ETH zürich

CYBATHLON

CYBATHLON SYMPOSIUM

Kloten, Switzerland
October 6, 2016

Keynote Speakers
Hugh Herr
Jon Sensinger
Michael Goldfarb
Ronald J. Triolo
José del R. Millán
Rory A. Cooper

WELCOME

Dear Attendees,

A warm welcome to the **Cybathlon Symposium 2016**, the scientific conference of the **Cybathlon**, both organized for the first time in Zurich, Switzerland! The **Cybathlon** is a championship for pilots with physical disabilities to showcase state-of-the-art assistive devices in races inspired from activities of daily living. It thereby aims to illustrate technological capabilities and to reduce barriers between people with disabilities, technology developers, and the wider public.

In this context, the **Cybathlon Symposium** offers a unique platform to review the most recent developments in each of the six disciplines of the **Cybathlon**, and to openly discuss the main challenges in the field of assistive technologies. The **Cybathlon Symposium** brings together international researchers from different scientific backgrounds, featuring six keynote lectures by renowned experts and opinion leaders, as well as eight short presentations by young talents. A podium discussion – involving end-users and representatives from academia, industry, and politics – will highlight opportunities and challenges in the field of assistive technologies, its industrial transfer, and user acceptance. In addition, an interactive poster session will promote exchange and discussions between junior and more advanced researchers.

We are delighted to announce that the best abstracts of the **Cybathlon Symposium**, as identified by a panel of experts, will be shortlisted for special issues in either the *Journal of NeuroEngineering and Rehabilitation* or the *IEEE Robotics and Automation Magazine*, focusing on the design, development, and evaluation of assistive technologies.

We thank you all for coming and for contributing to this unique event. We also thank our sponsors for making this event possible, and wish you an intellectually stimulating and inspiring **Cybathlon Symposium**!

Sincerely,

Roger Gassert
ETH Zurich
Chair

Olivier Lambercy
ETH Zurich
Co-Chair

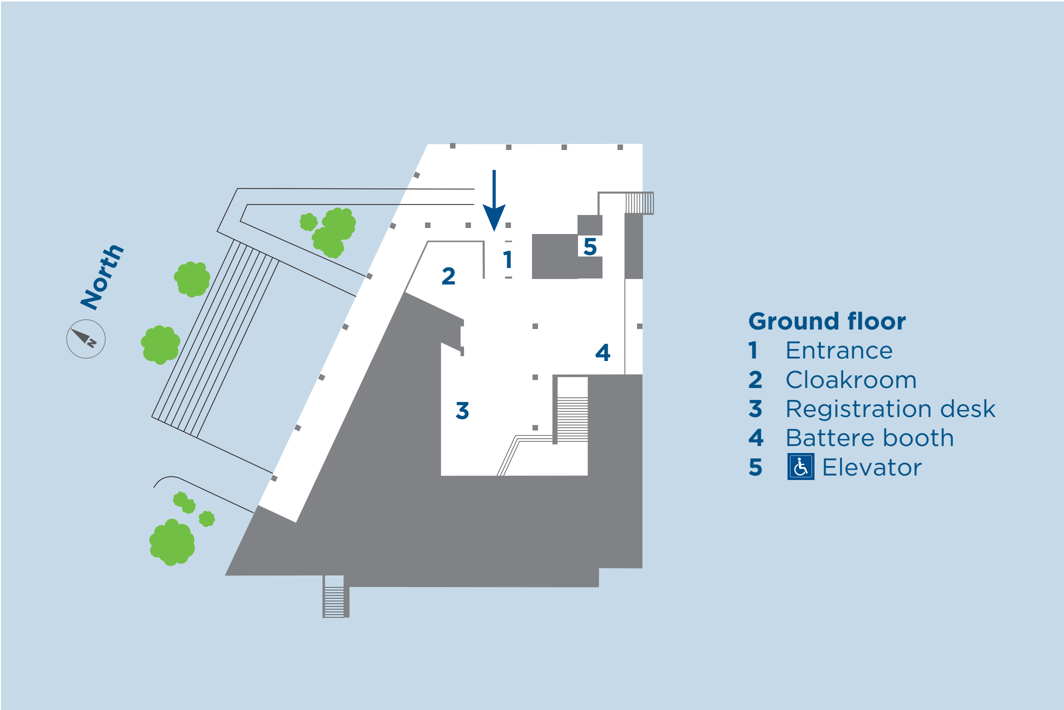
And the organizing committee:
Gunda Johannes, Stefan Schrade, Denise Schumacher, Ann Van der Aa, and Peter Wolf

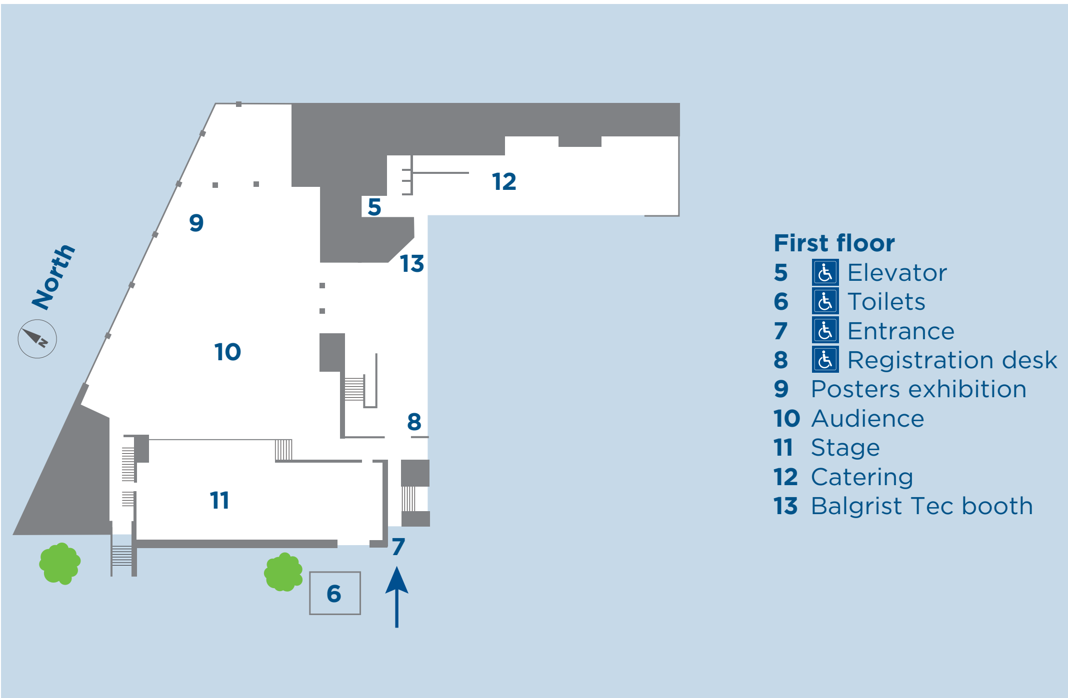
SPONSORS

OFFICIAL SUPPLIERS

VENUE

The **Cybathlon Symposium 2016** is held at the conference center Schluefweg (Konferenzzentrum Schluefweg, Schluefweg 10 in 8302 Kloten, Switzerland) next to the SWISS Arena.





HOW TO GET THERE

TRANSPORTATION

The timetables for trains and buses can be found on the website of the Swiss Federal Railways (SBB) at http://www.sbb.ch/en/.

Passengers with reduced mobility can obtain help with getting on and off trains by calling SBB Call Center Handicap: 0800 007 102 (calls are free within Switzerland; service hours are between 6am and 10pm). More information can also be found at http://www.sbb.ch/en/station-services/passengers-with-reduced-mobility/sbb-call-center-handicap.html.

INTERNET ACCESS

Free wireless Internet access is provided.
Log into SSID: CYBATHLON with password: ethcyba2016.

PROGRAM

08h00 – 09h00	Registration and poster setup	
09h00 – 09h10	Welcome address	
09h10 – 09h50	**Hugh Herr, PhD** (MIT) *Leg Prosthetics*	KEYNOTE
09h50 – 10h00	**Louis Flynn** (Vrije U Brussels)	T01
10h00 – 10h10	**Sasha Blue Godfrey** (IIT Genova)	T02
10h10 – 10h50	Coffee break & poster session	
10h50 – 11h30	**Jon Sensinger, PhD** (U New Brunswick) *Arm Prosthetics*	KEYNOTE
11h30 – 12h10	**Michael Goldfarb, PhD** (Vanderbilt U) *Exoskeletons*	KEYNOTE
12h10 – 12h20	**Amber Emmens** (U Twente)	T03
12h20 – 12h30	**Arun Jayaraman** (RIC and NWU)	T04
12h30 – 14h30	Lunch break & poster session	
14h30 – 15h10	**Ronald J. Triolo, PhD** (Case Western U) *Functional Electrical Stimulation*	KEYNOTE
15h10 – 15h50	**José del R. Millán, PhD** (EPFL) *Brain-Computer Interfaces*	KEYNOTE
15h50 – 16h00	**Juliana Guimarães** (U Brasilia)	T05
16h00 – 16h10	**Karina Statthaler** (Graz U Technology)	T06
16h10 – 16h50	Coffee break & poster session	
16h50 – 17h00	**Marcello Ienca** (U Basel)	T07
17h00 – 17h10	**Shuro Nakajima** (Wakayama U)	T08
17h10 – 17h50	**Rory A. Cooper, PhD** (U Pittsburgh) *Powered Wheelchairs*	KEYNOTE
17h50 – 18h30	**Podium discussion** Panel: Pascale Bruderer, Gery Colombo, Rory A. Cooper, Kelly James, Robert Riener, Alan Winfield Moderator: Janine Geigele	
18h30 – 20h00	Apéro riche	
19h30 – 21h30	PluSport Exhibition	

PODIUM DISCUSSION

We invite all participants to round off the symposium with a podium discussion on the following topics: **Opportunities and challenges in the field of assistive technology, user acceptance, industry transfer, and financing.**

Six distinguished participants from various backgrounds related to assistive technology will discuss the matters at hand:

Pascale Bruderer, lic. phil.
Politician, member of the Swiss Council of States, president of Inclusion Handicap, self-employed business consultant, and university lecturer on disability law.

Gery Colombo, Ph.D.
CEO and founder of Hocoma AG, and president of the International Industry Society in Advanced Rehabilitation Technology (IISART).

Rory A. Cooper, Ph.D.
FISA & Paralyzed Veterans of America Chair, distinguished professor of the Department of Rehabilitation Science and Technology, professor of Bioengineering, Physical Medicine and Rehabilitation, and Orthopedic Surgery at the University of Pittsburgh, and Founding Director and VA Senior Research Career Scientist of the Human Engineering Research Laboratories.

Kelly James, P.Eng.
CEO and founder of Biomech Designs Ltd., inventor of the C-Brace and C-Leg, which were turned into market-ready products through Ottobock and worn by thousands.

Robert Riener, Ph.D.
Professor of Sensory-Motor Systems at ETH Zurich and the Medical Faculty of the University of Zurich, head of the Department of Health Sciences and Technology, ETH Zurich, and initiator and organizer of the Cybathlon.

Alan Winfield, Ph.D.
Director of the Science Communication Unit and Professor at UWE Bristol, Member of the Ethics Advisory Board of the EC Human Brain Project, Co-chair of the General Principles committee within the IEEE Global Initiative on the Ethical design of Autonomous Systems.

Janine Geigele will moderate the discussion. She will also moderate the Cybathlon.

The floor will be opened for questions from the audience at the end of the discussion.

EXHIBITION: «FROM CAPTAIN HOOK TO IRON MAN»

Let PluSport and its partners take you on a journey from the dawn of assistive technologies right up to the present day. In this captivating exhibition with about 50 exhibits divided into four sections you will learn how prosthetics and wheelchairs have developed and evolved over the years, and the immense changes that these technologies have undergone.

Antiquity

Rarities

Everyday Life + Sports

Assistance for sport & everyday life

Modernity

Electronics & Robotics

Photos + Videos

Worldwide & Caricatures

Special Invitation for the tour for symposium participants

Following the symposium, we cordially invite you to join us on our guided tour of our extraordinary exhibition, located in the tent at the entrance to the premises of the outdoor pool (next to the conference center). Our two ambassadors, Armin Köhli and Rüdiger Böhm, will be happy to accompany you through the exhibition and provide you with a more in-depth look into the different epochs of assistive technologies with stories and anecdotes.

Take advantage of this unique opportunity and visit us on Thursday, 06.10.16, from 19.30 to 21.30, in the exhibition tent «From Captain Hook to Iron Man».

Your professional guides

Rüdiger Böhm, Wangen / SZ
Ski Alpin, Para-Triathlon, Author
www.ruedigerboehm.ch
www.facebook.com/nolegsnolimits

Armin Köhli, Hinteregg / ZH
Ex-Paralympics-Athlete, Cyclist, Journalist
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Facts & Figures PluSport

+ 12'000 Members
+ 2'500 Coaches and 1'500 Volunteers
+ 30 Employees at the Head Office
+ 90 Sports Clubs and 100 Sports Camps
+ 50 Training Courses
+ 20 Leading Athletes and 40 Young Talents
+ 20 Projects and Events
+ Co-founder of Swiss Paralympics

Objectives

+ Integration through sports
+ Targeted youth development in mass and top-class sports
+ Effective partnerships through corpotrate responsibility programmes

PluSport: Your Partner for the Additional Programme at Cybathlon

Apart from creating a competitive platform for the development of novel assistive technologies that are compatible for daily use, Cybathlon aims to contribute to the decrease of barriers between people with disabilities, the public, and technological innovators. Both the newest technologies and methods of assistive aids and an understanding of the everyday problems of people with disabilities are required to improve their lives sustainably.

PluSport
Behindertensport Schweiz
Sport Handicap Suisse
Sport Andicap Svizzera

PluSport, the umbrella organization and competence center for sports for disabled people, has been supporting disabled people since 1960: they should be able to pursue sports regardless of their condition. PluSport enables them to enjoy integration, joy, and success through the means of exercise in sports. Their ability to pursue sports is strongly affected by modern technological advances, which is particularly interesting for our Paralympic professional athletes.

CYBATHLON

The **Cybathlon** main event will take place on October 8, in the SWISS Arena, Kloten, Switzerland.

Tickets can be bought here at the **Cybathlon Symposium** at the registration desk from 12h00 to 20h00.

PROGRAM:

9h00	Doors open
10h00	Opening address
	Qualification races:
	Powered Arm Prosthesis Race
	BCI Race
	Powered Wheelchair Race
	FES Race
	Powered Exoskeleton Race
	Powered Leg Prosthesis Race
	Show acts and interviews with teams and experts
14h00	Main address
	Final races and medal ceremonies:
	Powered Arm Prosthesis Race
	BCI Race
	Powered Wheelchair Race
	FES Race
	Powered Exoskeleton Race
	Powered Leg Prosthesis Race
	Show acts and interviews with teams and experts
18h00	Closing address

CYBATHLON SYMPOSIUM

KEYNOTES

On the Design of Bionic Leg Devices: The Science of Extreme Interface

Hugh Herr, PhD

Professor and head of Biomechatronics research group at the MIT Media Lab

Short Biography

Hugh Herr, who heads the Biomechatronics research group at the MIT Media Lab, is creating bionic limbs that emulate the function of natural limbs. In 2011, *TIME* magazine coined Herr the "Leader of the Bionic Age" because of his revolutionary work in the emerging field of biomechatronics–technology that marries human physiology with electromechanics. A double amputee himself, he is responsible for breakthrough advances in bionic limbs that provide greater mobility and new hope to those with physical disabilities. Herr is the author and co-author of over a 150 peer-reviewed papers and patents, chronicling the science and technology behind his many innovations. These publications span the scientific fields of biomechanics and biological motion control, and the technological innovations of human rehabilitation and augmentation technologies. As published in the Journal of Neuroengineering and Rehabilitation in 2014, Herr's team advanced the first autonomous exoskeleton to reduce the metabolic cost of human walking, a goal that has eluded scientist for over a century. In the field of human rehabilitation, Herr's group has developed gait adaptive knee prostheses for transfemoral amputees and variable impedance ankle-foot orthoses for patients suffering from drop foot, a gait pathology caused by stroke, cerebral palsy, and multiple sclerosis. He has also designed his own bionic legs, the world's first bionic lower leg called the BiOM Ankle System. As published in the 2012 Proceedings of the Royal Society, the BiOM Ankle System has been clinically shown to be the first leg prosthesis to achieve biomechanical and physiological normalization, allowing persons with leg amputation to walk with normal levels of speed and metabolism as if their legs were biological once again.

Abstract

Critical to the advancement of bionic legs that emulate or extend normal physiological function is the design of extreme interfaces between the human body and electromechanics. In this talk, I describe research activities underway to advance the science of mechanical and electrical interface design. I present novel exoskeletal, orthotic and prosthetic limbs that behave dynamically like their biological counterpart, peripheral neural implants that serve as an electrical interface with the external bionic limb, and novel socket and bracing technology for the mechanical attachment of the bionic device to the residual limb. For each of these interfaces, anatomical, biomechanical and neuromechanical models are employed in the motivation of subsystem design. The therapeutic distinction of bionic leg devices to increase walking speed, reduce gait metabolism, enhance stability, and mitigate musculoskeletal stress is examined. Finally, critical areas of future research are discussed that must be advanced to step towards the next generation of bionic leg systems.

Paradigm Changes in Upper Limb Prostheses: From New Shifts in Technology to New Definitions of Success

Jon Sensinger, PhD

Associate Director of the Institute of Biomedical Engineering, University of New Brunswick

Short Biography

Jon Sensinger is the associate director of the Institute of Biomedical Engineering and an associate professor in Electrical Engineering at the University of New Brunswick. He is also a co-founder of Coapt LLC, a company that sells controllers for prostheses. His research focuses on the design, control, and human interaction of prostheses and exoskeletons. In the past this has included the mechatronic design of motors and transmissions to develop small, lightweight prosthetic arms. His recent research interests include developing computational motor control models of how humans control prosthetic devices, and the design and control of robotic prosthetic legs and exoskeletons.

