ANSYMB - Interdisciplinary Teaching for Human-Centered Robotics

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Abstract. In this paper we present the novel teaching project ANSYMB which we introduced during the last years at Technische Universität Darmstadt. In ANSYMB, students learn to analyse and synthesize human movements using research techniques used in biomechanics, computer sciences and engineering. Here, we explain key concepts and illustrate some of the outcomes of the educational courses. With this we hope to stimulate the discussion on how to teach students for preparing them to work in the growing research field of human-centered robotics and assistive devices.

1 Introduction

Replicating human locomotion through artificial devices (e.g. humanoids, active leg prostheses or orthoses) is an open challenge in the field of robotics [1,2]. This is due to the fact that the generation of human locomotion is fundamentally different from robotic systems. This holds not only for the neuronal control, but also for the different components of the physiology or hardware structure, e.g. muscle properties, soft-tissue dynamics or joint architectures [1,2]. Additionally, human individuals are self-conscious with individual cognitive processes which alter their behaviour and often make it hard (or even impossible) to predict how a person would respond to a certain challenge or condition. This is of special interest when robotic systems are directly interacting with the human user, e.g. wearable and assistive devices such as exoskeletons.

In order to prepare students (upcoming engineers and researchers) for working with human-centered robotic systems, we need to include these challenges in the related teaching curricula. However, the integration of such competences within educational courses is still a challenging topic as it requires the synthesis of different scientific backgrounds ranging from human sciences, medicine, biology, computer science, physics and engineering. The integration of all involved stakeholders (departments, administrative teaching services, lecturer and students) from an early state on is of high importance in order to clearly work out the demand (from different disciplines), possible teaching approaches (within the existing frameworks or curricula) and potential founding schemes.

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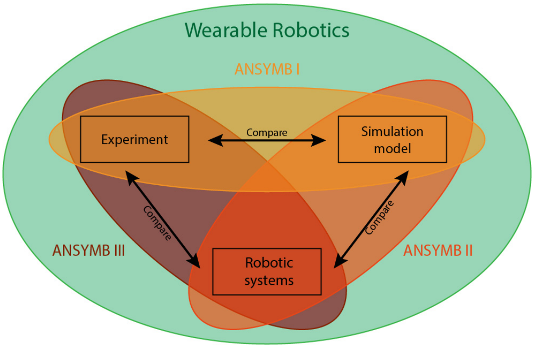

Fig. 1. The ANSYMB framework, adapted from [3,4].

At Technische Universität Darmstadt, we implemented the novel interdisciplinary teaching project ANSYMB (www.ansymb.tu-darmstadt.de) during the last three years comprising three bachelor and master student courses. To address the above-mentioned challenges, our syllabus comprises human experiments, computer simulation models and simple robotic systems.

2 ANSYMB Teaching Approach

Our teaching concept focuses on a holistic and equivalent consideration of the three methodological approaches [3,4]: (1) biological movement (e.g. human hopping motion), (2) simulated movement (e.g. biomechanical computer model of human hopping) and (3) engineered movement (e.g. hopping robot) (Fig. 1). The three approaches of ANSYMB (human movement analysis, simulation models and robotic implementation) are finally converging in the design of assistive wearable systems such as active prostheses [5] driven by simulation models [6] which are based on human gait experiments.

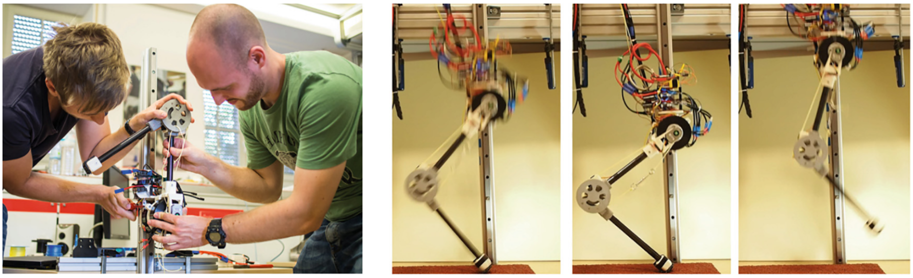

Fig. 2. The robotic leg GURO: students assemble different components (left) and hardware setup during hopping (right).

