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Exoskeletons in Rehabilitation Robotics

Tremor Suppression

Springer

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To our families

Foreword

Robotics is undergoing a major transformation in scope and dimension. From a largely dominant industrial focus, robotics is rapidly expanding into human environments and vigorously engaged in its new challenges. Interacting with, assisting, serving, and exploring with humans, the emerging robots will increasingly touch people and their lives.

Beyond its impact on physical robots, the body of knowledge robotics has produced is revealing a much wider range of applications reaching across diverse research areas and scientific disciplines, such as: biomechanics, haptics, neurosciences, virtual simulation, animation, surgery, and sensor networks among others. In return, the challenges of the new emerging areas are proving an abundant source of stimulation and insights for the field of robotics. It is indeed at the intersection of disciplines that the most striking advances happen.

The Springer Tracts in Advanced Robotics (STAR) is devoted to bringing to the research community the latest advances in the robotics field on the basis of their significance and quality. Through a wide and timely dissemination of critical research developments in robotics, our objective with this series is to promote more exchanges and collaborations among the researchers in the community and contribute to further advancements in this rapidly growing field.

The monograph written by Eduardo Rocon and José Pons is a contribution in the area of rehabilitation robotics, which has been receiving a growing deal of attention by the research community in the latest few years. The contents are focused on the management and suppression of pathological tremor in upper limb exoskeletons. Solutions deal with both cognitive and physical human-robot interaction issues of such wearable devices. Results are validated in a rich set of experiments, revealing a promising outlook toward the application to a wide range of so-called soft robots.

Remarkably, the monograph is based on the first author's doctoral thesis, which received the prize of the Seventh Edition of the EURON Georges Giralt PhD Award devoted to the best PhD thesis in Robotics in Europe. A very fine addition to STAR!

Naples, Italy
September 2010

Bruno Siciliano
STAR Editor

Preface

The scientific community is becoming more and more interested in rehabilitation robotics. From a robotics perspective, exoskeletons are mechatronic systems worn by a person in such a way that the physical interface leads to a direct transfer of mechanical power and exchange of information. A wearable robot is designed to match the shape and function of the human body. Segments and joints correspond to some extent to those of the human body while the system is externally coupled to the person. Initially, the primary applications of these robotic mechanisms were teleoperation and power amplification. Later, exoskeletons have been considered as rehabilitation and assistive devices for disabled or elderly people. One important and specific feature of wearable robotics is the intrinsic interaction between human and robot. This interaction is twofolded: first, cognitive, because the human controls the robot while it provides feedback to the human; secondly, a biomechanical interaction leading to the application of controlled forces between both actors.

The fact that a human being is an integral part of the design is one of the most exciting and challenging aspects in the design of biomechatronics wearable robots. It imposes several restrictions and requirements in the design of this sort of devices.

Tremor is characterized by involuntary oscillations of a part of the body. The most accepted definition is as follows: "an involuntary, approximately rhythmic, and roughly sinusoidal movement". Tremor is a disabling consequence of a number of neurological disorders. Tremor, the most common of all involuntary movements, can affect various body parts such as the hands, head, facial structures, tongue, trunk, and legs. Most tremors, however, occur in the hands. Tremor is a disorder that is not life-threatening, but it can be responsible for functional disability and social inconvenience. More than 65% of the population with upper limb tremor have serious difficulties performing daily living activities. In many cases, tremor intensities are very large, causing total disability to the affected person. The overall management of tremor is directed towards keeping the patient functioning independently as long as possible while minimizing disability.

It has been established in the literature that most of the different types of tremor respond to biomechanical loading. In particular, it has been clinically tested that the increase of damping and/or inertia in the upper limb leads to a reduction of the tremorous motion. This phenomenon gives rise to the possibility of an orthotic management of tremor. An orthosis is a wearable device that acts in parallel to the affected limb. In the case of tremor management, the orthosis must apply a damping or inertial load to a selected set of limb articulations. As a wearable device, it must exhibit a number of aesthetic and functional characteristics. Aesthetics is more directly related to size, weight and appearance of the exoskeleton. Functionality is related to generating required torque and velocity while maintaining the robustness of operation.

This book will give a general overview of the robotic exoskeletons field and will introduce the reader to this new robotic field with an extensive review of its main applications and the technologies suitable for its development. In addition, it provides detailed studies of the main topics in the wearable robotics field. The book will use the development of an upper limb exoskeleton for tremor suppression in order to illustrate the influence of a specific application in the designs decisions. It will present the development and validation of an upper limb exoskeleton with three main objectives: monitoring and diagnosis, and validation of non-grounded tremor reduction strategies.

At the end, the book focuses on describing the upcoming research in the rehabilitation field which leads to the concept of Soft-Robots (SRs). They are also wearable, but SRs use functional human structures instead of artificial counterparts, e.g. artificial actuators are substituted by Functional Electrical Stimulation (FES) of human muscles. The borderline between human and robot becomes fuzzy and this immediatilly leads to hybrid Human-Robot systems.

Madrid, September 2010

Eduardo Rocon
José L. Pons

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