Abstract

Upper-limb prostheses are a poor substitute for the human arm—so much so that many persons with an amputation choose to live their lives without the added weight of a portable vice hanging on them all day long. But there is also much promise, both in the field itself, and when we look at the technologies being developed in related fields such as smart phones and autonomous cars. This talk will briefly cover some of the game-changing paradigm shifts happening in the field, including osseointegration and peripheral nerve innervation, followed by recent advances in low-tech devices, high-tech devices, and control strategies. It will end by introducing a relatively new framework, computational motor control, which provides a causal model for why humans make the behavioral control decisions they do in light of the control and sensory uncertainty with which they interact. This framework offers the promise to improve the control and feedback devices available for use in prostheses by pinpointing optimal solutions to complex problems.

References

[1] Lenzi, Lipsey, and Sensinger (2016). The RIC arm – a small, anthropomorphic transhumeral prosthesis. IEEE Transactions on Mechatronics. DOI: 10.1109/TMECH.2016.2596104.

[2] Johnson, Kording, Hargrove, and Sensinger (2014). Does EMG control lead to distinct motor adaptation? *Frontiers in Neuroscience*, DOI: 10.3389/fnins.2014.00302.

Powered Exoskeletons and Their Emerging Promise for Providing Assistance and Therapy to Individuals With Neuromuscular Impairment

Michael Goldfarb, PhD

H. Fort Flowers Professor of Engineering, Vanderbilt University

Short Biography

Michael Goldfarb, PhD, is the H. Fort Flowers Professor of Mechanical Engineering at Vanderbilt University, with secondary appointments as a Professor of Electrical Engineering, and Physical Medicine and Rehabilitation. Dr. Goldfarb's work focuses on the development of assistive devices that improve quality of life for people with physical disabilities. Dr. Goldfarb has published approximately 200 papers on related topics, including ones that were awarded best-paper awards in 1997, 1998, 2003, 2007, 2009, and 2013. Recent work includes the development of robotic limbs for upper and lower extremity amputees, and lower limb exoskeletons for individuals with SCI and stroke.

Abstract

Powered exoskeletons, which have been an elusive goal of robotics researchers for decades, have recently become technologically viable, and as such have recently begun to emerge in both research laboratories and the commercial marketplace. Such exoskeletons enable a number of new and potentially impactful possibilities for improving the quality of life and quality of care for individuals with neuromuscular impairment (e.g., individuals with paresis or paralysis from SCI, stroke, MS, CP, and TBI). Depending on the nature with which a powered exoskeleton interacts with a patient, the exoskeleton can serve as an assistive device for improving or enhancing the mobility and/or functionality for the conduct of activities of daily living; or can serve as a therapeutic device for facilitating functional or neuromuscular recovery in individuals capable of such recovery; or in some cases, can provide both functions. Despite the recent emergence of multiple commercially-available powered exoskeletal devices, the potential of such devices for providing improved functionality in the home and community, and their potential for facilitating recovery, remains largely unknown. Further, methods and best practices for human interaction (i.e., the nature of man-machine interaction) to provide these respective objectives in various patient populations also remains an area of knowledge that is relatively unexplored and largely unknown. As such, despite impressions given by rapidly emerging hardware, the field is still in early stages, and realization of the full potential of powered exoskeletons will require the collective efforts and contributions of many researchers over the next several years. This talk will focus on some experiences with powered exoskeletons with individuals with SCI and stroke, in both the context of an assistive device (for improving mobility), and that of a therapeutic device (for facilitating recovery), and provide some recent outcomes and results from investigations of both.

Implanted Neuroprostheses: Technical and Clinical Challenges to Enhancing Standing, Walking and Seated Posture, Balance and Mobility after Paralysis

Ronald J. Triolo, PhD

Professor, Case Western Reserve University and
Senior Research Career Scientist, US Department of Veterans Affairs

Short Biography

Dr. Triolo received MS and PhD degrees in Biomedical Engineering from Drexel University in Philadelphia PA, where he was Director of Research for Shriners Hospitals until 1994. He is the founding Director of the Center for Advanced Platform Technology and a Senior Research Career Scientist for the US Department of Veterans Affairs, as well as a Professor of Orthopaedics and Biomedical Engineering at Case Western Reserve University in Cleveland OH. Dr. Triolo currently leads NIH, VA and DARPA funded research programs to develop and assess assistive technologies to enhance independent upright and seated mobility, balance and sensation to individuals with CNS dysfunction or limb loss.

Abstract

Assistive technologies that communicate directly with the peripheral nervous system can facilitate or restore the independent performance of many functions compromised by CNS disease or trauma. Implanted neural stimulators have allowed dozens of individuals with low cervical or thoracic spinal cord injuries to exercise, transfer, stand and step under the power of their otherwise paralyzed muscles, and new generations of implantable technologies with enhanced abilities to selectively activate isolated components within a compound nerve are improving the quality of clinical outcomes. Short- and long-term clinical feasibility trials of first and second generation implanted systems for lower extremity and core hip/trunk function after paralysis indicate that the technology is reliable, recipients maintain the functional gains observed at discharge, and devices are routinely utilized for exercise and function. Major challenges facing wider spread dissemination of the technology currently being addressed include integrating neural stimulation with voluntary muscle activity or external assistive devices, developing biologically inspired control systems to automatically regulate standing or seated posture and balance, eliminating reliance on the upper extremities to maintain stability, delaying the effects of muscle fatigue, and improving consistency of clinical performance over individuals with various body sizes. This presentation will summarize ongoing research in a comprehensive program to re-establish or improve personal mobility (standing, stepping, seated posture and balance, and manual wheelchair propulsion) after paralysis by spinal cord injury, stroke or multiple sclerosis, and more recent efforts to provide natural sensation to lower limb amputees via implanted neural stimulation technologies.

References

[1] Triolo RJ, Bailey S, Miller M, Rohde L, Anderson J, Davis J, Abbas J, Diponio L, Forrest G, Gater D, Yang L, Longitudinal performance of a surgically implanted neuroprosthesis for lower extremity exercise, standing, and transfers after SCI. *Arch Phys Med & Rehab.* 93(5):896-904, 2012.

[2] Audu M, Lombardo L, Schnellenberger J, Foglyano K, Miller M, Triolo R, A neuroprosthesis for control of seated balance after spinal cord injury, *Jou NeuroEngr & Rehab* 15, 12-8, 2015.

Translating Brain-Computer Interfaces to End-Users

José del R. Millán, PhD

Defitech Foundation Chair at the Center for Neuroprosthetics, EPF Lausanne

Short Biography

Dr. José del R. Millán currently holds the Defitech Foundation Chair at the Center for Neuroprosthetics of the École Polytechnique Fédérale de Lausanne (EPFL).

Dr. Millán has made several seminal contributions to the field of brain-computer interfaces (BCI), especially based on electroencephalogram (EEG) signals. Most of his achievements revolve around the design of brain-controlled robots. He puts a strong emphasis on the use of statistical machine learning techniques so as to achieve a seamless coupling between the user and the brain-controlled device. During the last years he is prioritizing the translation of BCI to end-users with motor disabilities.

Abstract

Over the last years, we have developed a variety of brain-computer interfaces (BCI), mainly based on the analysis of scalp electroencephalogram (EEG) signals, which have been extensively tested by users with motor disabilities after a short training period. A substantial number of tests have been carried out at end-users' home and clinics, outside well-controlled laboratory conditions. Equally significantly, non-BCI experts (assistive technology professionals and therapists) have run many of these tests independently or with a minimum of remote assistance from researchers.

A central concern in our research is how to facilitate the operation of brain-controlled devices over long periods of time. This is a challenging problem due to the limited (and variable) information carried by brain signals we can measure, no matter the recording modality. I will argue that efficient brain-computer interaction, as the execution of voluntary movements, requires the integration of several parts of the central nervous system and the external actuators. In this talk I will summarize this work and the main lessons learned from this major effort, highlighting new principles incorporated in the brain-controlled devices. In particular, our approach is based on spontaneous and voluntary modulation of EEG rhythmic brain activity that does not require any kind of external stimulation, thus reducing users' fatigue. Our BCIs analyze EEG signals to determine users' intents through the use of a probabilistic classifier with evidence accumulation. Our BCI approach incorporates some additional principles —in particular, shared control— so as to increase reliability, reduce workload, and facilitate split attention.

References

[1] Leeb, R., Tonin, L., Rohm, M., Desideri, L., Carlson, T., and Millán, J.d.R. (2015). Towards independence: A BCI telepresence robot for people with severe motor disabilities. Proceedings of the IEEE, 103(6):969–982.

[2] Perdikis, S., Leeb, R., Williamson, J., Ramsey, A., Tavella, M., Desideri, L., Hoogerwerf, E.-J., Al-Khodairy, A., Murray-Smith, R., and Millán, J.d.R. (2014). Clinical evaluation of BrainTree, a motor imagery hybrid BCI speller. Journal of Neural Engineering, 11(3):036003.

Advancing Wheeled Mobility and Function for People with Disabilities

Rory A. Cooper, PhD

Distinguished Professor and FISA Foundation – Paralyzed Veterans of America Chair
Founding Director, Human Engineering Research Laboratories
U.S. Department of Veterans Affairs

Short Biography

Dr. Cooper has authored or co-authored over 300 peer-reviewed journal publications, and has over 20 patents awarded or pending. Cooper authored: "*Rehabilitation Engineering Applied to Mobility and Manipulation*" and "*Wheelchair Selection and Configuratio*n". He was a bronze medalist in the *Paralympic Games*, Seoul, Korea. Cooper was awarded the *International Paralympic Scientific Achievement Award*. *PN Magazine* included Cooper as one of the people who have transformed the lives of people with SCI. Dr. Cooper's work has received coverage by TIME*, CNN, Popular Science, Forbes, ESPN, NBC, BMJ, Reuters, NPR, and other national and international media outlets.

Abstract

Advances in robotics and intelligent machines are making breakthroughs in the lives of people with disabilities. As computing power, sensors, the internet of things are brought to bear on improving the lives of people with disabilities, there should be tremendous opportunity for social inclusion and full participation. Robotic technologies are improving mobility and function for people with severe disabilities affording greater independence. Wheelchair mounted robotic arms provide the ability to perform activities of daily living with less assistance. Robotic transfer devices expand the environments where people can visit and stay for extended periods and are reducing the strain on caregivers. Robotics in wheeled mobility is transforming powered wheelchairs to provide independent mobility to more people in a wider variety of environments.

Intelligent systems are transforming assistive technologies as well as our environments. Virtual coaches are changing the way people use their powered seat functions to improve compliance with clinical guidelines. Smart environments improve quality of life in our homes, schools, work places and communities.

References

[1] Grindle, G.G., Wang, H., Jeannis, H., Teodorski, E., Cooper, R.A. (2015) Design and User Evaluation of an Electrical Powered Wheelchair Mounted Robotic Assisted Transfer Device, BioMed Research International, 2015(ID:198476): 9 pages.

[2] Daveler, B., Salatin, B., Grindle, G.G., Candiotti, J., Wang, H.W., Cooper, R.A. (2015) Design of a Mobility Enhancement Robotic Wheelchair. Journal of Rehabilitation Research and Development, 52(6): 739-750.

* http://time.com/3975280/robotics-disabled/

SHORT TALKS

Name* - author presenting
<u>Name</u> - author attending

VUB-CYBERLEGs Transfemoral Prosthesis

Louis Flynn[1]*, Joost Geeroms[1], Tom Van Der Hoeven[1], Rene Jimenez-Fabian[1], Bram Vanderborght[1], Dirk Lefeber[1]

[1] Vrije Universiteit Brussel, Mechanical Engineering, B-2650 Brussels, Belgium

Abstract

The CYBERLEGs Beta-Prosthesis is a highly compliant, transfemoral prosthesis that attempts to match the quasi-static stiffness of the knee and ankle using passive components when possible. With integration of these passive components with series-elastic actuators, the prosthesis can provide the full knee and ankle torque during the normal gait cycle with minimal active driving of the motors. The ankle is a series elastic actuator incorporating an MACCEPA architecture with a parallel spring to reduce required peak motor torques. There is a weight acceptance (WA) mechanism to efficiently handle stance flex in the knee by inserting a stiff spring at the time of heel strike, unlocking when necessary for the swing phase. The CYBERLEGs Beta-Prosthesis is a test bench to learn about controlling highly compliant robots designed for human interaction.

The prosthesis has been used with four male amputee test subjects, with ages ranging from 48 – 72 years, for walking, stair climbing, and sit-to-stand operations. During treadmill walking, there were subjects who increased their preferred gait speed by 0.2 km/hr, implying some benefit from the active system. Also, while the prosthesis weight was around 5 kg, the subjects reported that the prosthesis did not feel so heavy when it was running correctly. The subjects walked with a speed which was far below the target, resulting in lower than expected pushoff torques. Also the subjects did not utilize the WA mechanism as designed. It is believed that this was mostly due to training, and with longer training periods it is believed this can be changed.

In order to further develop this system a new electronics system, based on EtherCat and Simulink, has been developed as well as a new control system that does not rely on the more complicated Wearable Sensory Apparatus of the CYBERLEGs project. Refining this new system is ongoing.

References

[1] Flynn, L., Geeroms, J., Jimenez-Fabian, R., Vanderborght, B., and Lefeber, D. (2015), CYBERLEGS Beta-Prosthesis Active Knee System, IEEE Int. Conf. Rehabil. Robot. ICORR 2015, 410–415.

[2] Jimenez-Fabian, R., Flynn, L., Geeroms, J., Vitiello, N., Vanderborght, B., and Lefeber, D. (2015) Sliding-Bar MACCEPA for a Powered Ankle Prosthesis, J. Mech. Robot., (7), March, 1–2.

Short Biography

Louis Flynn is a PhD Student at the Vrije Universiteit Brussel. His research is focused on the behavior of transfemoral active prostheses.

The Softhand Pro-H: A Shoulder-Driven, Motor-Actuated Prosthetic Solution

Sasha Blue Godfrey[1]*, Cristina Piazza[2], Manuel Catalano[1,2], Matteo Rossi[1,2], Antonio Bicchi[1,2]

[1] Istituto Italiano di Tecnologia, Genoa, Italy
[2] University of Pisa, Pisa, Italy

Abstract

Body-powered and myoelectric prosthetic terminal devices have similarly high rates of rejection: 26 and 23%, respectively [1]. This is in part because, despite technological advances, each comes with distinct advantages and disadvantages. Body-powered devices typically feel more secure on the body because of the harness worn on the contralateral shoulder, while, depending on the physiology of the wearer, potentially allowing a more comfortable and secure socket. Inherent to body-powered actuation is a certain amount of feedback as one senses the shoulder movement with proprioception; however, the force the shoulder must repeatedly exert can also be a source of fatigue and, over time, even overuse injuries. Myoelectric prostheses, in contrast, are actuated by motors, avoiding some of these fatigue or overuse issues. Further, most myoelectric devices are anthropomorphic in nature and thus have improved cosmesis compared to their body-powered counterparts (often hooks). However, myoelectric control is not accessible or preferable for all prosthesis users either because of the length of the residual limb, difficulty in reliably controlling residual muscles, or simply user preference. The SoftHand Pro-H marries the concepts behind traditional body-powered and myoelectric prostheses by translating shoulder motion into motor commands. The terminal device is the SoftHand Pro: a 19 degree of freedom, underactuated prosthetic hand based on the neuroscientific principle of motor synergies that is thus able to grasp a wide variety of objects with human-like motion. While the typical SoftHand Pro uses myoelectric control, the SoftHand Pro-H employs a typical body-powered harness to transmit user intention to the hand's microcontroller. As with these devices, the SoftHand Pro-H can be used as a voluntary-open or voluntary-close hand wherein either open or close motion, respectively, is driven by movement of the shoulder and the opposing motion occurs with relaxation. Here we present the device, first trials with a prosthesis user, and plans for future work.

References

[1] Biddiss, E. A., & Chau, T. T. (2007). Upper limb prosthesis use and abandonment: a survey of the last 25 years. Prosthetics and orthotics international, 31(3), 236-257.

Short Biography

Sasha Blue Godfrey received her PhD degree in biomedical engineering from the Catholic University of America in 2012. Currently, she is a postdoctoral fellow in the department of Advanced Robotics at the Isitituto Italiano di Tecnologia (Italian Institute of Technology) and a research affiliate at the Mayo Clinic. Her main research interests are rehabilitation robotics, prosthetics, and motor control.

A Comparison between Control Strategies for Balancing with a Powered Ankle-Foot Orthosis

Amber Emmens[1]*, Edwin van Asseldonk[1], Iolanda Pisotta[2], Marcella Masciullo[2], Herman van der Kooij[1]

[1] Biomechanical Engineering Department, University of Twente, Enschede, the Netherlands
[2] Neurological and Spinal Cord Injury Rehabilitation Department A, Fondazione Santa Lucia, Rome, Italy

Abstract

Exoskeletons that are designed for people with a Spinal Cord Injury (SCI) generally rely on crutches for balance maintenance. Our goal is to enable these subjects to maintain balance in an exoskeleton without additional supporting devices, by designing proper balance controllers. Therefore, as a first step, we tested and compared various balance controllers on a powered Ankle-Foot Orthosis (pAFO) acting in the sagittal plane to assist subjects with a SCI with balancing.

Two SCI subjects affected by an incomplete low lesion participated in experiments in which they had to maintain their standing balance, without stepping, while receiving perturbations on the pelvis from a robotic pushing device. We tested different controllers on the pAFO: a fixed stiffness around the ankle; a PD-controller on the Center of Mass (CoM) that controls the CoM to a reference location; and a Momentum-Based Controller (MBC) that tries to find joint torques such that a certain desired centroidal momentum is obtained [1]. The first controller operates in joint space and the latter two in CoM space. Using force plates, the torque generated by the subject was estimated and compared to the torque delivered by the pAFO, to evaluate the supportive effect of the pAFO.

We found that the PD-controller on the CoM, and to lesser extent the MBC, provided a substantial assistive torque to the subjects after a perturbation had been applied. The ankle torque of the subjects decreased without worsening the balancing performance. In contrast, when a fixed ankle stiffness was implemented on the pAFO, the subjects needed to provide most of the necessary torques for balancing themselves, which shows the added value of controlling in CoM space compared to joint space. In future work, we will extend the CoM space controllers to a wearable exoskeleton with more actuated degrees of freedom.

