Preface

As a result of years and through effective natural selection, nature tested every field of science and engineering leading to inventions with solutions for everything that can work well, adapt and last long. The evolution of nature led to resolve of many research and development challenges. Biomimetics as an emerging area of research development that studies and examines nature, its models, elements, processes, systems, structures, mechanisms, etc. to take inspiration from, or emulate, nature's best biological ideas and products in order to solve modern science and engineering problems. Biomimetics incorporates materials, behaviors, structures, concept, sensing and techniques drawn from naturally made substances, and resembles the aspiration of biological systems in structure, mechanism and/or function. Biologically inspired approaches will create new reality with great potential. In addition, biomedical robotics research and development area is evolving rapidly with an increasing number of robotic systems with different capabilities that perform wide variety of tasks, such as, surgical robots, rehabilitative and prosthetic devices, neurosurgery, preparation of bone surfaces, biomedical image analysis, image-guided prenatal cardiac interventions and telesurgery, assisting living. In addition, robots have also been developed to improve the accuracy of radiation treatment, organizing and dispensing food and drugs, as well as other materials within the hospital or health care. Finally, the use of robotics provides a remote presence of a physician.

This handbook includes 20 chapters that contribute with the state-of-art and up-to-date knowledge on research advancement in the field of biomimetics and biomedical robotics. The chapters provide relevant theoretical knowledge, practices, technological evolution and new findings. Furthermore, the handbook helps to prepare engineers and scientists who are looking to develop innovative, challenging, intelligent, bioinspired systems and value added ideas for autonomous and smart interdisciplinary products and systems to meet today's and future most pressing challenges.

Chapter 1 is titled "Biomimetics and the Evolution of Robotics and Intelligent Systems." This chapter presents biomimetics as an evolving interdisciplinary area of research development that studies and examines nature, its models, elements, processes, systems, structures, mechanisms, etc. to take inspiration from, or emulate, nature's best biological ideas in order to solve scientific and engineering problems. It also highlights some of the challenges and considerations for future development in the field of biomimetics.

Chapter 2 is titled "Investigation of Human Locomotion With a Powered Lower Limb Exoskeleton." This chapter studied lower limb exoskeleton both as a measurement device for studying human locomotion and as an assistive device that restores human ability to walk. In addition, the chapter considered the way the geometry of the supporting surface affects the sensory system of the robot through different development of new foot design structures.

Chapter 3 is titled "Active Assistive Orthotic System: (Exoskeleton) Enhancing Movement." Active orthosis (exoskeleton) is assistive device with a wearable structure to help generating the natural human motion. The chapter focuses on developing an active/assistive orthosis system (AOS) with enhanced movement. The design is bioinspired by musculoskeletal system of human upper and lower limbs, and mimics the muscle-tendon-ligament structure. It was fabricated using light materials and powered by pneumatic artificial muscles with more than fifteen degrees of freedom. AOS can operate in three modes.

Chapter 4 is titled "Hybrid Exoskeletons for Upper Limb Stroke Rehabilitation." This chapter presents a review on the state of the art of upper-limb hybrid exoskeletons with a particular focus on current need of stroke rehabilitation and how the hybrid exoskeletons can provide a solution to difficulties in this field. The chapter shows in particular that more investigation is needed with regards to the potential benefit of hybrid exoskeletons as a patient-monitoring and rehabilitation assist-as-need tool.

Chapter 5 is titled "Modeling a Predictive Control of Human Locomotion Based on the Dynamic Behavior." This work presents the development of a lower limb orthosis based on the continuous dynamic behavior and on the events presented on the human locomotion. Computational model was developed to approach the different functioning models related to the bipedal anthropomorphic gait. Virtual model was implemented and its kinematic and dynamic motion analyzed through simulation of an exoskeleton, aimed at lower limbs, for training and rehabilitation of the human gait, in which it is already developed the dynamic model of anthropomorphic mechanism and predictive control architecture with robust control.

Chapter 6 is titled "Towards Cost-Oriented User-Friendly Robotic Systems for Post-Stroke Rehabilitation." This chapter deals with robotics for assisting patients in their recovery after stroke with focus on key physiotherapist movements that are needed in post-stroke treatment. In addition, it discusses sets of experimental data for defining the main specifications for post-stroke rehabilitation devices. Also the chapter presents key achievements in the field, critical analysis and solutions concerning rehabilitation robotics for post-stroke treatment aiming at the definition of new concepts for developing cost-oriented user-friendly robotic system.

Chapter 7 is titled "The 'Arm' Line of Devices: For Neurological Rehabilitation." This chapter introduces the development effort of a line of prototypal devices for the rehabilitation of the upper-limb, called "Arm". Arm devices focus on the main features requested by a robot therapist: mechanical adaptation to the patient, ranging from passive motion to high transparency, assist-as-needed and resistive modalities; proper use of sensors for performance monitoring; easy-to-use, modular and adaptable design. These desirable features are combined with low-cost, additive manufacturing procedures, with the purpose of meeting the requirements coming from research on neuro-motor rehabilitation and motor control and coupling them with the recent breakthrough innovations in design and manufacturing.