A. Analysis of Human Movements

In this part of ANSYMB, students learn the common techniques for analyzing human movements. This includes e.g. 3D high-speed motion tracking using infrared cameras, recording of ground reaction forces using force plates and surface electromyography (EMG) for measuring muscle activities. Students learn to plan and perform their own experiment starting by defining individual research hypotheses, make decisions on appropriate measurement techniques and the subject's task. This also includes experimental plans and potential influences of cognitive and psychological factors of subjects and experimenters. Students are encouraged to actively participate in an experiment providing them the opportunity to experience and take the subject's perspective.

B. Simulation Models of Human Movements

In the second part of ANSYMB, the focus is on modeling the dynamics and control of human movements using computer simulation tools. Here we start with simplified biomechanical models for jumping, running, walking [7,8] and balancing [9]. Further, we introduce models describing the musculo-skeletal and neural control level of human movements [6,10]. These models are then used to study discrepancies to experimental data as well as different concepts of stability or parametric sensitivities. This helps students to evaluate the given limitation of every modeling approach and allows them to explore the importance of different simplified motion features for synthesizing appropriate locomotion.

C. Hardware Systems for Human-Like Movements

To demonstrate how to design and implement bio-inspired control on a real robotic hardware system, a two-segmented leg hopping robot called GURO was developed (robot mass 2.8 kg, upper and lower leg segment length 0.27 m, Fig. 2). Two direct-drive brushless DC motors were used to actuate hip and knee joint. Carbon fiber tubes were chosen as segments to withstand high load while minimizing the weight and moment of inertia. Apart from screws and bearings, all mechanical parts were 3D printed to keep the leg weight and hardware costs low. By this, students can easily modify the mechanical design, print the parts and assemble the robot. Human muscle-like properties and reflex (force, length and velocity) based controller can be implemented in the control of the motor [6,10].

3 Example Student Research Projects

A. GURO Hopper

One group of students studied stable hopping with the GURO hopper (Fig. 2) by employing human-like muscle properties and reflex feedback gains. For comparison, students also implemented a more technical impulse-based jumping height controller.

B. Active Cane for Assisting Human Walking

Another group of students designed and manufactured a robotic cane for supporting elderly people during walking. The embedded linear pneumatic actuator controls cane length based on the elbow angle. The cane length increases during the stance phase to assist the user during push-off and decreases during swing phase. The can design and control approach was validated in human walking experiments on a treadmill and on stairs (Fig. 3).

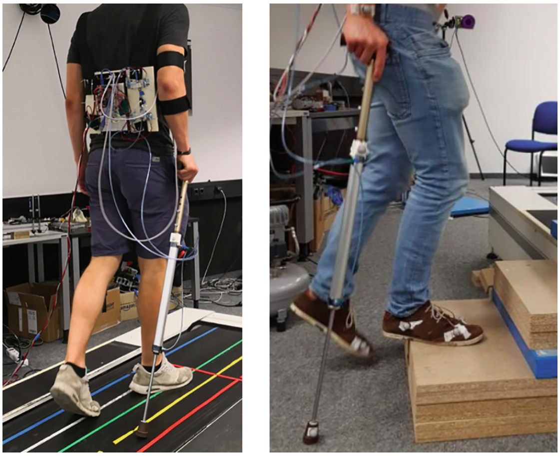

Fig. 3. Walking with the robotic cane on treadmill (left) and stairs (right).

4 Discussion and Conclusions

The ANSYMB project attracts students from many disciplines including mechatronics, physics, computer science, mathematics and sports science. The high diversity of the student's background was beneficial for a successful execution of the projects by motivating for learning outside of their own field of study. Some of the project outcomes reached a level that allowed a direct continuation in follow-up research projects (e.g. within a master thesis).

Still, a number of important aspects of human-centered robotics (interaction dynamics between the robotic and the human body as well as human factors, e.g. mood, motivation, and user intentions) are not yet sufficiently addressed in the ANSYMB project.

Another important topic which should be addressed in future are ethical issues when using technology to support and enhance human motor capabilities. Such technological development might fundamentally change many aspects of our future society, in private life, in sports and in business. Here, a broad discussion with other disciplines (e.g. political sciences, philosophy, social sciences) would be required. This could be organized on a larger-scale level, e.g. within a network connecting universities working on these technologies in Europe and world-wide. The COST action on wearable robotics (www.wearablerobots.eu) is a European network to support such activities. Within such networks, teaching materials and experiences can be exchanged to stimulate a successful implementation of similar educational means at different universities.

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