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Short Biography

Amber Emmens studied Mechanical Engineering at the University of Twente and received her master’s degree (cum laude) in 2013. At the end of 2013 she started working as a PhD student in the Symbitron project, in which the main goal is to design a wearable, lower-limb exoskeleton for paraplegics. Her main focus is on designing controllers for the exoskeleton that provide balance for the combination of human and exoskeleton.

Making a Case for Wearable Robotics in the Field of Rehabilitation

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Abstract

Wearable robotics is an area of research that has gained substantial attention in recent times. Interestingly, the acceptance of these eloquent devices into everyday clinical practice and home use is limited by past and present research. 1 Currently, there exists a void between the research evidence from engineering groups and clinical teams on the predicated utility and actual usability of wearable robotic systems.2 This research summary will highlight some of the research studies being conducted at the RIC, where engineering and clinical science is combined, performed simultaneously and sequentially to gain insight to clinical utility of wearable robots to specific clinical populations. Results of these studies indicate the continued need for adaptations in the hardware and controller mechanisms of these devices when used on disabled individuals who struggle with differential muscle weakness, range of motion limitations, cognitive disabilities, variable balance and altered neuromotor control. Specifically, the larger rigid robots with variable assistance modes provide better mobility options in individuals with severe neurological impairments compared to traditional therapeutic strategies. Single-joint or modular robots are able to provide the ability for individuals with neurological impairments to perform at higher metabolic capabilities, thus improving their ability to perform different activities of daily living which require more effort and endurance. However, there seems a need for specific training strategies and clinical guidelines when training individuals with varying disabilities to use these devices as therapy or personal mobility devices. This information will help clinicians and scientists gain some additional insight into how this wearable technologies can be progressed further into the field of rehabilitation for every day home and community use.

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Short Biography

Arun Jayaraman PT is the Director, Max Näder Center for Rehabilitation Technologies & Outcomes Research at the Rehabilitation Institute of Chicago. He is also an Associate Professor at Departments of Physical Medicine & Rehabilitation and Physical Therapy & Human Movement Sciences at Northwestern University. Dr. Jayaraman's group is a clinical lab that develops and executes research in prosthetics, rehabilitation robotics, and other assistive and adaptive technologies to treat physical disability. The lab conducts all its outcome research using advanced wearable patient monitoring wireless sensors and machine learning techniques in addition to the traditional outcome measures.

Clinical Features and Responsiveness to Electrical Stimulation: An Exploratory Study to Find Candidates to FES Bike Race

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Abstract

Function Electrical Stimulation during cycling (FES-cycling) was recommended in a variety of aspects to improve the general paraplegic condition and to prevent deterioration secondary the Spinal Cord Injury (SCI). However, not all the people with paraplegia respond to electrical stimulation. In order to explore the characteristics of the concerned public and get insights to find candidates to compete in the FES Bike Race, we investigate clinical features from people with paraplegia, assessing their responsiveness to neuromuscular electrical stimulation (NMES) and the number of sessions necessary to get a primary response. Fourteen volunteers attended a public recruitment forum to be assessed about their responsiveness. No elective criterion was considered, since we wanted to explore the responsiveness to electrical stimulation from people of all backgrounds interested in attending FES-Cycling. The participants were enrolled in a 16-sessions protocol starting with a knee extension program via surface NMES applied on quadriceps muscle and progressing to other muscle groups as the responsiveness was positively visualized by means of contractions strength classified as grade 3/5 (movement possible against gravity). After the 16-sessions, volunteers were separated in two groups (responsive and non-responsive to NMES) which were investigated in the light of some personal, clinical, structural and functional features. Fifty seven percent of the initial sample responded to electrical stimulation with a visual contraction. This responsive group was predominantly composed by subjects presenting traumatic spinal cord injuries above T12 vertebral level. Only two subjects became responsive at the 3rd and 16th sessions. Among the observed features, the etiology and level of injuries seems to be more associated to responsiveness. Our observations seem to indicate that subjects with traumatic spinal cord injury above T12 level were the best potential candidates for FES-cycling. Our outlook is to propose a list of minimum requirements and the best user-driven design to find candidates suitable for FES bike race competition.

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Optimized Individual Mental Tasks to Control BCIs

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Abstract

Various mental tasks can be used to control a brain-computer interface (BCI), but not every task or combination is suitable for every user, which makes it necessary to find the individual one for each user.

We recorded the electroencephalogram (EEG) of five healthy people and one end user using 32 active electrodes equidistantly spread over frontal and sensorimotor areas. Guided by the Graz-BCI paradigm, each participant performed 7 different mental tasks [1] and a rest class. For each possible mental task combination a 5x5 fold cross validation was computed to estimate classification accuracies: (i) Six separate common spatial pattern filters were trained on EEG data of second 4 to second 7 after the visual cue in a one vs. one class manner. (ii) We applied the first and the last two CSP projections and calculated 24 logarithmic bandpower features. (iii) A multiclass analytical shrinkage regularized linear discriminant analysis was trained using features located 2.5, 3.5 and 4.5 seconds after the visual cue. (iv) Filter and classification models were applied to the test data for performance evaluation.

Table 1: Best individual four task combination for six volunteers. Significanzlevel [2] was 30,5%.

participants	best task combination				mean acc [%]
S1	feet	mental subtraction	spatial navigation	auditory imagery	47,58
S2	hand	mental subtraction	spatial navigation	auditory imagery	47,86
S3	feet	hand	mental rotation	auditory imagery	**69,77**
S4	feet	word association	mental rotation	rest	37,18
S5	feet	hand	mental rotation	rest	50,32
End user 1	feet	hand	mental subtraction	rest	**65,79**

We successfully determined the most performant mental task combinations of six volunteers. Best combinations included at least one motor imagery and for four users also a brain teaser task (mental subtraction and word association as defined in Friedrich et al.). This work supports the findings of [1], namely that BCI performance can be improved by determining user-specific mental tasks.

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Short Biography

Karina Statthaler is an undergraduate student of biomedical engineering at Graz University of Technology. This abstract represents the main findings of her Bachelor thesis which is done within the GRAZ-BCI racing team. For her masters, she plans on specializing in Neural Engineering.

Open, Cheap, Non-Obtrusive and User-Oriented: Incorporating Ethics in Pervasive Assistive Technology

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Abstract

Assistive technology (AT) is reshaping the delivery of care and rehabilitation for older people as well as people with physical and/or cognitive disability. With the ageing of the global population and the erosion of the caregiver-patient ratio, the deployment of pervasive ATs designed to support independent living, rehabilitation, and interaction with the social environment opens the prospects of improving the quality of care, reducing caregiver burden, and empowering the elderly and disabled population [1]. However, the potential benefits of pervasive ATs risk to be tampered if ethical and psycho-social issues remain unaddressed2. Currently, the adoption of ATs among many population segments –e.g. dementia patients and older adults with disability- is still reportedly low as a consequence of an information gap in the cross-section of technology and healthcare [2,3]. Ethical research on assistive technology has largely focused on post-development evaluation of existing tools, with little engagement in the proactive incorporation of ethical factors early in the design of new ATs.

In this paper, we propose a collaborative ethical framework for the proactive integration of ethical factors into the design of future ATs. This framework articulates six main families of factors: (i) autonomy/independence, (ii) relationality, (iii) adaptiveness, (iv) usability, (v) privacy, and (vi) fair access. While designed to comprehensively encompass the entire AT spectrum, specific adaptations are proposed for each main AT type. These are illustrated through six major technological families: (i) powered mobility tools, (ii) exoskeletons, (iii) wearables, (iv) rehabilitation devices, (v) personal robotics and (vi) brain-computer interfaces. This framework aims at favoring interdisciplinary collaboration at the level of AT design, favoring translational healthcare technology, and helping maximize the social benefits of pervasive AT while preventing unintended consequences.

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Short Biography

Marcello Ienca, (MSc,/MA), studied Philosophy and Cognitive Science at the Humboldt University of Berlin and Biomedical Ethics at KU Leuven. He is currently a PhD candidate at the Institute of Biomedical Ethics, University of Basel and the Student/PostDoc Representative of the International Neuroethics Society (INS). His interdisciplinary PhD project (in collaboration with the geriatrics unit at Basel University Hospital) focuses on incorporating proactive ethical considerations into the design of assistive technologies. In 2015 he was awarded the Prize A.P. de Carvalho for Social Responsibility in Neuroscience from the University of Coimbra and the Sonia Lupien Award from the IRCM (Canada).

Powered Wheelchair for Cybathlon, RT-Mover Personal Mobility Type WA

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Abstract

We developed some personal mobility vehicles in the RT-Mover series [1], [2]. Their concept centers on efficient wheel transport over paved surfaces and other gentle terrain, but also envisions a need to negotiate rough terrain. That is why there are two major mechanisms for their movement: a wheel mechanism and a leg mechanism. Better energy efficiency and higher speed capability than crawler or leg mechanisms are the strength of the wheel mechanism, and high mobility performance on rough terrain is the strength of leg mechanism. The concept of the gait algorithm is the following: “RT-Mover Gait Algorithm” = “Wheel mode, normally” + “Leg motion, if necessary”.

Previously proposed RT-Movers face difficulty in completing tasks of Cybathlon. The problem is that there is no capability for climbing up and down three-step stairs. The reason for this is that the body tilts at maximum almost 40 degrees when climbing stairs. In addition to that, there is no space to adjust supporting wheels in order to provide sufficient static stability. Previous research outcomes cannot deal with this situation [2]. Another problem is that it is difficult to reach a table and a door. The reason is that wheel and body parts of the device interfere with that motion, because a pilot's seat is located at the center of the device.

We have developed a brand-new machine for Cybathlon, named RT-Mover PType WA. Major mechanical improvements compared with previous models are as follows. The slider to move the seat forward/backward is added in order to expand the movable area of the seat, and the mechanism, body length, width, gear ratio and so on are modified for tasks.

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Short Biography

He received Ph.D. from Tohoku University, Japan through two-year research. He entered Graduate School to get master’s degree by grade-skipping. He worked at East Japan Railway Company from 1997 to 2003. Then, he worked at Chiba Institute of Technology as a researcher, lecturer and associate professor. During the term of associate professor, he did his research at University of California, Berkeley, as a visiting scholar. Now he is a professor at Wakayama University, Japan. He developed one of demonstration robots at EXPO 2005. He was a recipient of 2012 Best Paper Award of Japan Society for Design Engineering.

POSTERS

Name* - author presenting
<u>Name</u> - author attending

LEG PROSTHETICS

Powered 2-DOF Ankle-Foot Prosthesis for Agile Gait

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Abstract

In the past decade, several powered ankle-foot prostheses were developed by various research groups. They were designed to improve sagittal plane mobility by focusing on control of the ankle in one degree of freedom (DOF); that is, each seeks to regulate plantarflexion and dorsiflexion of the robotic ankle. Activities of daily living however, include gait scenarios that require agility and maneuverability, such as turning, traversing slopes, and adapting to uneven terrain profiles. These activities require ankle action in both the frontal and sagittal planes [1]. The authors developed a 2-DOF cable-driven powered prosthesis with controllable Dorsiflexion-Plantarflexion (DP) and Inversion-Eversion (IE) (Figure 1) [2]. This prototype uses Bowden cables allowing the placement of the motors and gearboxes away from the distal parts of the limb and near the center of gravity of the user, reducing the metabolic cost. In addition, they allow for flexibility on the customization of the prosthesis, especially when long residual limb would limit the amount of space available for the active components. The proposed design offers versatility to the users by allowing them to switch between powered and non-powered states by physically disconnecting the actuation (DC motors, Bowden cables, and battery) from the prosthesis. Therefore, the device can be used as a passive or active device based on their daily activity. The results of the preliminary evaluations show that the prosthesis can closely follow the recorded human ankle trajectories, as shown in Figure 2 [2].

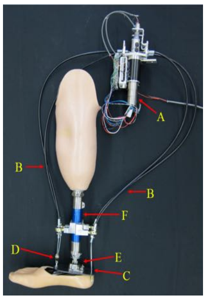

Fig. 1: 2-DOF ankle-foot

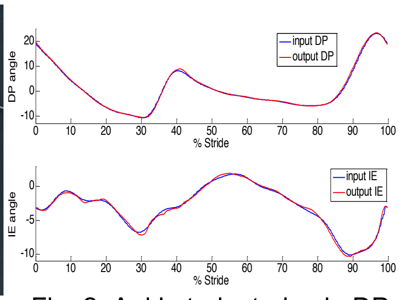

Fig. 2: Ankle trajectories in DP and IE directions closely follow the human ankle rotations

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Short Biography

Mohammad Rastgaar received his Ph.D. degree in mechanical engineering from Virginia Tech, Blacksburg, VA, USA (2008). He was a postdoctoral associate at the Newman Laboratory for Biomechanics and Human Rehabilitation at the Massachusetts Institute of Technology, Cambridge, MA, USA (2008–2010), before joining Michigan Tech, where he is an associate professor of mechanical engineering and the director of the Human-Interactive Robotics Lab (HIRoLab). His present research focuses on advancing the maneuverability in ankle–foot robotic prostheses and lower extremity assistive robots by characterizing the agility in the human gait. Dr. Rastgaar is a recipient of 2014 NSF CAREER Award.

Ankle-Foot Coupling using Rubber Cushion to Allow Multi-Axis Movement for SACH Foot

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Abstract

Amputees in some developing countries, mainly caused by anti-personnel mines, eagerly demand a low-cost but highly-effective prosthesis to improve the quality of life. Current widely-available prosthesis, the solid ankle cushion heel (SACH) foot, is very simple with a solid ankle that allows little movement of the foot. We proposed a novel ankle-foot coupling called the Multi-Axis Rubber Coupling (MARC) to add an ankle joint function to the traditional SACH foot. The MARC is composed of a ball joint and a rubber cushion in order to facilitate multi-axial movements necessary for walking. The MARC is simple, i.e., composed of only two parts and easy to manufacture locally because the materials are locally available and able to be processed. Thus, it is inexpensive and suitable for developing countries. Based on preliminary experiments, we designed the cushion with optimal holes to control multi-axial elastic properties during walking. Since the rubber cushion stores and releases walking energy properly, the SACH foot can stand on ground more stably. We evaluated a basic MARC prototype using motion analysis of walking on the flat ground. The ankle joint angle and the ground reaction force were measured among three conditions; barefoot walking, the gait produced by the SACH foot alone, and the gate produced by the SACH foot with the MARC. The MARC using as an adaptor for SACH foot closely replicated the inversion-eversion and planter flexion-dorsiflexion movements of barefoot walking. The result of the ground reaction force demonstrated that the MARC absorbs impacts on heel contact and maximum moment of the z-axis in the stance phase is the same degree as barefoot walking. To sum up, optimal holes in the rubber cushion of the MARC can control the multi-axial ankle joint movements with the SACH foot, and thus contributes to stable walking with high efficiency.

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Short Biography

Naomi Okamura is a Ph.D candidate at the Graduate School of Creative Science and Engineering and the Graduate Program for Embodiment Informatics, Waseda University. She received the B.E. and M.E degree from Waseda University in 2014 and 2016, respectively. Her main research interests are muscle function and sports instruments for people with physical disabilities. She received the 2nd place award in the LIMBS Summit Design Competition 2015 with her ankle-foot coupling. She is a student member of IEEE Engineering in Medicine and Biology Society, and European College of Sport Science.

A novel approach for a touch-sensitive prosthetic leg

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Abstract

Under normal conditions, sensorimotor control is based on multiple intertwined feedback loops between the upper and lower extremities on the one end, and the central nervous system on the other end. With an amputation, this feedback loop is suddenly interrupted, and many movements can only be executed in a feed-forward mode.

In order to restore this feedback loop at least partially, we have combined vibration feedback on the remaining stump with a re-routing of the corresponding sensory nerves. With this approach, we have demonstrated for the first time the feasibility of a sensory feedback device for lower extremity prostheses that is based on the principle of targeted sensory re-innervation. The device has been accepted very well by the patient, and has led to a significant increase in his quality of life. The surgery has successfully eliminated the pain caused by the neuroma, and no incidents of pain were elicited by the re-innervation of the dermatome. The observed association of the re-innervated skin areas with the locations on the foot innervated by the activated cutaneous foot nerve has remained somewhat behind our expectations, and was at the time of writing still incomplete.

Our findings confirm the results by other groups [1], that the availability of sensory feedback can have a positive effect on gait dynamics, and that it is very well received by the patients. Once the subject perceives the vibrations reproducibly as stimulation of the corresponding part of the foot, we plan to conduct more extensive gait analyses to quantify the effect of this sensory feedback on postural stability and gait dynamics.

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Short Biography

Stefan Salzmann as obtained his Master Degree for Biomedical Engineering from the University of Applied Sciences in Linz, Austria, in 2014. For his master thesis he worked on the gait detection of trans-femoral amputees through inertial sensors and EMG with Össur in Reykjavik, Iceland. Since then he has been employed as research scientist at the Univ. of Applied Sciences in Linz. In 2015 he started working on his PhD, with the Vienna University of Technology, on sensory feedback through targeted nerve stimulation.

The ETH Knee Perturbator: Quantifying joint impedance for assistive devices

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Abstract

Human locomotion is a complex activity that requires precise coordination between the internal and external forces acting on the legs [1]. An increased understanding of how the neuromechanical properties of the knee (e.g. the impedance) are modulated to regulate these forces may lead to lower-limb prosthesis and orthosis designs and control strategies with enhanced comfort, safety, and energetic efficiency under both undisturbed and disturbed conditions.

Perturbation-based system identification is an experimental technique for identifying such properties, but requires the development of highly specialized tools. The ETH Knee Perturbator is a novel wearable actuated exoskeleton that can apply position perturbations to the knee during gait, with minimal effects on baseline gait patterns [2]. When coupled with measurements of interaction torque, muscle activity, and multi-joint kinematics, such a device can be used to compute the joint's mechanical impedance throughout the gait cycle and during different walking conditions.

Bench-top tests indicate that the device is capable of identifying a passive second-order system. Pilot tests on human subjects indicate that the ETH Knee Perturbator can apply well-timed and reproducible position perturbations at different points during the stance and swing phases of gait. A method is proposed for using the device to compute the intrinsic and passive components of impedance during gait.

