farina, Ph.D.**
Department of Neurorehabilitation Engineering
Bernstein Focus Neurotechnology (BFNT) Göttingen
Bernstein Center for Computational Neuroscience Göttingen
University Medical Center Göttingen
Georg-August University, Germany

After a period (2002-2004) as Research Assistant Professor at Politecnico di Torino, he moved to Aalborg University, Denmark, where he was an Associate Professor in Biomedical Engineering (2004-2008) and then Full Professor in Motor Control and Biomedical Signal Processing (2008-2010). In the latter period, he has been the Head of the Research Group on Neural Engineering and Neurophysiology of Movement at Aalborg University. In 2010 he was appointed Full Professor and Founding Chair of the Department of Neurorehabilitation Engineering at the University Medical Center Göttingen, Georg-August University, Germany, within the Bernstein Center for Computational Neuroscience Göttingen. He is currently the Chair for Neuroinformatics of the Bernstein Focus Neurotechnology of Göttingen. His research spans engineering, physiology, neuroscience, and clinical sciences in a translational approach and focuses on the study of neural control of movement and on methods to replace, restore, and modulate lost or impaired motor functions.

# AWARDS

Student Award "BEST STUDENT CONTRIBUTION"

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Committee:

*Prof. José L. Pons*, Cajal Institute, CSIC, Spain
*Prof. José L. Contreras-Vidal*, University of Houston, USA
*Prof. Herman van der Kooij*, University of Twente, The Netherlands
*Prof. Rogelio Soto*, Tecnológico de Monterrey, Mexico
*Prof. Changsoo Han,* Hanyang University, Seoul, Korea

Finalists:

17. Marta Moltedo, Tomislav Bacek, Kevin Langlois, Karen Junius, Bram Vanderborght and Dirk Lefeber. A Compliant Lightweight and Adaptable Active Ankle Foot Orthosis for Robotic Rehabilitation

19. Mark Vlutters, Edwin H. F. van Asseldonk and Herman van der Kooij. Joint-level responses to counteract perturbations scale with perturbation magnitude and direction

55. Ivan Vujaklija, Sebastian Amsuess, Aidan Roche, Dario Farina and Oskar Aszmann. Clinical evaluation of a socket-ready naturally controlled multichannel upper limb prosthetic system

59. Amber Emmens. Improving the Standing Balance of People with Spinal Cord Injury through the use of a Powered Ankle-Foot Orthosis

11. Fernando Trincado-Alonso, Antonio J. Del Ama-Espinosa, Elisa Piñuela-Martín, Soraya Pérez-Nombela, Ángel Gil-Agudo, Guillermo Asín-Prieto, Jose Luis Pons and Juan C. Moreno. Detection of subject's intention to trigger transitions between sit, stand and walk with a lower limb exoskeleton

## POSTER SESSION

P2. Thomas Sugar, Eduardo Fernandez, Darren Kinney, Kevin Hollander and Sangram Redkar, HeSA, Hip Exoskeleton for Superior Assistance.

P18. Laura De Rijcke, Matthias Näf, Carlos Rodriguez-Guerrero, Dirk Lefeber, Jan Babic, Bernard Graimann, Jaap van Dieën, Han Houdijk, Katja Mombaur, Michael Russold and Nejc Sarabon, SPEXOR: Towards a Passive Spinal Exoskeleton.

P29. Nikos Karavas, Jinsoo Kim, Ignacio Galiana, Ye Ding, Adam Couture, Diana Wagner, Asa Eckert-Erdheim and Conor Walsh, Autonomous Soft Exosuit for Hip Extension Assistance.

P38. Martin Grimmer, Sangjun Lee, Brendan T. Quinlivan, Philippe Malcolm, Denise M. Rossi and Conor J. Walsh, Comparison of Ankle Moment Inspired and Ankle Positive Power Inspired Controllers for a Multi-articular Soft Exosuit for Walking Assistance.

P52. Taira Miyatake, Sangjun Lee, Ignacio Galiana, Denise M. Rossi, Christopher Siviy, Fausto A. Panizzolo and Conor J. Walsh, Biomechanical analysis and inertial sensing of ankle joint while stepping on an unanticipated bump.

P16. Madeline Corrigan and Richard Foulds, A Novel Approach to Increase Upper Extremity Active Range of Motion for Individuals with Duchenne Muscular Dystrophy Using Admittance Control: A Preliminary Study.

P32. Peter Michael, Ghaith Androwis and Richard Foulds, Modulation of Muscle Tone in Cerebral Palsy to Enable Use of Exoskeletons for Rehabilitation.