With this new tool, we aim to improve existing models of locomotor control. This information can inform the development of the next generation of prosthetic and orthotic devices, and lead to new paradigms for the diagnosis and rehabilitation of gait impairments.

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Short Biography

Michael R. Tucker received the B.Sc. and M.Sc. degrees in mechanical engineering from Clarkson University in Potsdam, New York and the Ph.D. in mechanical engineering and robotics from ETH Zurich, Zurich, Switzerland.

His research interests include the design and control of wearable robotic systems, robot-assisted rehabilitation, physical human-robot interaction, dynamic system modeling, and zymurgy.

Towards Seamless Integration of Active Assistive Devices into the User's Body Schema

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Abstract

Active assistive devices for lower limbs like prostheses or ortheses support the user by providing additional torque to restore and improve locomotion abilities. In order to ultimately achieve their seamless integration into the user's experience of everyday routine locomotion, they must provide a customized, familiar and predictable behavior that autonomously supports versatile locomotions, which describes formidable challenges for research and development. Moreover from a psychological perspective, the user might regard the device as part of his or her own body, which would mean a successful integration into the body schema. We suggest an integrated investigation of related research questions from psychology, biomechanics, and engineering from the beginning of any development of active assistive devices. Several experimental platforms have been developed by an interdisciplinary group of researchers. They serve as novel research methodologies towards seamless integration of active assistive devices into the user's body schema. One of the objectives is to investigate how humans incorporate visual, tactile and proprioceptive perception and how to utilize this knowledge in engineering design. The Int2Bot platform is a robot testbed with the shape of a human leg that mimics squatting movements of subjects in order to investigate rubber hand illusion paradigm transferred to lower limbs. Another setup uses a head-mounted display and a treadmill to give subjects the experience of walking through a virtual park. Measures like proprioceptive drift, feeling of presence and agency, body ownership, and location are assessed. Both platforms contribute to a novel prosthesis-user-in-the-loop concept for a holistic, mechanical and perceptive simulation of human gait with different prosthetic concepts. It aims at a user-centered design of assistive devices by utilizing user experience and assessment. First results indicate that optimized variable stiffness actuation and specific visual and auditory stimuli improve the user's experience.

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Short Biography

Janis Wojtusch studied electrical engineering with a focus on mechatronics and control design at TU Darmstadt, Germany, and Nihon University, Japan, and graduated in 2011. Currently, he is a research associate and doctoral candidate at TU Darmstadt.

ARM PROSTHETICS

The Robotic-SixthFinger: a Wearable Robotic Compensatory Tool for Grasp Compensation in Chronic Stroke Patients

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Abstract
A novel solution to compensate hand grasping abilities is proposed for chronic stroke patients. The goal is to provide the patients with a wearable robotic extra-finger that can be used as grasp compensatory tool for hemiparetic upper limbs to compensate for grasping in many Activities of Daily Living (ADL). The robotic device and the paretic limb act like the two parts of a gripper, cooperatively holding an object. The device is intrinsically-compliant, modular, underactuated and cable driven. It can be wrapped as bracelet to reduce the encumbrance when not being used. The motion of the robotic device can be controlled by using the eCap, an Electromyography (EMG) interface embedded in a cap. The user can control the device through contracting the frontalis muscle by moving his or her eyebrows upwards. The light weight and the complete wireless connection with the EMG interface guarantee a high portability and wearability. The performance characteristics of the device is measured through experimental set up and the shape adaptability was confirmed by grasping various objects with different shapes. We tested the device through qualitative experiments based on ADL involving six chronic stroke patients. The prototype successfully enabled the patients to complete various bi-manual tasks. After the experiments, we asked the patients about their satisfaction and possible concern related to the proposed grasp compensatory robotic device. Results show that proposed robotic device improves the autonomy of patients in ADL and allow them to complete tasks which were previously impossible to perform. Currently we are investigating the possibilities to introduce the device early in rehabilitation phase for the patients who are seeking for the improvements in their skills.

The readers are encouraged to watch the video, here. http://tinyurl.com/hsxd58m

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Short Biography
Irfan Hussain received his 2nd Level Master degree in Automatica and Control Tecnologies from Politecnico Di Torino, Italy. He got Master degree in Mechatonics Engineering from National University of Sciences and Technology, Pakistan. From 2012 to 2013, he worked as research assistant in Gyeongsang National University, South Korea. From 2008 to 2011, he worked as assistant manager engineering in Trojans Pakistan. He is currently a PhD candidate at the Department of Information Engineering of the University of Siena. His research interests include bio-robotics, mechatonics and haptics.

From NinaPro to MeganePro towards the natural control of myoelectric prosthetic hands

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Abstract

The loss of an upper limb strongly affects capabilities and quality of life of a person. Dexterous robotic hand prostheses controlled by surface electromyography (sEMG) can significantly improve the condition of hand amputees. However, despite the excellent mechanical capability of the devices and a usually long training period, their control is currently limited and often not sufficiently natural. Remarkable improvements in myoelectric prosthetic control were reached applying machine learning and pattern recognition techniques. In 2014, the NinaPro project released the biggest publicly available database on kinematics and sEMG of hand movements. The aim is to improve the myoelectric hand prosthetic control by creating a benchmark database, so worldwide research groups can develop, test and compare solutions. The NinaPro database contains data of several repetitions of 50 different hand movements (including grasps), recorded from 67 intact and 11 transradially amputated subjects. The set of movements is based on the existing literature and the acquisition protocol is easily reproducible. The activity of the extrinsic hand remnant muscles, the kinematics and dynamics of the hand were measured. Several signal features and classification methods were used to perform movement classification using the data. The results encourage the use of NinaPro data and machine learning methods to increase naturalness and robustness of myoelectric control. Nevertheless, the improvement achievable with only sEMG information seems insufficient for reaching a fully natural control for all needs in daily life. High classification accuracy was obtained adding accelerometer information. This is consistent with recent studies: movement classification can be increased using additional sources of information. An increased recognition rate was also observed in subjects experiencing vivid phantom limb sensation. The MeganePro project aims at improving the control of robotic prosthetic hands via multisensor integration and considering the interplay between reaching, phantom hand sensations and eye-hand coordination in upper limb amputees.

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Short Biography

Cognolato Matteo was born in Padova (Italy) in 1989. He studied Biomedical Engineering and Bioengineering at the University of Padova, achieving the master degree in 2015. Since January 2016 he has been working at the HES-SO Valais-Wallis on the MeganePro project in the eHealth unit coordinated by Prof. Henning Müller.

Pilot Study of Using Force MyoGraphy for Natural Control of Upper-Extremity Prostheses

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Abstract

Force Myography (FMG) has demonstrated a promising alternative to conventional sensing techniques to naturally control a robotic upper extremity prostheses. It is based on pressure sensors and has the potential to provide the highest accuracy in prediction, stability over time, wearability, simplicity in socket embedding, and affordability of cost [1]. Although, applicability of this technique to types of amputation and use in a clinical settings has not been widely investigated.

We present an experimental case study aimed to naturally control a bionic hand with FMG by a transradial amputated test subject. The prosthetic configuration simulates a real case scenario, where all the pressure sensors and processing capabilities are embedded inside a prosthetic socket. Both static position and dynamic motions' data analysis has been performed, showing that the former does not represent the best indicator of prosthesis performances even in a constrained laboratory environment. Different techniques to assess the effect of the limb position and improve dynamic classification accuracies are investigated: use of inertial measurement units, use of advanced dynamic protocols during the training phase, and a socket weight compensation technique. The proposed prosthetic configuration used in conjunction of FMG allowed classifying 6 hand grips with an accuracy of 82.2% and 75.5% for the static and dynamic case respectively. An extended configuration, containing 11 grips, showed an interesting 72.8% accuracy in the static case only.

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Short Biography

In November of 2014, Lukas-Karim Merhi (MASc.), joined the MENRVA Research Group under the direction of Dr. Carlo Menon. Lukas' primary role at MENRVA involves management of the Force Myography research group that specializes in smart wearable technology for biomedical applications. The Cybathlon presented an opportunity to showcase the potential of the FMG technology for natural control of robotic prosthesis. His goal is to make it as intuitive as possible for individuals with amputations to control their prosthesis.

Vibrotactile Sensory Feedback System for Upper Limb Amputees

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Abstract

Although during the last decades, the dexterity of active myoelectric-controlled prosthesis has made significant progress, there is still no or very limited sensory feedback in the commercial prosthesis. Sensory feedback is important for active prosthesis users because it can not only increase grasping performance but also introduce an embodiment feeling to the amputee user. There has been some research focused on providing non-invasive sensory feedback to amputees because non-invasive feedback has higher user acceptance, compared to invasive ones. For non-invasive sensory feedback, vibrotactile was widely used for its relative small size, light weight, and low power consumption.

A sensory feedback system were designed, incorporating pressure sensors, wireless communication modules, and a non-invasive haptic display. The flexible skin made of TangoBlack was attached to the robotic hand. Five miniaturized pressure sensors were embedded in the skin, one on each finger. The sensed pressure data were transmitted by custom-designed wireless communication modules to the haptic display control module. The sensory feedback was delivered by five pancake-shaped eccentric rotating mass (ERM) embedded in the socket. The distribution of ERMs corresponds to the shape of the phantom fingers. The vibrational amplitude was proportional to the sensed pressure. This system was tested on one amputee with phantom map. The finger identification test and handling fragile objects task were conducted. For the first one, the amputee was blind folded and wearing a headphone to eliminate visual and audio cues. The experimenter pressed the robotic finger and the subject answered which finger he felt being touched. The amputee could answer all the fingers correctly for all the trials. Then the subject was asked to grasp eggs and move them to a small basket. The amputee could move all the eggs without dropping or breaking any. There were no detectable interference between the feedback and EMG sensors.

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Short Biography

Huaiqi Huang is a PhD student from EPFL and BFH. She got her M.Sci from Department of Microelectronics and Microsystems in EPFL. Her current research interests include modeling and designing sensory feedback system for upper limb amputees, EMG signal processing, and hand phantom map study.

Usability Evaluation of a Soft Hand Exoskeleton for Assistance and Rehabilitation in Stroke Survivors

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Abstract

Approximately two-thirds of stroke survivors suffer from persistent hand impairment. The inability to use the affected hand may limit recovery or even result in a decline due to learned non-use. Wearable robotic devices are a promising technology to enable the use of the impaired limb in activities of daily living, thereby enhancing rehabilitative training after stroke.

In collaboration with the groups of Prof. Jumpei Arata at Kyushu University, Japan, and Prof. Gregory S. Fischer at Worcester Polytechnic Institute, USA, a compact and lightweight hand exoskeleton with remote actuation has been developed [1]. The current prototype is fully wearable (hand weight 115g, total weight 867g) and assists flexion and extension of the four fingers. It presents a unique compliant 3-layered spring actuation mechanism [2], ensuring safe operation and inherent adaptation to the shape of grasped objects.

In a usability study the potential for assistance and rehabilitation of the hand exoskeleton was evaluated and design features that need to be further optimized were identified. 3 chronic stroke patients were recruited in collaboration with the University Hospital Zurich. Participants were asked to complete subparts of the Action Research Arm Test (ARAT, a standardized clinical assessment for grasping function) while wearing the hand exoskeleton. Participants then filled in a questionnaire based on the standardized System Usability Scale (SUS) complemented with additional questions of interest.

First positive results from the usability study highlighted that the generated motion is perceived as comfortable, the uncovered palmar side of the hand allows for natural somatosensory feedback during object manipulation and that passive finger ab/adduction was highly appreciated. Potential for improvement lies especially in the thumb module of the exoskeleton (further degrees of freedom required), the fixation on the fingers and the maximum output force (currently limited to 5 N per finger).

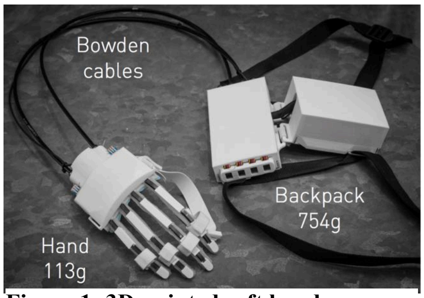

Figure 1: 3D-printed soft hand exoskeleton. Motors, electronics and battery are placed in the backpack.

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Short Biography

Tobias Bützer received his MSc degree in mechanical engineering from ETH Zurich in 2015. He started his PhD at the RELab in April 2015 and focuses on hand and upper limb rehabilitation after stroke.

TACT-HAND: Improving control of prosthetic hands using tactile sensors and realistic machine learning

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Abstract

Recent advances in hand prostheses have made significant progress, but have been slowed down by awkward user interfaces (e.g., selecting poses on a smartphone), or non-reliable control from noisy sensors. The TACT-HAND project, started in 2016, aims at providing hand amputees with improved dexterous capabilities. The project bases its development on the i-LIMB Ultra prosthetic hand by Touch Bionics. To counter the well-known drawbacks of surface electromyography (sEMG), historically the main modality to infer hand movement intent, TACT-HAND proposes to exploit tactile sensing as a complementary source of information, in the form of a compact bracelet with 320 sensors [1]. Such source has surprisingly been neglected in prosthetics, although it can be exploited to acquire movement intent at low cost, low power consumption and simple usability. We present an approach treating the control of prosthetics as a regression problem fusing information from the tactile array and the sEMG signals. For this purpose, we extend Gaussian mixture regression (GMR) to online subspace clustering techniques working with high dimensional data. The approach concords with the acknowledged importance of representing and exploiting synergies in artificial hands, and of reducing dimensionality jointly in input and output spaces instead of separately. The approach is then extended to the tactile array by exploiting recent advances in tensor methods, aiming at extending conventional linear algebra to data of higher dimensions for statistical analysis and compression, by processing data jointly in spatial and spectral ways, instead of flattening the data in a matrix form. The aim is to provide users with more robust and flexible control of their prosthetics, with transparent and user-friendly online adaptation.

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Short Biography

Noémie Jaquier is a Research Assistant with the Robot Learning & Interaction Group (http://www.idiap.ch/rli/) at the Idiap Research Institute in Martigny, Switzerland. She holds a Master in Robotics and Autonomous Systems and a Minor in Computational Neurosciences from EPFL. Her research interests cover humanoid manipulations, human-robot interaction and machine learning.

Distribution of the Muscle Bulge of an Upper limb Amputee for Joint Angle Estimation

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Abstract

The powered prosthetic has been studied and developed over a long time. In those studies, it is not easy to detect the intention of the extent of motion such as joint angle, because an electromyogram which is commercially used is noisy and varied. To solve this problem, we proposed the muscle bulge movement on the forearm skin surface as a new bio-signal for estimating the extent of motion. The muscle bulge means the deformation of the skin caused by the muscle contraction. In a previous study, we found the muscle bulge movement is feasible to estimate the intended wrist joint angle for intact subjects [1]. Thus, in the present paper, we validate the feasibility of our method for an amputee. We recorded the muscle bulge movement as the distribution on skin surface using a tactile sensor composed of a sponge with 48 distance sensors. As a result, we found following two results from an experiment with one amputee with his right forearm amputated below the elbow and three intact subjects. First, the distribution of the muscle bulge for the amputee was changed same as for the intact subjects, it corresponded to the extent of the intended wrist joint angle. Second, from the result of the angle estimation, it is possible to estimate the intended angle for an amputee as for the intact subjects. The error between the estimated and measured angle for the amputee was slightly larger than that of intact subjects. It is because, for an amputee, measured muscle was contract individually in contrast to intact people’s antagonistic muscle. Therefore, we should apply the muscle characteristics to our estimation algorithm. Finally, it is feasible to use the distribution of the muscle bulge on the forearm skin surface of an upper limb amputee for estimating the intended wrist joint angle.

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Short Biography

Akira Kato received the BS and MS in Mechanical Engineering in 2014 and 2016, respectively, from Waseda University, Japan. Currently, he is a Ph.D. candidate at the Graduate School of Science and Engineering, Waseda University, and in the graduate program for Embodiment Informatics. His research interests include the control of wearable robot especially powered prosthesis, bio-signal processing, motion intention recognition. He is a student member of IEEE Engineering in Medicine and Biology Society (EMBS), and the Japan Society of Mechanical Engineers (JSME).

Tactile Display on the Remaining Hand for Unilateral Hand Amputees

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Abstract

Humans rely profoundly on tactile feedback from fingertips to interact with the environment, whereas hand prostheses used in clinics provide no tactile feedback to amputees. In this study we demonstrate the feasibility to use a tactile display glove that can be worn by a unilateral hand amputee on his/her remaining healthy hand to display tactile feedback from a hand prosthesis. The main benefit of this device is that users could easily distinguish the feedback for each finger, even without training. The claimed advantage is supported by experiments with healthy subjects. Our experiments on five healthy subjects showed that displaying tactile information on the back of fingers is feasible and intuitive. The displayed information (finger localization and contact force level) can be readily recognized even without training. The response time of subjects reduced and demonstrated a learning effect during the experiments.

We expect that this tactile display method works well with unilateral hand amputees. When a hand amputee subject manipulates objects with a hand prosthesis, the tactile events are generated actively. As a result, the amputee has a prediction of the tactile feedback before it happens. Therefore, an actively generated tactile event is probably even easier to recognize than a passive one. This tactile feedback approach may lead to the development of effective and affordable tactile display devices that provide tactile feedback for individual fingertip of hand prostheses.

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Short Biography

Tao Li received his Ph.D. degree in Informatics from the University of Zurich in 2014. He currently holds a scientific associate position at the Institute of Human-Centered Engineering, Bern University of Applied Sciences (BFH). He leads the BFH team to develop non-invasive tactile feedback devices and to implement system integration for the Nano-Tera RTD WiseSkin project. His research interests include assistive robotics, haptic feedback interfaces, and machine learning.

Personalized fingers design with silicone rubber texture fingertips for increased grip in transmetacarpal powered hand prostheses

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Laboratorio de Investigación en Biomecánica y Robótica Aplicada (LIBRA)

Abstract

There is a lack of powered prosthetics for transmetacarpal and congenital amputees with partial hand loss, mostly because there is little space available for actuators and electronics. Thus, body powered prostheses are the common solution for these cases and many open-source designs can be found, such as the Raptor Hand prosthesis, which can be used by both transmetacarpal and congenital amputees, and flexes the fingers with a tendon mechanism powered by the user's wrist. Its main disadvantage is that grasping requires high forces on the wrist and causes fatigue to the user. This issue could be addressed with myoelectric control of powered fingers. State-of-the-art micromotors allow us to design for the available volume.

Another important limitation of active upper limb prosthetics is the size standardization, which results in a noticeable difference between the user's prosthesis and the healthy hand. The need of customization of fingers and palm design is achieved with parametric modeling and 3D printing for rapid prototyping. A four-bar linkage mechanism for the fingers allows us to modify the length of the links or phalanges according to the user specific anthropometric data with no significant impact on grip force and speed.

Additionally, to increase the actual force that the prosthesis can exert on grabbed objects, it is essential to take into account its friction coefficient, which depends on the material. Commercial powered prosthesis, such as the i-limb and Bebionic, have powerful micromotors with torques comparable to the exerted in human hand articulations [1]. However, they lack the compliant texture of human skin and fingertips ridges which are significant factors for grasp effectiveness. These ridges coefficient of friction is comparable to that of elastomers [2], and in this work they are designed for the customizable fingers using a bio-inspired texture based on silicone rubber.

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Short Biography

Renato Mio received the bachelor degree in Mechatronic Engineering from the Pontifical Catholic University of Peru with an Academic Excellence Scholarship. He has participated in assistive robotic projects, and his undergraduate thesis involved upper limb exoskeleton design. Subsequent projects in which he worked include the control of lower limb powered exoskeleton and upper limb prosthetics design.

Towards strong prosthetic machine intelligence

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[2] RLAI Laboratory, Dept. Computing Science, University of Alberta, Edmonton, AB, Canada

Abstract

Intelligence has been described as the most powerful phenomenon in the universe. Humans leverage intelligence as they plan, coordinate, execute, and interpret the movement of their body during interactions with the world around them. Sensorimotor components of human intelligence include the ability to acquire diverse information via the peripheral nervous system, process that information, and use it to perform actions. When a limb is lost through injury or illness, aspects of that natural sensorimotor intelligence are diminished. In the case of upper-limb amputation, new prosthetic technologies aim to potentially restore a full range of dexterous movements and the resulting sensations, thereby replacing lost sensorimotor intelligence. However, as the complexity of new prostheses grows, and the information both from the prosthesis and from the user increases in volume and diversity, synthesizing information for control and feedback becomes a significant bottleneck to restoring upper-limb function [1]. Prosthetic devices need to take an active role in leveraging information to support their users. We propose that increased intelligence on the part of prostheses will play a crucial role in restoring and someday reaching far past the abilities lost due to amputation. With this view in mind, we present a concrete example of how real-time machine learning allows users to personalize and improve the control of their upper-limb prostheses. Our experiments with adaptive and autonomous control switching methods show statistically significant gains in terms of task completion time and switching burden for both amputee and non-amputee participants. We further demonstrate how massively parallel prediction-learning algorithms can dramatically expand the machine intelligence of an advanced, dexterous prosthetic limb. This work contributes novel preliminary evidence that advanced prosthetic devices can and should be thought of as intelligent systems, and presents a first roadmap for pursuing strong machine intelligence within prosthetic devices.

References

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Short Biography

Dr. Patrick M. Pilarski is a Canada Research Chair in Machine Intelligence for Rehabilitation, and an assistant professor in the Division of Physical Medicine and Rehabilitation, Department of Medicine, at the University of Alberta. Dr. Pilarski leads an interdisciplinary initiative focused on the use of machine intelligence and reinforcement learning to expand the abilities of individuals with amputations. He is the author of more than 50 peer-reviewed articles and is supported by national and international research grants.

Finger Force Estimation based on Hill's Model

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Abstract

To this day controllability in upper limb myoelectric prostheses presents a challenge to their users. Gesture recognition had present an improvement to previous approaches however this control scheme only allows the use to perform some discrete gestures, while the exerted forces to manipulate objects, are controlled entirely by the prosthesis, limiting the interaction of the user and the dexterity of the hand. In the last years independent finger force estimation have gain great interest, in order to solve this two issues. In the literate, machine learning algorithms with multiple EMG channels have been the most popular approach. Even though, some of these works have shown high correlation values, machine learning relay on arbitrary parameters that not exploit physiological information, such muscle synergies, muscle force models, etc. Only a few have tried using this information, but their success is modest. This work presents a novel approach for finger force estimation, based on the Hill-type model. We pose that the exerted force at the fingertips of the fingers, are a linear mixture of the forces generated by the muscles of the forearm. The training consists of two algorithms; the first finds the crosstalk matrix of the activity of the muscles, using the principle of muscle synergies. The second finds the parameters of the finger force model, which are the Hill's model parameters and the mixing matrix of the muscle force weights. Ones the training parameters are found, the muscles activities are estimated, then the muscles force, and finally the finger force using the mixing matrix. The prediction model, presents a high coefficient of determination ($R^2 = 0.85$), which is comparable with previous works. Even though it still does not exceed the state of the art algorithms, this work shows the potential of the posed model in finger force estimation.

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[2] A. Holobar and D. Farina. (2014). Blind source identification from the multichannel surface. Electromyogram Physiological Measurement, 35(7):R143.

Short Biography

I'm a research assistant in the laboratory LIBRA in the Pontificia Universidad Católica del Perú (PUCP), finishing my master thesis program in DSP. My main interests are EMG signal processing for finger/hand force prediction and hand gesture prediction for active hand prosthesis and EMG acquisition and conditioning hardware development. At the present time, I'm working as part of a team developing a 6 DoFs myoelectric hand, with independent finger force control and biofeedback loop. I'm designing capacitive sensors for EMG acquisition and conditioning and I will implement a real time finger force estimation algorithm for the control of the prosthesis.

Prosthetic arm design: iLimb Revolution versus customized body powered arm in a work environment combining bodily exertion, wide temperature ranges, wide body motion ranges, heavy workload and subtle grips

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[2] Balgrist Tec, Zurich, Switzerland

Abstract

Prosthetic arm research focuses on "bionic" but not body powered arms. Forensic medicine is a demanding environment, also physically, also for non-disabled people, on both large and small metric scales (distances, weights, size). The first author (WS) is in a unique position to provide direct comparison of a "bionic" myoelectric iLimb Revolution (Touch Bionics) and a customized body powered arm (CBPA). The CBPA contains a number of new developments initiated or developed by the user (WS) whereas the second author (DE) assembled the prostheses: (1) quick lock steel wrist unit developed after WS' specifications in cooperation with a manufacturer specializing in connectors; (2) cable mount modified to allow for complex rather than unilateral curved force distribution initiated and developed by WS; (3) avoiding nerve compression typical for conventional figure 9 harnesses (F9H) with a cast shape modeled shoulder anchor that also decreases extension to open gripper from around 12-15 cm (F9H) to around 5 cm, initiated by WS, developed by both authors; (4) suspension with usual complications (congestion or friction) on the stump was improved by employing a soft double layer with a pinlocked (Ossur Icelock) liner (Ohio Willowwood) and tube gauze (Molnlycke), initiated by DE. The iLimb is mounted on an epoxy socket; a lanyard fixed liner (Ohio Willowwood) contains magnetic electrodes (Liberating Technologies). Results: side by side comparison with wearing these devices for 12-14 hours a day for two weeks under realistic (real) work conditions shows that the CBPA provides reliable, comfortable, effective, powerful as well as subtle service with minimal maintenance; most notably, grip reliability, grip dosage, grip performance, center of balance, component wear down, sweat / temperature independence and skin state are good. This is relevant as Swiss disability insurance specifically supports prostheses that enable actual work integration.

Short Biography

Wolf Schweitzer is a Swiss forensic pathologist who makes use of his prosthetic arm devices for daily work. The job contains aspects not even non-disabled people can master all too easily (temperature ranges outdoors -10 to 35 deg C; wearing full protective gear; handling, undressing, turning and moving of bodies in the full human adult weight range with the specific requirement to not introduce any injuries; detailed grip work in context of instrument and evidence collection usage including forceps, scalpel, dissection, syringes).

Multi-Modal controlled Prosthetic Arm

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Abstract

Conventional control of arm prostheses for above elbow amputees requires the systematic control of each joint in turn to attain the desired motion. The result is an action which is not intuitive to the user. We are therefore using a multi-modal approach combining eye movements with muscle signals. In this project a robotic arm e.g. for an above-elbow amputee has been designed with 3 degrees of freedom (DOF): flexion and extension of the elbow, wrist rotation and shoulder control. Eye movements provide a high resolution 3D cursor that can be used to target the end-point of the movement by moving the arm towards the case target and executing the movement controlled by MMG commands. The initiation of the device's movement is triggered by the measurement of long-term stable mechanomyographic (MMG) signals [4,5] from the muscles in the user's remaining stump. In order to improve the accuracy of the prosthesis the system utilizes the gaze vector to locate the users intended target object within the 3 dimensional space. To detect the gaze vector position, a wearable, video-based, eye tracker is utilized, operated at a sampling rate of 100Hz. Two eye-tracking cameras, focused on the user's eyes record their movements using non-collimated infrared light to create corneal reflections. Gaze vectors are calculated between the pupil center and the reflection to assess gaze direction [3]. Movement of the head and remaining stump are monitored using accelerometers and gyroscopes providing additional inputs to the control algorithm to compensate for voluntary movements. The initiation of movement is provided by MMG signals from the stump, real time processing then determines the end location of the arm using continuous gaze vector and head pose estimations. Inverse kinematics are then utilized to provide control inputs for the drive motors. The calculated angles and parameters are fed as inputs to the microprocessor, located within the prosthetic arm, to perform motor rotations. Thereafter, the robotic arm moves towards the desired end point. The project demonstrates that the incorporation of several low-cost technologies can augment the use of prosthetic hands for above elbow amputees, providing a more intuitive action. This multi-sensor approach enables enhanced user intention decoding and holds a great potential regarding embodiment of prosthetics and simplification of human machine interaction.

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EXOSKELETONS

AUTONOMYO: an assistive powered leg exoskeleton without crutches?

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Abstract

Lower limb exoskeletons are promising solutions for the support and enhancement of mobility among the wide variety of people with gait disorders. However, many challenges remain for a widespread use of the technology. Devices on the market focus mainly on Spinal Cord Injury (SCI) patients, while the population suffering from gait disorders (unable to walk more than 400m) is about 60 times larger based on the National Health Interview Survey from 2012 in the United States. Elderly people and people suffering from neurological disorders such as post-stroke, multiple sclerosis or myopathy constitute large population segments with important gait disorders. Specific exoskeletons for all these cases will have to be developed, as the needs are quite different than those of SCI patients. First, different levels of residual capacity both physically and neurologically, have to be accounted for. The main issue may not be verticalization and mobilization, but balance control and performances augmentation (walking speed and endurance). Second, muscle disorders are not necessarily localized only at the lower or the upper limbs. The use of external support such as crutches or walkers are thus not an option in many cases. The challenge addressed here is to design an assistive exoskeleton providing stability (balance control) while improving walking performance. A novel exoskeleton design is proposed. It is composed of three motorized degrees of freedom per leg: the knee flexion/extension, the hip flexion/extension and the hip abduction/adduction. The device being underactuated compared to a human leg (with seven active degrees of freedom), a dynamic balance control strategy has been adopted. In order to improve the interaction between the wearer and his exoskeleton the aspects of back-drivability of the joint transmissions have also been addressed.

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Short Biography

Amalric Ortlieb obtained his Bachelor (2009) and Master (2012) degree in Mechanical Engineering with a major in Mechatronics and a minor in Biomechanics from the Ecole Polytechnique Fédérale de Lausanne, Switzerland. He then joined the Laboratory of Robotic Systems as a PhD student under the supervision of Prof. H. Bleuler and Dr. M. Bouri where his work focuses on the development of medical and assistive wearable robots.

A Novel Approach to Increase Independence for Individuals with Duchenne Muscular Dystrophy Using Admittance Control

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Abstract

Progressive muscle weakness characteristic of Duchenne muscular dystrophy (DMD) results in loss of upper extremity active range of motion (AROM) despite residual muscle strength that is insufficient to lift the arms against gravity. Passive arm supports attempt to increase upper extremity AROM for these individuals but are largely unsuccessful in delivering the independence they seek to provide. Admittance control is a robotic control paradigm well suited for use by individuals with DMD as it allows for utilization of residual muscle strength to intuitively control the motion of a powerful robot without requiring sufficient strength from the user to overcome gravity and the friction and inertia of the robot [1]. A preliminary study examined the feasibility of using an admittance control robot to increase upper extremity AROM of individuals with DMD to a greater degree than that provided by a commercially available passive arm support. The results demonstrate that the admittance control robot significantly increased the reachable surface area scores compared to the passive arm support (paired-samples t-test, $t(5)=3.984$, $p=0.010$, Cohen's $d=1.6$). The study also demonstrated the efficacy of admittance control to allow for increased independence in the performance of user-identified activities of daily living. To allow individuals with DMD access to this technology for real-world use, a working prototype of a wheelchair-mountable admittance control arm support was developed by affixing a modular admittance control "kit" to a commercially available passive arm support. Ongoing work will evaluate the efficacy of this device to increase independence in activities of daily living and reduce disuse atrophy and contractures to delay upper extremity functional loss.

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Short Biography

Madeline Corrigan is a Ph.D. candidate and a part of the Rehabilitation Engineering Research Center on Wearable Robots for Independent Living (NIDILRR-HHS 90RE5021). Her dissertation work includes the development and testing of upper extremity wearable robotic solutions to increase independence for individuals with DMD. With an extensive background in volunteer and personal care work with individuals with disabilities, Madeline has a personal and professional commitment to assistive technology development and rehabilitation engineering with a unique, user-centered approach to ensure functional and impactful end products.

Alternative Biological Expression of Natural Ambulation Control

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Abstract

Natural-quality, independent ambulation is a prerequisite for community use of lower extremity exoskeletons by individuals with disabilities. In general, current exoskeletons generate pre-programmed gait, where the user cannot exercise volitional control necessary to navigate over uneven surfaces and avoid obstacles. Using the Cybathlon exoskeleton tasks as a guide, we have developed and prototyped an intuitive strategy that allows user-driven control of the exoskeleton's movement in real time, using trajectories produced by the hands. The concept allows neurally defined ambulation trajectories to be expressed through alternative biological articulators. This novel approach uses admittance control to compute each exoskeleton's foot position from Cartesian forces exerted by the user's hands on trekking poles that are connected to each foot through a multi-axis load cell. The algorithm has been evaluated by naïve, non-disabled users who walked a 10 degree of freedom, ½ scale biped robot on a treadmill. The results show that the users' hands produced robot-generated gait kinematics that are very similar to human gait kinematics. This confirms that the hands are capable of producing high quality gait that shares the semi-autonomous nature of natural legged walking, with similar low cognitive demand. Haptic feedback of foot trajectory and ground force reactions to the hands also provides sensory information that allows the exoskeleton gait to closely resemble unimpaired biological gait.

A human-scale exoskeleton, the Trekker, has been developed to demonstrate this control method with pilots. The prototype has actuators at the hip, knee and ankle, and is capable of 'flat-footed' walking. Expansion of the admittance control method allows intuitive force patterns made by the hands to control squatting and sitting in addition to ambulation. Force sensors under the device's project ground force reaction to the onboard computer to assist with stabilization of stance and balance. This prototype will be demonstrated at the Symposium.

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Short Biography

Professor Foulds is with the department of biomedical engineering and directs the Rehabilitation Engineering Research Center (RERC) on wearable robots at New Jersey Institute of Technology. The RERC was established at NJIT and the Kessler Research Foundation in late 2015 with a 5-year grant from the National Institute on Disability, Independent Living and Rehabilitation Research of the U.S. Department of Health and Human Services. Dr. Foulds the past-president of the Rehabilitation Engineering Society of North America, and was previously at the University of Delaware and Tufts University.

What are the experiences of patients and clinicians from a Spinal Injuries unit using an EKSO® exo-skeleton device as part of an acute rehabilitation programme?

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Abstract

Exo-skeletons have become a relatively common tool to be used by people following spinal cord injury. In Nov 2014 a charitable foundation purchased an EKSO® exo-skeleton for use by an NHS SCI in-patient rehabilitation unit. Review of existing literature indicated that there was little research considering users experiences of exo-skeleton robotic technology [1] and none considering its application in acute rehabilitation. The following research question was therefore adopted: What are the experiences of patients and clinicians from a Spinal Injuries unit using an EKSO® exo-skeleton device as part of an acute rehabilitation programme?

The study was undertaken in collaboration by Sheffield Teaching Hospitals Foundation Trust and Sheffield Hallam University. Ethical approval was granted in September 2015.

Methodology

A qualitative approach was undertaken through semi structured interviews. Patient participants were approached by the service lead. Staff participants were recruited through posters. Interviews were arranged at the participants convenience, were 30-45 minutes long and were recorded for later transcription. A completed transcript was shared with the participant for member checking. Data was analyzed using thematic analysis.

Participants

Patients - 4 male, aged 27-45, 3 complete SCI, 1 incomplete, 2-18 sessions with the EKSO®
Clinical Staff - 4 female, 1 male .

Results

Shared themes across both participant groups were identified as education and usability
Patient specific themes were identified as physical, psychological and financial
Staff specific themes were engagement, preconceptions, workload and effectiveness

Conclusion

Patients and Staff had mixed experiences of the exo-skeleton. Overall the patients were more positive and their motivation to support recovery and their perceptions of physical benefits outweighed the negative experiences. Staff were more cautious in their acceptance of the new technology but were willing to acknowledge its potential.

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Short Biography

Dr. Jackie Hammerton is the Lead for Physiotherapy Education at Sheffield Hallam University. Her clinical specialty is neurology and her research interests following completion of her PhD in 2004 have predominantly focused on the use of technology in rehabilitation. Following a number of studies and publications on the role of technology in the recovery of the upper limb after stroke an opportunity arose to work with STH to investigate their exo-skeleton. The data collection and analysis was undertaken by postgraduate Physiotherapy students, supervised by Dr. Hammerton, as part of their final dissertation.