P49. Arvind Ramanujam, Ann Spungen, Pierre Asselin, Erica Garbarini, John Augustine, Stephen Canton, Peter Barrance and Gail F Forrest, Training Response to Longitudinal Powered Exoskeleton Training for SCI.

P5. Chris Baten, Thijs Tromper and Leonie Zeuge, Adaptive activity classification through Hidden Markov Modeling with automated optimal initialization.

P27. Matteo Bianchi, Roberto Conti, Francesco Fanelli, Lapo Governi, Enrico Meli, Alessandro Ridolfi, Federica Vannetti and Benedetto Allotta, Design and motion analysis of a wearable and portable hand exoskeleton.

P33. Karol Quirós Espinoza, Carol Jiménez Quirós, Raquel Mora Morales and Jose Pérez González, Nitiglove: Nitinol-driven robotic glove used to assist therapy for hand mobility recovery.

P66. Masashi Sekine, Kahori Kita, Hiroshi Kawahira and Wenwei Yu, Proposal of Device with Speed-Increasing Gear for Improving Trade-off Relationship in Pneumatic Artificial Muscle

P70. Pierre Letier, Gonzalo Rodriguez, Guillaume Fau, Shashank Govindaraj, Torsten Siedel, Jeremi Gancet and Michel Ilzkovitz. 3D Printed Arm Exoskeleton for Teleoperation and Manipulation Applications

P68. Moonki Jung, Guillaume Fau, Pierre Letier, Uwe Mittag, Jochen Zange, Jörn Rittweger and Arnaud Runge. Musculoskeletal simulation of SOLEUS ankle exoskeleton for countermeasure exercise in space

P9. Sebastian Glowinski, Andrzej Błażejewski and Tomasz Krzyzynski, Human Gait Feature Detection Using Inertial Sensors and Wavelets

P10. Tom Verstraten, Glenn Mathijssen, Bram Vanderborght, Dirk Lefeber, Joost Geeroms and Louis Flynn, On the importance of a motor model for the optimization of SEA-driven prosthetic ankles.

P14. Kevin Abbruzzese and Richard Foulds, Assessment of a 7-DOF Hand Exoskeleton for Neurorehabilitation.

P59. Amber Emmens, Improving the Standing Balance of People with Spinal Cord Injury through the use of a Powered Ankle-Foot Orthosis.

P72. Rafael Mendoza, Rogelio Soto and Jose Luis Pons. Transparent Mode for Lower Limb Exoskeleton

P60. Ker-Jiun Wang, Mingui Sun and Zhi-Hong Mao, Human-Robot Mutual Force Borrowing and Seamless Leader-Follower Role Switching by Learning and Coordination of Interactive Impedance.

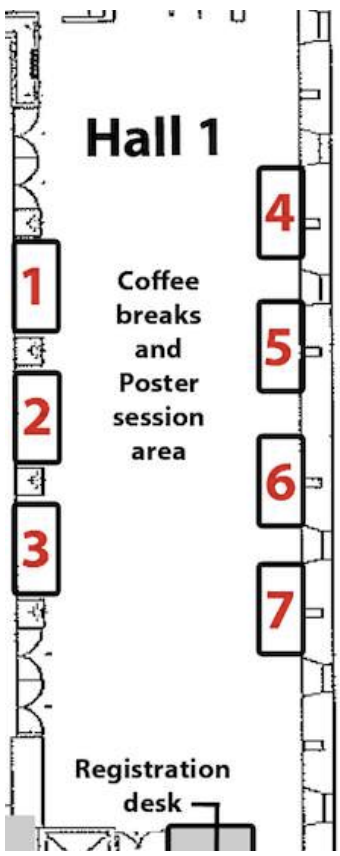
P15. Rok Goljat, Tadej Petrič and Jan Babič, Upper Limb Exoskeleton Control for Isotropic Sensitivity of Human Arm.

P20. Amalric Ortlieb, Mohamed Bouri and Hannes Bleuler, AUTONOMYO: Design challenges of lower limb assistive device for elderly people, multiple sclerosis and neuromuscular diseases.

P47. Ralph Macke, Arvid Keemink and Arno Steinen, Passive Lower Back Moment Support in a Wearable Lifting Aid: Springs versus Counterweight.

P37. Hao Su, Ye Ding, Ignacio Galiana, Jozefien Speeckaert, Nikos Karavas, Philippe Malcolm, Christopher Siviy, Conor J. Walsh. Evaluation of Force Tracking Controller with Soft Exosuit for Hip Extension Assistance.

# EXHIBITOR PLAN





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