Design and Control of a Hybrid Ankle Foot Orthosis

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Abstract

Exoskeletons (wearable robots) act in series or in parallel to a human limb to assist in motion economy by augmenting joint torque and work done [1]. An ankle-foot orthosis (AFO) is a type of exoskeleton that surrounds the ankle and foot. AFOs are externally applied and intended to control position and motion of the ankle, compensate for weakness or correct deformities. AFOs could be divided into three groups which are passive, active, and hybrid. Since hybrid AFOs combine the advantages of passive and active AFOs by compliant actuators, they are more advantageous than other types of AFOs. The purpose of this study is to build a hybrid AFO prototype for rehabilitation of the pathologies such as peripheral nervous system trauma, incomplete signal cord injuries, stroke, multiple sclerosis, muscular dystrophies and cerebral palsy, and endurance augmentation. In order to achieve this goal, first, appropriate materials such as motor, ball screw, spring, coupling, and bearings have been compared and selected for the design of the prototype; then a CAD model of the hybrid AFO has been designed (Fig.1). Second, an adaptive backstepping control system has been developed to accomplish the desired gait cycle. The novelty of the hybrid AFO is related to the control architecture which allows the system adapt itself to the variable conditions such as ground reaction force and walking speed. An untethered control system relying on lightweight and powerful battery packs and also, the design of an embedded control system will be a goal for the future developments. Built prototype may also lead to a commercial product.

Figure 1: Hybrid Ankle Foot Orthosis

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Short Biography

Oguzhan Kirtas is an M.Sc. student in mechanical engineering at Bogazici University and research assistant at Haptics & Robotics Lab. He received his B.S. in mechatronics engineering from Sabanci University in 2014. His main research interests are rehabilitation robotics and control.

Introducing an Exoskeleton for Ankle and Knee Support of Individuals with a Spinal Cord Injury

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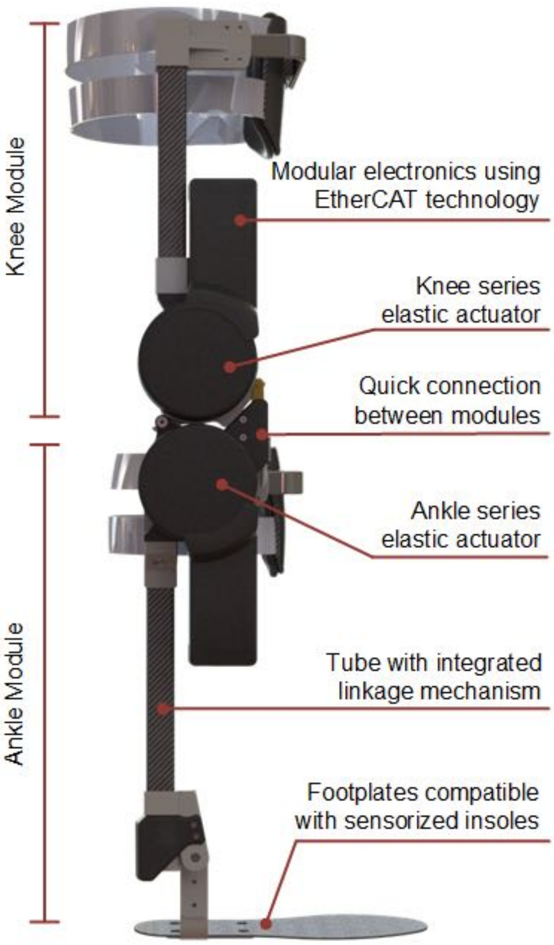
Abstract

In the Symbitron Project [1], one of the main objectives is to develop a safe, bio-inspired, and personalized wearable exoskeleton that enables individuals with a spinal cord injury (SCI) to walk without additional assistance, by complementing their remaining motor function. The first target group of five subjects, have enough hip control to keep themselves upright, but need support around the ankle and/or knee joint. The figure shows the main features of the newly developed exoskeleton. The table below list the preliminary specifications.

Description	Value		Unit
	Knee	Ankle	
Peak output torque	70	100	Nm
Peak output speed	120	60	rpm
Average motor Power	750		W
Actuation unit mass	1.5		kg
Mass per leg	5		kg
Torque resolution	0.012		Nm

The exoskeleton structure is personalized in the design phase using 3D scans of the subjects. The advantage of this approach is the high degree of comfort, reduced weight, and a compact envelope around the body. The modular design of the exoskeleton enables a flexible configuration and easy doing on and off the device. This technology can greatly improve the usability of future exoskeletons.



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Short Biography

Cory Meijneke, M.Sc. is a design engineer Delft University of Technology (TU Delft). His skillset and passion lie in helping researchers design lightweight, compact and portable mechatronic systems. Meijneke was a mechanical designer in the Mindwalker project and is currently responsible for the hardware for the Symbitron project.

A Mechanism to Compensate Joint Misalignment in Exoskeletons

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Abstract

The rigid structures of exoskeletons can impose kinematic constraints leading to undesired effects for the user such as movement alteration, faster fatigue and overall discomfort. One source of these constraints in exoskeletons and other orthotic devices comes from misalignment between the joint axes of the rigid structure and the corresponding axes of the human joints. Misalignment may come mainly from inaccurate alignment, slippage during operation, or because an exoskeleton joint does not accurately replicate the anatomy of the corresponding human joint. This work introduces a mechanical mechanism that is designed to compensate for misalignment constraints and evaluates if this mechanism is a suitable approach to ease the constraints.

Eleven healthy subjects performed hip and knee movements while wearing a lower limb exoskeleton. The exoskeleton has an integrated misalignment compensation mechanism at the human-exoskeleton interface that can be locked to mimic a system without the compensation [1]. It was equipped with position and force sensors that measured the relative motion and forces at the interfaces. We tested with different magnitudes of joint misalignment and with the compensation mechanism either locked or unlocked. The results showed that the integration of a misalignment compensation mechanism as suggested in this work reduces undesired constraints. This effect is stronger for conditions that imposed a high constraining force, namely a large misalignment combined with a high range of motion in the misaligned joint. We conclude that the integration of a compensation mechanism should rather be considered for high ranges of motion, if a high mechanical transparency is required or if an accurate joint adjustment is not possible. Then the use of a compensation mechanism can have a major impact in the comfort and functionality of exoskeletons.

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Short Biography

Volker Bartenbach received his diploma in engineering in 2010 from the Karlsruhe Institute of Technology (KIT), Germany, after writing his thesis on adaptive knee prostheses. From August 2010 until July 2012 he worked as a researcher at the KIT focusing on humanoid robotics and the design and control of haptic interfaces. In 2012 he joined the Sensory-Motor Systems Lab at ETH Zurich, Switzerland, where he is working towards his PhD focusing on lower limb robotic exoskeletons.

MAXX – Soft Exosuit for Everyday Mobility Assistance

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Abstract

Lower limb exoskeletons have great potential to improve mobility and independence of people suffering from muscle weakness. However, current devices are limited in their suitability and acceptance among people with muscle deficiencies. These devices are expensive and have bulky structures that can restrict natural movements, and thus, leading to user discomfort when worn over a long period of time. Soft, textile exoskeletons - exosuits - are fundamentally different from these conventional assisting technologies in that; by definition, they lack rigid structures. Therefore, exosuits have the potential to reduce some of the disadvantages of rigid exoskeletons, namely kinematic constraints and large masses, but they are limited in the amount of assistance they can provide. We have developed a first prototype of such a soft, robotic device for the lower limbs: MAXX - Mobility Assisting teXtile eXoskeleton. MAXX works in parallel with the user's muscles to support neural control synergies and substitutes for losses of motor function – specifically designed for paraplegics that have remaining motor function in the lower limbs. Our exosuit can simultaneously support multiple joints with only one actuator per leg. By actively supporting extension of the hip, knee and ankle joint during different movements, the multi-articulated exosuit architecture is able to compensate for gravity in these joints. Besides the active support, the suit incorporates passive elements which store a portion of the energy that is provided during joint extension. The passive elements are incorporated in a bio-inspired, antagonistic structure. This particular arrangement increases upright stability and allows support of both flexion and extension moments. The use of functional textiles and efficient actuators enables the system to transmit high forces. By providing external assistance, we expect that the exosuit will not only improve mobility and independence significantly, but also have a positive impact on the musculoskeletal system, neuromuscular synergies and immobility related comorbidities.

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Short Biography

Kai Schmidt received his Bachelor's (2011) and Master's (2014) degree in Mechanical Engineering from the Technical University of Berlin, Germany. Afterwards, Kai worked on exosuits as a Research Fellow at Conor Walsh's Biodesign Lab at Harvard University. In February 2015 he joined the Sensory-Motor Systems Lab as a PhD student. Kai is investigating novel mechanisms using soft materials and suitable control methods to create soft, assistive exosuits that are able to support recovery and substitute lost capabilities.

VariLeg – A Lower Limb Exoskeleton with Variable Stiffness Actuation for Paraplegic Users

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Abstract

Humans modulate the impedance of their legs for optimal efficiency and stability during gait. However, commercially available exoskeletons typically consist of stiff links and stiff actuators, which increases the risk of falling and mechanical failure in case of collision with an object. We hypothesize that gait assistive devices, such as exoskeletons, should be capable of impedance modulation for improved safety, efficiency and ambulation speed.

The VariLeg exoskeleton was designed to overcome these limitations and restore natural gait for paraplegics with complete or incomplete loss of leg motor functions. The system has three degrees of freedom per leg in the sagittal plane – two are active (knee and hip) and one is passive (ankle). The novelty of this device lies in the actuation of the knee joint through a variable stiffness actuator (VSA), which is based on the MACCEPA [1].

The VSA is used as a series elastic actuator following position reference trajectories. The gait trajectories were adapted from motion capture recordings of unimpaired subjects. They are scalable in time and space to adjust the stride time, length or height [2]. In this way, the exoskeleton's motion can be adapted both to the user's needs and the environment, and can be tuned as the training with the device progresses. Such scalable trajectory templates were defined for each activity of the powered exoskeleton discipline in the Cybathlon 2016.

In the future, the VSA will be driven by an impedance controller modulating stiffness according to unimpaired human gait data [3] in order to improve stability, e.g., on uneven ground. Pilot studies with paraplegics will be performed to systematically investigate the impact of the VSA on gait efficiency and stability. These experiments will provide useful insights for the implementation and control of VSAs in assistive devices.

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[3] S. Pfeifer, et al. "Knee stiffness estimation in physiological gait." 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE, 2014.

Short Biography

Stefan Schrade received his M.Sc. degree in mechanical engineering from ETH Zurich in 2014. He started his PhD at the ETHZ Rehabilitation Engineering Lab in 2015, and is investigating the effects of variable impedance actuation on gait with lower-limb assistive devices such as prostheses and exoskeletons.

Clutchable Series Elastic Actuator for a Gait-Assistive Active Orthosis for Subjects with SCI

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Abstract

A spinal cord injury (SCI) disrupts the motor and sensory functions of the nervous system, limiting motion capabilities and reducing the quality of life of affected people. An active stance-control knee-ankle-foot orthosis was developed and tested to aid incomplete SCI subjects by increasing their mobility and independence [1]. A further improvement of the orthosis is conducted by the incorporation of elastic actuation to utilize advantages of the compliant system regarding efficiency and human-robot interaction, as well as the reproduction of the physiological compliance of the knee joint. The optimal structure and parameters is determined via optimization using elastic actuator models while considering the efficiencies of various components. This leads to the concept of a series elastic actuator with a locked actuator position during the first half of the gait cycle by an additional mechanism. The series compliance is selected to mimic the physiological stiffness of the knee. During the second half of the gait cycle, a desired motion of the knee is realized with an EC-motor, controlled by means of impedance control. The locking mechanism avoids operation of the motor in a period of the gait cycle, where its efficiency is low due to the respective torque-velocity characteristic. In addition, the selection of an optimal gear ratio for the second half of the gait cycle maximizes recoverable energy. Simulations of this clutchable series elastic actuator (CSEA) yield a theoretical generation of 1.52 J per gait cycle in contrast to a consumption of 6.3 J of the directly-actuated system. Control strategy and actuation system are implemented in a test bench, modeling the foot and shank as a pendulum. The conducted experiments provide a proof-of-concept while revealing gear friction as the main limitation of the system. Future work could improve the prototypic CSEA to generate a light and aesthetic design for the implementation at the active knee-ankle-foot orthosis.

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Short Biography

Florian Stuhlenmiller studies Mechanical and Process Engineering at Darmstadt University of Technology. He works on elastic actuation for assistive robotics since 2012 and (co-) authored several papers in international conferences. This work is conducted as part of his final degree project in cooperation with the Biomedical Engineering Research Centre at Universitat Politècnica de Catalunya in Barcelona.

Exoskeletons supporting postural balance – the BALANCE project

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[1] Tecnalia Research and Innovation

Abstract

Lower extremity exoskeletons have become an established technology. The features and pricing of these devices are such that they are mostly only suitable for providing gait training in clinical rehabilitation.

In the future, applications of leg exoskeletons are foreseen as assistive device in the all-day living environment or as support for workers that perform strenuous tasks. For such applications a number of issues have to be resolved for exoskeletons to become a feasible technology. Important issues being: cost, range of use (battery life, energy use), size/bulkiness, cooperative control, meaning the ability to function efficiently together with a (partially) functional person, and finally safety, mainly in the sense of avoiding falls.

In all current exoskeletons the devices provide or support the essential movements of the stance and swing leg that contribute to progression of the body during walking, but they do not provide or support the adequate behavior of the legs as is needed to maintain postural stability. This means that such exoskeletons when used by patients have to be used in combination with crutches, walkers, or overhead supports in cases where the user is not able to maintain postural balance.

In the BALANCE project control approaches are developed and implemented that support the maintenance of postural balance during walking. In this context we developed and implemented a 'Stability Index' (SI), which is an approach to observe the actual state of balance, in the sense of a stability margin, or actual risk of falling, based on real time processing of wearable and wireless IMU based motion capturing. This SI serves as an input the trigger supportive control actions as well as a metric to validate the quality of balance control. Real Time Implementation strategy and initial validation of this SI will be presented.

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Short Biography

Dr. Jan Veneman is with the Medical Robotics Department in the Health Division of Tecnalia Research & Innovation, Spain. Specialized in exoskeleton robots, gait rehabilitation and gait assessment, especially in the topics benchmarking and standardization. He is currently Spanish expert in the ISO/IEC, as well as European lead of the IEEE standardization study group. He is also active in the working group "Benchmarking of Bipedal Locomotion", and coordinator of the FP7 ICT research project "BALANCE" on postural balancing supportive control of leg exoskeletons, as well as Topic Group leader Wearable Robotics in euRobotics.

Knee-exoskeleton control for gait rehabilitation based on sEMG of trunk muscles

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[3] Biophysics Medical Center, Universidad de Oriente, Cuba
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Abstract

Controllers for robotic rehabilitation must be adapted to the functional capabilities of users and recognize human-motion intention. Surface electromyography signals (sEMG) are often used as a control command signal due it is one of the most important biological signals which directly reflect the human-motion intention. sEMG signals from lower limb muscles are recorded as primary actor in locomotion, however, the erector spinae muscle (ES) from trunk also can be used to recognize motor intention related to lower limb movement [1].

This work presents the development of a control system for a knee exoskeleton based on velocity adjustment and motion intention from ES muscle, which can be used in gait rehabilitation. In order to explore trunk muscles to recognize motor activities related to knee motion, a protocol to acquire a database was developed. An acquisition equipment (BrainNet BNT 36) is used to get sEMG signals from healthy subjects (sampling rate of 400 Hz, band-pass filter from 10 to 100 Hz) of the following muscles: rectus femoris, vastus lateralis, biceps femoris, semitendinosus and gastrocnemius, erectus spinae at levels C7, T3, T7, T12 and L4. Artificial neural network, linear discriminant analysis, and support vector machine (using Gaussian kernel) were used as classifiers. As results, was obtained an acceptable accuracy between signals from trunk and lower limb muscles related to the recognition of the following motor tasks: knee-flexion/extension, standing/sitting, walking and rest stand/sit. The sEMG signals are used as controller input signals. Once the motion intention is recognized, the velocity controller adjusts the knee movement according to both: user torque and an adjustable gain related to the sensibility of the movement based on a hyperbolic function. Preliminary results in passive knee rehabilitation therapy show a good performance of the controller. The assist level of the exoskeleton can be adjusted until the user's motion intention to track a desired trajectory and to stop it when the user decides.

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Short Biography

Ana Cecilia Villa Parra is currently working towards Ph.D. degree at the Intelligent Automation Laboratory, Universidade Federal do Espirito Santo, Vitória, Brazil. Her research interest includes rehabilitation robotics, sensing, actuation and gait assessment.

Responses to pelvis perturbations during human walking

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Abstract

Most current lower extremity exoskeletons require guidance and assistance of its user to stay upright. To realize the opposite, that is, to have an exoskeleton assist its user in maintaining balance in a natural way, it is of major importance to gain an understanding of human balance control. Successfully transferring such knowledge to an exoskeleton could, for example, make crutches unnecessary for paraplegic users.

We present results of four pelvis perturbation studies in healthy human walking. Such perturbations change the movement of the body's center of mass relative to the feet, as might happen following unexpected contact with another person or object. We focus on foot placement adjustment in response to the perturbations. This is often considered the most important strategy to maintain balance during walking [1,2]. Subjects walked on an instrumented treadmill and received unexpected anteroposterior and/or mediolateral pelvis perturbations of various force magnitudes, randomly delivered as 150 ms pushes using an actuator. Experiments were conducted with subjects walking freely, or with one of various constraints. For example, a pair of modified ankle-foot orthoses were used as a physical constraint to investigate effects of limited ankle control on balance recovery. Kinematic and kinetic data were collected for analysis of the recovery responses.

In general, for the first recovery step after the perturbation, the center of mass velocity at heel strike showed major predictive value for the location towards which the center of pressure will shift at the subsequent toe-off. This appears to hold even when the ankle joint is disabled through a physical constraint. The results have implications for exoskeleton design and control: depending on the perturbation magnitude and direction, not only foot location adjustments, but also modulation of single and double support durations, as well as ankle torque modulation have important contributions in human-like balance recovery.

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Short Biography

Mark Vlutters (1989) received his Master degree in biomedical engineering at the University of Twente (NL) with honors (cum laude) in December 2012. Since January 2013 he is a PhD student at the biomechanical engineering group of the University of Twente, working on the analysis of human balance control during walking. His research interests are, among others, in locomotion, kinematics and dynamics, and human motor control.

Neuromuscular controller tested with paraplegics exhibits preferred speed-step length relationship

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Abstract

We evaluated the performance of a bioinspired, neuromuscular controller (NMC), implemented on a haptic gait trainer worn by subjects with spinal cord injury (SCI). In particular, we tested if the preferred speed v – step length s relationship found in healthy gait, $s \sim v^{\beta}$ with $\beta = 0.54 \pm 0.10$ [2], could be reproduced. The power law represents the economical step length for a given speed. The NMC, based on Geyer and Herr [1], produced desired assistive torques based on simulated Hill-type muscles activated in reflex loops by joint angle and stance/swing state inputs. We hypothesized that the NMC's virtual dynamics, in conjunction with SCI subjects walking in knee and hip gait trainer LOPES on a treadmill, could produce a similar power law. The subjects (N=4, male, 24 to 33 years of age, mass M 71.8$\pm$12.6 kg, mean$\pm$s.d., height H 1.83$\pm$ 0.02 m, 3 complete at T11, T9, T7, 1 incomplete at L1) in NMC-controlled LOPES were able to walk at various speeds (0.6 m/s to 1.4 m/s). These speeds are relatively fast considering only one subject (L1) could walk unsupported (at 0.06 m/s). We determined exponent β (and offset α) from linear regression of $\log s = \log \alpha + \beta \cdot \log v$ for each subject. Three subjects demonstrated the power law with $\beta = 0.76 \pm 0.06$ (mean $\pm$ s.d., mean $R^2 = 0.84$), and the fourth exhibited a more linear trend ($\beta = 1.16$, $R^2 = 0.97$). Therefore, the power law emerged for most of the subjects, albeit with relatively longer step length at faster speeds. This could be explained by body weight support (23% M to 38% M) and use of handrails (33% M to 47% M), as the fourth subject had the most vertical support. Ankle actuation was also absent, and the NMC was not optimized for subject anthropometry or multiple walking speeds— both to be addressed in future work. Nonetheless the power law enables evaluation of controller designs for economical gait.

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Short Biography

Dr. Amy Wu is a postdoctoral researcher in the Biorobotics Laboratory at EPFL (Swiss Federal Institute of Technology at Lausanne, Switzerland). She completed her Ph.D. in Mechanical Engineering (2015) in the Human Biomechanics and Control Lab at the University of Michigan, Ann Arbor. She is currently part of the EU FP7 Symbitron project. Her research interests include biomechanics and control of balance and locomotion.

FUNCTIONAL ELECTRICAL STIMULATION (FES)

Preliminary experiments on the effect of square and trapezoidal stimulation patterns for FES cycling

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Abstract

Functional Electrical Stimulation cycling has benefits for subjects with Spinal Cord Injury (SCI), including improvements in cardiovascular function and muscular atrophy, as well overall motivation due to engagement in physical exercise [1]. However, some limitations, e.g. lack of optimal control strategies that would delay fatigue, may still prevent this technology from achieving its full potential [2]. The current work analyses two stimulation patterns for FES cycling control: square and trapezoidal functions. The main control strategy relies on the crankset angle to dictate simulation intensity. However, muscle dynamic response implies that applying stimulation in the form of a trapezoid or square might result in differences on cycling movement. Three able-bodied subjects cycled the EMA trike [3] using both strategies: step and ramp functions. Current intensity was calibrated for each subject and they were able to cycle with no volitional effort, as instructed. We analyzed crank angular speed in steady state for approximately 30 seconds. Both in ramp and step, subjects were able to cycle close to the reference speed in steady state (300º/sec). Data from one subject indicate oscillation decreased in steady state on the ramp reference (lower standard deviation), whilst data from the other two subjects indicate the opposite. Subjects also reported that ramp references are more comfortable compared to the alternative. However, the results were not conclusive, and one subject reported difficulties on not making any volitional effort. Therefore, more tests with SCI subjects are needed. Also, testing with different speeds will help us better understand the effects of muscle dynamics on FES cycling. Although inconclusive, new tests promise to increase performance during cycling.

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Short Biography

Lucas Fonseca is a Control and Automation Engineer, and Biomedic Engineering Msc. He is currently a grad student at University of Brasília, Brazil. Lucas is the Project EMA's Technical Manager, actively working on software and hardware to make the EMA Trike a great tool for rehabilitation, locomotion and leisure.

Closed-loop machine learning for real-time control optimization of FES stimulation during cycling

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Abstract

Functional Electrical Stimulation (FES) is a technique that uses an electrical current to activate muscles that are either weak or paralyzed. The placement of electrodes directly on to the skin of the legs of a person who has suffered a spinal cord injury (SCI) or neurological dysfunction enables the muscles to be contracted by electrical stimulation. This action can be used to develop a pedaling motion which has been used as an aid to rehabilitation.

We are combining two innovations, 1. Closed-loop machine learning optimization to adaptively improve the simulation parameters and 2. Novel sensors that enable us to stimulate and record muscles at the same time. We are using our closed loop dynamic optimization approach (see Bohte et al. [2] for review), deployed in neural engineering settings by Ferrante et al. [3] and Lorentz et al. [4]. The FES stimulus parameters are adaptively changed so as to maximize a desired cost function (maximal and steady force output) under constraints of muscle stimulation efficiency. Probabilistic estimation techniques are used to recursively update our estimate of the cost functions dependence on the stimulus parameters. Stimulation at the next pedal cycle is updated to lay on the location of the extremum of the cost function. Predicted and measured output are compared and the recursive estimator is updated and at the optimization cycle repeated. Muscle stimulation efficiency is tracked using simultaneous electrical stimulation with recording of elicited muscle activity. While electrical stimulation induces direct artifacts and cross-talk in EMG, we are using our novel MMG sensors, that measure mechanical signals of muscle vibrations. This enables us to track muscle contraction performance during stimulation. These projects demonstrate the development of a closed loop FES system capable of detecting such factors as external disturbances, muscle fatigue or a change in intended speed by the user and adjusting stimulation parameters accordingly. In order to achieve this objective, the system must be able to effectively and safely stimulate the user's muscles, obtain feedback relating to muscle force; fatigue and pedal cadence and implement a control algorithm to process the inputs and outputs. Bayesian optimization machine learning technique is used to determine how the system should respond to the input factors in real time. This approach aims to respond and compensate controls in a manner similar to the brain.

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BRAIN-COMPUTER INTERFACES (BCI)

Performance of an embedded computer for a Brain Machine Interface

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Abstract

A brain machine interface (BMI) is a system that enables communication and control of devices using brain signals. Technological advancements allow current embedded PCs to carry enough computational resources to process EEG signals and to develop embedded BMIs. In this work, the performance of the Odroid XU4 embedded PC is evaluated as a processing and control device for BMI, based on motor imagery (MI) paradigm, to obtain a portable, low cost, and trustworthy device [1]. The Odroid XU4 is valued at $74 and has an Octa core processor (2GHz). In comparison, the Linux PC used has an Intel Core i7 processor (3.4GHz) and costs around $1500. To analyze the effectiveness on each device, a 2-class and 4-class motor imagery datasets were used (BCI Competition II-III). The first dataset comprises 280 trials sampled at 128Hz, filtered between 0.5-30Hz, C3, C4 and Cz channels. Instead, the 4-class dataset was sampled at 250Hz, filtered between 1-50Hz and comprises 60 channels; however, only 20 channels were used.

For the 2-class MI dataset, a Wavelet Transform (WT) was used as the feature extraction method. The resulting feature vector trained two classifiers: Support Vector Machine (SVM) and Multilayer Perceptron (MLP). For the 4-class MI dataset, the feature extraction methods used were WT and One-Versus-Rest Common Spatial Patterns (OVR-CSP). Training was computed using a Multiclass SVM classifier [2].

In the first case, results show that both systems offer the same accuracy (92.8%) on each classifier. Nonetheless, the PC(t:0.009s) performs approximately 6 times faster than the Odroid(t:0.06s). For the second dataset, WT showed 77% accuracy, while OVR-CSP achieved 89% accuracy. Processing times indicate the PC outperforms the embedded system approximately by 5 times using WT (PC:0.46s;Odroid:2.25s) and OVR-CSP (PC:0.47s;Odoríd:2.64s). Despite noticeable differences, the Odroid system has proven its potential for the development of accessible fully embedded BMIs.

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Short Biography

Kevin Acuña received his B.Sc degree in Electronic Engineering from Universidad Nacional Mayor de San Marcos (UNMSM). He is currently a M.Sc student in Mechatronics Engineering at Pontificia Universidad Católica del Perú (PUCP). His research interests include brain-computer interface, embedded system, biomedical signal processing and advance control system.

Mobile, Complex BCI Control via HUD and P300

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Abstract

Brain-Computer Interfaces (BCIs) have been lauded for their potential to extend external device control to everyone regardless of physical disability. The largest hurdle to widespread adoption is the difficulty of harnessing and discretizing brain waves to specific commands. The P3001,2 response is an event related potential that occurs when the subject reacts to a stimulus. This response has traditionally been used by displaying a grid of letters and numbers to a patient while the columns and rows flash in sequence. By focusing on a specific target, the user can slowly type out commands when the P300 filter identifies their target of interest. However, these P300 speller applications incorporate 36 discrete targets, and require significant training sessions. This large number of targets also increases the time it takes for the program to classify which target is associated with the P300 response.

Lowering the number of choices to the six or fewer most commonly requested actions allows training and classification times to be significantly reduced. Additionally, using symbols instead of alphanumeric characters allows much more complex actions without additional cognitive or processing load. By displaying these symbols on a wearable heads-up display (HUD) in concert with a BCI, mobile mental control of external devices is possible.

This application works by displaying the command options on a Vuzix HUD. If the user would like to move the prosthetic, they simply look at the desired command and wait for the P300 response to be measured by the OpenBCI EEG system. The signals are then processed on a Rasberry Pi running OpenVibe and classified with 85.2% accuracy. After the P300 is detected, the system actuates the arm to the position chosen by the user. This technology establishes a platform for complex mobile BCI control that can be rapidly adapted for any imaginable dynamic assistive device, from a prosthetic to a wheelchair and beyond.

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Short Biography

The presenting author is Sam Dreyer who received his Bachelor Degree in Bioengineering from the University of Illinois at Chicago (UIC) in May 2016 and will receive his Master’s degree by May 2017. He plans on pursuing a PhD in Neural Engineering. Additionally, he spent the last year serving as the President of the Biomedical Engineering Society on campus. The team behind the work presented consists entirely of UIC undergraduate students.

Neurofeedback for State of the Art Paradigms in Brain-Computer Interfacing

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Abstract

The modern day paradigm used for decoding signals in brain-computer interfaces (BCIs) recorded with an electroencephalogram (EEG) is the motor imagery (MI) paradigm. To classify EEG signals, it is necessary that the recorded signals are sufficiently discriminable. Unfortunately, not all people are able to modulate motor imagery tasks very well.

This work investigates and tests several paradigms on people with disabilities as well as on healthy people to obtain sufficiently many discriminable paradigm related conditions. Investigated paradigms include MI, imagery of audio, mental subtraction of numbers, word association, spatial navigation, and mental rotation. Each of these paradigms will be compared against each other with recent transfer learning approaches regarding paradigm specific task enjoyment [1], discriminability in terms of decoding performance, and peak latency. The best performing paradigms for individual subjects are further improved by using an extension of the adaptive neurofeedback training initially proposed in [2]. During neurofeedback training, the application determines the modulation ability of the subjects' paradigm specific signal in the cortical region of interest compared to the relevant resting state rhythms and provides real time feedback to the subject on how well he is modulating this signal.

Initial results of the neurofeedback training show a visible improvement in the log mean band power in the cortical region of interest. To obtain significant results more neurofeedback studies have to be conducted.

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Short Biography

Natalie Faber is 26 years old and holds a M.Sc. in Computer Science from the Technische Universität Darmstadt. She is coordinating the Athena-Minerva Team and undertook the signal processing as well as the paradigm design part for the Cybathlon competition. In these parts Natalie implemented and evaluated several paradigms as well as some signal processing approaches for preprocessing the recorded EEG signals. Natalie uses neurofeedback training on the teams pilot to improve his modulation ability for his paradigm specific signals.

Personalized Brain-Computer Interfaces for Non-Laboratory Environments

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Abstract

Brain-computer interfaces (BCI) based on Electroencopahlography (EEG) have to meet a range of requirements. Besides dealing with general problems like variations across subjects, sessions and paradigms, usage in non-laboratory conditions induce additional problems to deal with noise, calibration and setup. In this work, we study recent developments to create a BCI for non-laboratory environments tailored to individual subjects. We first investigate different paradigms based on mental tasks, motor imagery and more, to get a discriminative collection of neural activity patterns. A customized set of paradigms is then composed depending on task enjoyment [1] and modulation abilities. Thereafter, state-of-the-art artifact reduction techniques are examined to enhance the signal to noise ratio for the decoding tasks. Band-power features extracted from the preprocessed signals ranging from usage of explicit expert knowledge of the paradigms to advanced spatial filters and recent EEG structure exploitation [2] are used to create different feature spaces for BCI classifiers. Different classification models including recent transfer learning extensions to cope with subject-specific variations are trained on offline data to obtain a combination of high performing classifiers and feature spaces. Finally, we compare three real-time decoding architectures based on hierarchical combinations of the classifiers and error correcting codes. Exploitation of temporal correlation of incoming signals enable custom trade-offs between sensitivity to noise and certainty of predicted brain conditions. First results suggest that different subjects have various strength across different paradigm, so that initial transfer learning approaches show promising results in subject-specific classifier adaptation.

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Short Biography

Tamara is a 24 years old B.Sc. Computer-Science student at the Technische Universität Darmstadt. She joined the Athena-Minerva Team in March 2016. In her curiosity about the human brain, its structure and how thoughts can be measured and processed, she evaluates new customized paradigms for individual subjects. Tamara further participates with the Brain-Computer Interface Group of the Max Planck Institute for Intelligent Systems (Tübingen) in the development of a low-cost BCI System to enable encouraging neurofeedback training of brain rhythms at home.

P300 BCI system for detection of covert emotional focuses of attention

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Abstract

Brain-computer interface (BCI) enables an individual to send messages or control devices, directly using their EEG [1]. P300 BCI is based on the visual oddball paradigm, known to elicit the P300 component of the event-related potentials (ERP), when the user is consciously paying attention to the desired stimulus. However, the attention response to external stimulus can be obtained when the presented stimuli vary in their significance according to subject's personal experience. To develop a P300 BCI-based system for detection of covert intentions or psycho-emotional states we used photos of neutral and emotional human faces.

Fourteen healthy subjects took part in the experiment. The task in the 'Emotional Unattended' mode was just to view the center of the screen, where the photos were presented. The task in the 'Emotional Attended' and 'Neutral Attended' modes was to count the number of the target photo appearances among others (emotional among neutral ones or neutral among neutral ones).

We discovered that using emotional faces as stimuli enhanced the amplitude of several ERP components. In the 'Emotional Unattended' condition the emotional faces were classified as target stimuli with the accuracy of 36.4%, which exceeds the random level more than twice. The mean classification accuracy in 'Emotional Attended' condition was 97.1%. Our results provide evidence that using emotional faces as stimuli increases the efficiency of P300 BCI operating and can be used for creating ERP-based systems for emotional focuses detection which can be applied in clinics as a part of the complex psychological conditions diagnostics and treatment assessment, as well as be used in the entertainment area.

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Short Biography

Ilya Ganin graduated from the Faculty of Biology of the Lomonosov Moscow State University and obtained PhD degree in Physiology in 2013. His main research interests cover brain-computer interface development and neurophysiological mechanisms of attention. He is currently occupied as a research associate at the Neurophysiology and Neuro-Computer Interfaces Lab at the Lomonosov Moscow State University. In collaboration with research and clinical institutions he conducts fundamental and applied investigations of developing the BCI technology and adapting it for the clinical purposes as well as for entertainment area.

BCI SPELLER BASED ON C-VEP PARADIGM

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Abstract

Brain-computer interface (BCI) is a system that utilizes electrographical correlates of focused brain states to establish communication with computer [1]. Here we examine C-VEP BCI paradigm – BCI based on code-modulated visual evoked potentials. Within this approach, binary m-sequence is used as pattern of visual stimulation. Circular shift is introduced, and resulting shifted sequences are used to determine flashing pattern of stimuli. When user gazes at the elements, flashing this pattern, code-modulated response is generated [2]. This response can be extracted using canonical correlation analysis, and used to identify the target that has been chosen by user.

20 healthy adults participated in the experiment. 32 targets were arranged as a matrix on LCD monitor. Each target was altering between black and white with pattern derived from 64-bit binary m-sequence. The time period of the sequence was 1 second. Two flashing modes were present: “straight pattern” and “inverse pattern”, produced by inverting the same m-sequence.

Accuracy above 97% was achieved by several participants in online mode. Average length of EEG sample needed to discriminate between targets was 3.5 seconds. At the offline mode we managed to achieve ITR of 150 bits/min, further online testing is required. No significant difference in performance was present between ‘straight’ and ‘inverse’ sequences. Correlation coefficient between learning and online samples can rise up to 0.6 in average time of 2 seconds. Difference in characteristics of ‘straight’ and ‘inverse’ EP are not described with simple positive or negative correlation. The nature of differences between evoked patterns proposes complex mechanism of EP generation.

We have successfully created BCI based on C-VEP paradigm. The characteristics of this type of BCIs, specifically number of commands, ITR and accuracy, make this type of interfaces a viable replacement for traditional and well-proven t-VEP P300 BCIs. C-VEP BCI is suitable for communication and device control.

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Short Biography

Rafael Grigoryan graduated from MSU in 2014 as a physiologist. He started to work at the BCI lab of Dr. Alexander Kaplan as a student, and now conducts his Ph. D. project at the same laboratory. His scientific interests include non-invasive BCIs, robotic-assisted rehabilitation and neurodegenerative diseases.

First contact screening of a BCI Pilot

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Abstract

Mental tasks, like motor imagery induce changes in the electroencephalogram (EEG) which can be detected and translated into commands for several applications by a brain-computer interface (BCI). However, BCI use is challenging and BCIs do not work satisfactory for everybody. To find the pilot of the GRAZ-BCI Racing Team MIRAGE91, we checked the BCI aptitude of a candidate. We share our experience and present the first contact screening results of our candidate. The Pilot is a 31 year old man, suffering from severe motor impairment due to a brainstem stroke in 2014. For EEG recording we used 16 active Ag/AgCl electrodes which were positioned in an equidistant manner over sensorimotor areas around C3, Cz and C4 electrode positions. Using the paradigm described in [1], we recorded 50 trials per class of motor imagery (MI) of left hand, right hand and feet. In addition we performed a second session where we recorded MI of right hand, feet and a rest-condition. For analysis, data was filtered between 6 Hz and 35 Hz and artefact-contaminated trials were excluded. In a cross validation loop (10 times 5 fold), common spatial patterns (CSP) filters were trained in a one versus one class method. We calculated 12 logarithmic bandpower features (first and last two projections of each CSP model) and trained a shrinkage regularized linear discriminant analysis with features located 2.5 seconds after the cue.

We successfully performed BCI screening in two sessions. The results in Figure 1 show higher accuracies in session 2 (70% vs 45%). In conclusion, a second screening session can be beneficial and a prospective pilot should not be disregarded after one session. We credit the differences to agitation and the novelty of BCI technology to the user in the first session.

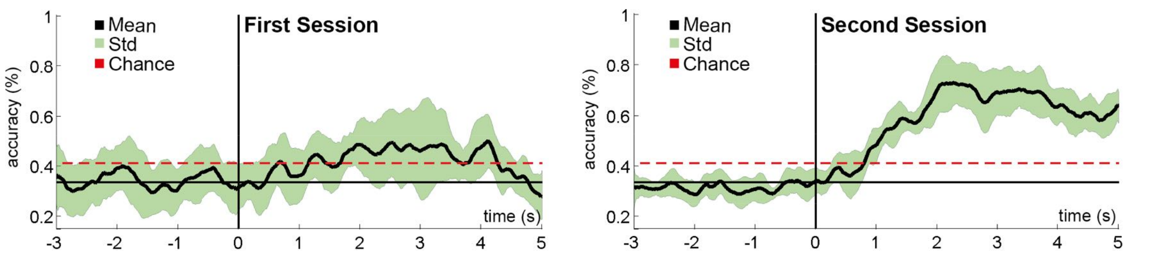

Figure 1: Average session performance overview of three classes (session 1: left hand, right hand, feet; session 2: rest, right hand, feet)

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Short Biography

Maria K. Höller is studying Biomedical Engineering at Graz University of Technology. This abstract shows a brief insight on her bachelor thesis, which is done within the GRAZ-BCI racing team. For her masters, she plans to extend her experiences towards Brain-Computer interfaces and to focus on Neural Engineering.

Convolutional Neural Networks for raw EEG time series classification

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Abstract

For people with high level spinal cord injuries (SCI) and degenerative neurological disorders, brain-machine interface devices offer an alternative pathway to interact with their environment other than the muscular one. It has previously been noted that the acceptance of this technology among people with motor dysfunction is hindered by the lack of system accuracy. The Deep Learning (DL) approach to machine learning has previously shown positive results for image and speech recognition. Zheng et al. [1] have shown that Convolutional Neural Networks can outperform previous techniques in the classification of electrocardiogram signals. Yet DL remains little explored for the time series classification of electroencephalography (EEG) as the noise inherent in this kind of signal, along with the short time windows and high input dimensionality make this task difficult.

In order to decode these signals, team Imperial will use a machine learning algorithm called convolutional neural network (CNN). This algorithm is efficient in the field of image recognition and can be adapted to work with time-series. Based on the way the visual cortex recognizes objects, the CNN learns patterns in the EEG signals when provided with enough training examples. For each one of the possible commands, the network will be fed with thousands of examples of what EEG signals corresponding to this particular command may look like. The performance of the whole system does not depend only on the accuracy of the algorithm but also on the training of the subject. When playing the game, the subject will receive feedback of his actions from the screen. This closed-loop system allows him to act indirectly on his brain signals so as they get more and more correlated with the intended commands.

This body of work focuses on the development of convolutional network architectures that may be used to better exploit space and time relations of signals in EEG sensor space. The study assesses how this technique may be used to increase the accuracy of the signal measurement. It also develops a means to automatically determine the optimal filters for identifying the most important temporal features within our high density 160 channel EEG related to a number of different user related tasks.

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Short Biography

Pablo Ortega holds a BEng in Industrial Electronics and Automation from Universidad Politécnica de Madrid (Spain). He then continued training at the Dept. of Bioengineering, Imperial College London with a Master's thesis in the Brain & Behaviour Lab.

Cédric Colas holds a BEng in Electrical Engineering and Computer Science from Centrale-Supélec (France). He then continued training at the Dept. of Bioengineering of Imperial College London in collaboration with the Brain & Behaviour Lab.

BCI adaption for end user –The GRAZ-BCI approach

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Abstract

Non-invasive Brain-Computer interfaces (BCI) enable its users to interact with their environment only by thought. A possible BCI application may be to control a computer game solely by e.g. imagery of motor tasks. However, this requires several control commands and individual BCI training. So far, no gold standard procedure has been established on how to setup, train and individualize multi-class control for end users. In the following, we describe our four stage approach for individualizing and adapting BCI technology for an end user. Our approach is based on [1] and the findings of Friedrich et al. [2], and extended by personal experience and ideas.

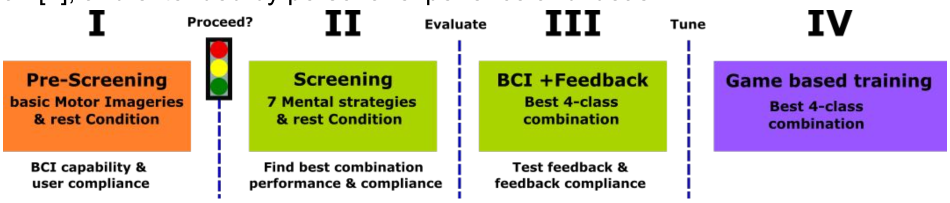

Figure 1: Stage Model

The procedure is divided into 4 different stages (Figure 1). In stage 1 we perform pre-screening to test whether the user is able to understand instructions, is comfortable with BCI technology and is able to produce distinct brain patterns. Results of this stage indicate whether continued training with the user is reasonable. Stage 2 incorporates a screening of several mental tasks as described in [2], including a non-control state. In an offline cross-validation setup of every possible combination, we determine the most effective (in terms of accuracy and user acceptance) combination of at least 4 different classes. BCI use commonly incorporates feedback, hence in stage 3, the previously identified class combination is used to test the user's compliance to feedback. In the beginning of stage 4, a BCI is closely tailored to the user based on the findings in the previous stages. Thereafter the user starts BCI training using the actual game. Our procedure provides a promising way to guide users from first contact with BCI technology to actually play a videogame by thought. We believe that an evidence based procedure, maybe similar to the one presented in this work, is a necessity to introduce BCI technology in the daily life of potential end users.

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Short Biography

Andreas Schwarz received his M.Sc. degree in information and computer engineering in 2014 from the Graz University of Technology. Currently he is working towards his PhD at the Institute of Neural Engineering under supervision of Prof. Gernot R. Müller-Putz. His research focusses on the EEG-based decoding of upper-limb movements, especially grasping movements which eventually can be used for controlling a neuroprosthesis.

Adaptive Training Strategies for BCI

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Abstract

Research on Brain-Computer Interface (BCI) systems consists amongst others of preprocessing the signals, artifact reduction, dimensionality reduction, applying filters and learning classifiers to generate actions that can be sent to actuators of exoskeletons or computer programs [1]. A problem with current BCI systems is that performance can decrease rapidly over time, since training can be tiring and the signals are non-stationary [2]. Furthermore, the motivation of the subject can drop quickly if no success in controlling the BCI system is experienced. Like in everyday life, if we want to learn a skill, we need feedback to be able to judge our current performance. A potential solution to the aforementioned problem is to develop adaptive training strategies. These strategies use a classifier to classify the data provided by the BCI system and an optimal agent which assists the subject to modulate and improve her/his signals. Continuous visual feedback about the performance is provided during the whole training time. With increasing training time, more and more control is given to the subject, reducing the effect of the optimal agent. With this approach, we want to increase the convergence rate of the subject's performance at controlling a BCI system. To verify this, we developed a simple computer game, closely related to the Cybathlon BCI challenge. In this game, the subject has to control an avatar to avoid obstacles by using different commands. The agent's policy to assist the subject is trained through reinforcement learning. Finally, we are interested in the generalization abilities of the subject to previously unseen situations. Therefore, we implemented different difficulty levels with higher or faster obstacles. Initial results indicate that our system supports faster learning of controlling the avatar. To further verify this, we need more subjects and do more exhaustive tests with the system.

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Short Biography

David Sharma acquired his Bachelor of Science in Computer Science in 2012 at Technische Universität Darmstadt. Currently he is writing his master thesis on the adaptive training strategies for BCI. He is interested in exploring neural data with machine learning techniques to find out more about how the human brain works and how diseases affect the brain. In the Cybathlon competition, he is responsible for implementing and evaluating classifiers for the data.

Battle of the Minds: Entertainment as Proof of Concept for Using Affordable EEG and Processing Systems

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Abstract

Brain-Computer Interface devices in the field of assistive technology utilize sophisticated and costly data acquisition and processing systems [1]. In 2013, the OpenBCI board became available as a cost-effective open-source EEG data acquisition system. Raspberry Pi is a cost-effective mini-computer that can be used to process complex data sets. In the present work we demonstrate the application of these two systems in a simulated arm-wrestling game. Implementation of this game serves as a proof concept for application of open-source and cost-effective systems in the field of assistive technology.

Ten participants contributed to this study. Each game occurred between two participants in meditative eyes-closed state. EEG signals were collected via a 32-bit OpenBCI board from the O2 scalp region. Using Raspberry Pi 3 model-B, raw EEG signals were filtered and processed online. In order to make the game impartial and compensate for variances in baseline activity amongst individuals, the ratio of spectral density of alpha band (8-12Hz) to 4-40Hz band was computed. Alpha band activity increased on average 1.2 times between eyes-open to eyes-closed states [2]. The ratio calculation amongst all participants proved the game significantly impartial to individual variety. During the game, the ratios of the two participants were calculated at every 1 sec interval, and linearly converted in to voltage signal sent to a servo motor connected to two attached prosthetic arms. At each interval, the motor turned the arms in favor of the more meditated participant that exhibited the highest ratio. The winner was declared the participant whom was able to turn the arms 90°. During multiple trials, it was documented that each game provided a 50-50 chance of win for each participant. This study serves as a proof of concept that affordable assistive technology could be developed using cost-effective, open-source, and easy to use data acquisition and processing systems.

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Short Biography

The presenting author is Sam Dreyer who received his Bachelor Degree in Bioengineering from the University of Illinois at Chicago in May 2016 and plans to complete his Master's degree by May 2017. He plans on pursuing a PhD in Neural Engineering. Additionally, he spent the last year serving as the President of the Biomedical Engineering Society student chapter, as well as conducting research on electroretinography.

The MIRAGE91 Brain–Computer Interface

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Abstract

MIRAGE91 (Motor Imagery Racing Graz established 1991) is the name of the official Brain-Computer Interface (BCI) Racing Team at the Graz University of Technology. Our BCI captures brain activity by electroencephalography (EEG) and utilizes changes in oscillatory components caused by four different mental tasks to generate control signals. We measure EEG with 32 active Ag/AgCl electrodes and two 16-channel biosignal amplifiers. A standard laptop hosts all necessary software and also sends the control commands via network to the Cybathlon Brain Runners game. Our custom made TOBI SignalServer handles data acquisition from the amplifiers and provides an interface to Matlab/Simulink, where signal processing is performed [1]. First we filter EEG in alpha and beta bands separately. Then, we normalize channels to their resting variance to reduce the influence of high variance channels. Resting variance is estimated from a prior resting measurement. After that, we perform spatial filtering with common spatial patterns (CSP) in a one class vs. one class manner and use four filters per CSP model. Then we calculate logarithmic band power over one-second sliding windows and use an analytical shrinkage regularized linear discriminant analysis (sLDA) to calculate class probabilities. If the class probability of one of the four classes exceeds a threshold for a certain time, we send a command to the game. With this BCI, the best run time of our motor impaired pilot was 117 seconds and the best run time over all was 107 seconds (10 fields per class, runtime without input is 165 seconds). Lessons learned from designing our system will influence future BCI system design in terms of robust signal processing at low trials-to-features ratios and BCI personalization.

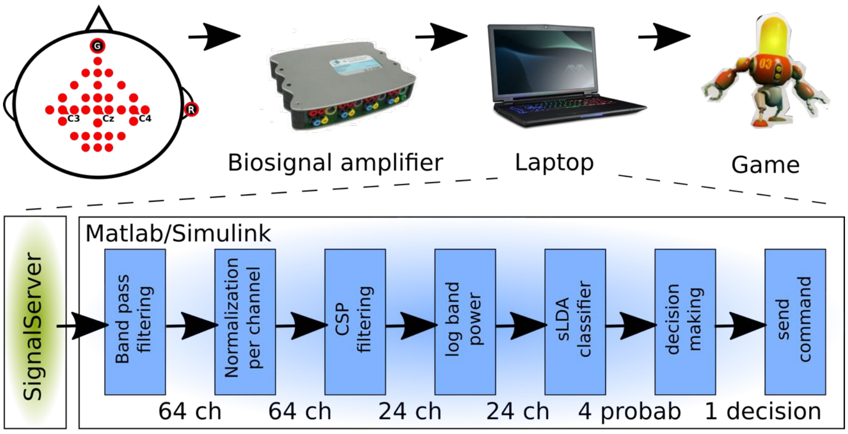

Figure 1: MIRAGE91 Brain-Computer Interface scheme

References

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Short Biography

David Steyrl is teaching and research assistant at the Institute of Neural Engineering (BCI-Lab), Graz University of Technology, Austria. He received his M.Sc. in electrical and biomedical engineering from Graz University of Technology in 2012. His research interests include biosignal processing and machine learning for simultaneous EEG-fMRI and brain-computer interfaces. Currently he is working towards his PhD degree in computer science.

POWERED WHEELCHAIRS

Eye-Based Wheelchair Navigation

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Abstract
For people who have spinal cord injuries (SCI) or degenerative neurological disorders, motor impairments negatively affect their ability to perform daily activities. It is estimated that around 10% of the world population presents a disability with 10% of these people needing a wheelchair to perform daily activities [1]. Most current wheelchair driving interfaces, such as joysticks, prove unsuitable for self-control by people with high level SCI or advance neurological degeneration. In these extreme cases it has been noted that while other motor functions may be impaired eye motion remains fully active. As such eye-tracking systems provide hands-free control allowing the users to move independently within the surrounding environment [3]. The use of eye-tracking devices for wheelchair control is a relatively new field of research. One main issue highlighted that can affect the efficiency of the system is termed "The Midas Touch problem". It describes the difficulty of distinguishing voluntary from involuntary eye-movements involved in gaze driven control system [2].
This research project provides an innovative platform using eye-based wheelchair navigation and avoiding the Midas Touch problem encountered by current technologies. The report details the development of a natural eye tracking decoder which aims to avoid the reliance on extra gaze gestures (such as winking or blinking) or the use of imposed gaze patterns whilst controlling a wheelchair. Experiments are established and data analysed using a commercial eye-tracker camera unit and a Microsoft Kinect. The latter is used to provide information regarding the surrounding environment, giving a reference to determine if the user's gaze is intended as a driving input or not. Data analysis is used to identify the factors influencing the natural decoder (e.g. subject's characteristics) which may be used to enable an extra gaze gesture if necessary to improve the efficiency of the control system.

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Short Biography
Lou-Ann Raymond trained with a Bachelor's and a Master's Degree at Université Libre de Bruxelles (Brussels, Belgium) and has specialised in Electro-mechanical engineering. She then continued training at the Dept. of Bioengineering, Imperial College London with a Master's thesis in the Brain & Behaviour Lab.

Hybrid Robotic Wheelchair

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Abstract

Modern technologies enable persons with disabilities to perform activities of daily living, thereby significantly improving quality of their lives. Robotic or powered wheelchairs, for example, improve mobility. Wheelchair electric drive facilitates mobility of physically impaired people. However, many of these devices, despite the high cost, do not allow overcoming of even the most common obstacles (steps, curbs, etc.) that occur in everyday life. The aim and motivation for the development of a new wheelchair concept was a desire for the improvement of existing solutions with new approaches and the consequent positive effects on the mobility of wheelchair users.

The solution is a hybrid powered wheelchair concept that integrates the best characteristics of wheels and tracks. The main propulsion system consists of four independently controlled and steered in-wheel motors. Such configuration enables best maneuverability, stability, power and velocity. Large wheels also allow the user to overcome most of everyday obstacles, such as curbs. However, overcoming of steep terrain and stairs would not be possible without a tracks system. Two independently controlled tracks with adjustable height from the ground via a two-degree-of-freedom (DOF) mechanism (enables also adjustment of tracks angle relative to the wheelchair) are mounted between the wheels. In order to keep the pilot in a comfortable position during climbing over steep obstacles, the chair is augmented with an inclination mechanism. In total the wheelchair has thirteen DOF (four wheels with 2 DOF each, pair of tracks and a reclining chair). They are all controlled by the pilot.

Safety of the pilot is guaranteed through the mechanical design (four-wheel platform with low center of gravity), selection of components (limited power and speed of actuators, brakes), sensor redundancy for all critical actuators, standardized electronics for control and software-implemented safety mechanisms.

Short Biography

Gašper Simonič received his B.Sc. degree in electrical engineering from University of Ljubljana, Slovenia in 2015. During his studies he was one of the organizers of the Days of Industrial Robotics event which was awarded with one of the highest university awards in Slovenia. His main interests are programming and robot control. He is currently studying for his master's degree in the field of robotics at the Faculty of Electrical Engineering in Ljubljana.

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