Chapter 8 is titled "Lithotripsy of Renal Stones With Avicenna Roboflex Robotic-Assisted Retrograde Intra-Renal Surgery (RA-RIRS)." The work in this chapter introduces an overview on robotic assistance for RIRS with focus to introduce ELMED's robotic device with its effects on surgical performance based on the IDEAL (idea, development, evaluation, assessment, long-term study) framework. Also, the chapter presents the robotic device, Avicenna Roboflex, is a teleoperated robot consisting of a surgeon's console (Master Control Console – MCC) and manipulator arm (MA) to house and couple with the FURS. It provides a suitable and safe platform for robotic assisted (RA) RIRS with significant improvements in ergonomics and potentially prolongs equipment durability.

Chapter 9 is titled "Brachytherapy Needle Steering Guidance Using Image Overlay." This chapter presents a physical simulator for needle steering in brachytherapy. As the user inserts the needle in a phantom tissue, images of the needle and prostate shape reconstructed from 2D transverse ultrasound

images are displayed online in a semi-transparent mirror. As the user inserts the needle in a phantom tissue, images can be seen as the user is floating inside the phantom accounting for scale and orientation. The ultrasound images of the needle are combined with a needle-tissue interaction model that predicts the needle deflection further along the insertion process. This platform allows the user to test different manual and robotically assisted needle steering techniques. Reported experimental results confirm the accuracy of the system in reconstructing and overlaying images onto the phantom.

Chapter 10 is titled "Neural Networks to Solve Nonlinear Inverse Kinematic Problems." This chapter proposes a new neural based learning approach to solve nonlinear inverse kinematic problems. The effectiveness of the proposed approach is demonstrated through simulations using kinematic models of a leg module with serial link structure and an industrial robot.

Chapter 11 is titled "Ant-Like Walking Behavior of MEMS Microrobot With Artificial Neural Networks." This chapter explains the development of MEMS microrobot system and how to mimic the alternating tripod gait of ant walking behavior using shape memory alloy-type rotary actuator and the link mechanism. The micro-electro systems mimic the electrical activity of biological neural networks using the artificial neural networks IC. The results show MEMS microrobot system could perform the ant-like walking behavior by a speed of 20 mm/min.

Chapter 12 is titled "Bio-Inspired Snake Robots: Design, Modelling, and Control." This chapter goal is to introduce the complexity and the fundamental design, modelling and control approaches for efficient snake robot locomotion in cluttered environments. As a contribution, the chapter presents shape-based modelling approaches and a number of available control schemes for operation in unknown environments are presented, which aims to motivate scholars to start working on snake robots. Some ideas about future research plans are also proposed to help operating in real world environment.

Chapter 13 is titled "Review of Friction and Surface Properties of Snakeskin." Natural systems tend to conserve energy; as such it is necessary to mitigate the effects of friction during motion. This chapter attempts to review the major findings about the tribology of the legless reptiles obtained through the last two decades.

Chapter 14 is titled "Kinodynamic Motion Planning for a Two-Wheel-Drive Mobile Robot." This chapter presents the development of kinodynamic motion planning to support convergence of the states of the two-wheeled mobile robot to an arbitrary target position while avoiding obstacles by combining the control based on the invariant manifold and the HPF.

Chapter 15 is titled "Discrimination of Dual-Arm Motions Using a Joint Posterior Probability Neural Network for Human-Robot Interfaces." This chapter describes a novel dual-arm motion discrimination method that combines posterior probabilities estimated independently for left and right arm movements, and its application to control a robotic manipulator. With this method, all the dual-arm motions consisting of each single-arm motion can be discriminated through leaning of single-arm motions only. The method was applied to the discrimination of up to 50 dual-arm motions and the results showed that the method enables relatively high discrimination performance.

Chapter 16 is titled "Off-Line Calibration of Autonomous Wheeled Mobile Robots: From Theory to Experiment." This chapter provides an overview of wheeled mobile robots (WMRs) mechanisms, differential drive and omnidirectional. In addition, it introduces an odometry-based method to correct the motion of both types of WMRs. Experimental results on four robots exhibited that positional error was significantly improved.

Chapter 17 is titled "A Real-Time Compressive Tracking System for Amphibious Spherical Robots." An improved RGB-D visual tracking algorithm with dual trackers is proposed and implemented in this

chapter. Compressive tracking (CT) was selected as the basis of the proposed algorithm to process color images from a RGB-D camera, and a Kalman filter with a second-order motion model used to predict the state of the target, select candidate patches or samples and reinforce the tracker's robustness to high-speed moving targets. A visible and infrared fusion mechanism or feedback strategy is introduced in the proposed algorithm to enhance its adaptability and robustness. Microsoft Kinect, which is a combination of color and depth cameras, was adopted for use in a prototype of the robotic tracking system.

Chapter 18 is titled "Self-Powered Height Sensor With ZigBee Networks for Intelligent Systems." A self-powered height sensing system with ZigBee technology is presented in this chapter. It specifically targets to replace an original wired system with an integrated wireless sensor which is comprised of all necessary parts: sensing module, processing module, RF transceiver and power supply. Experiments several were conducted to test and analyze the feasibility of the developed system.

Chapter 19 is titled "Analyzing the Goal-Finding Process of Human Learning With the Reflection Subtask." This chapter presents experimental results on analyzing the human's goal finding process in continuous learning. The objective of this research is to make clear the mechanism of continuous learning. To fill in the missing piece of reinforcement learning framework for the learning robot, the authors focus on two human mental learning processes, awareness as pre-learning process and reflection as post-learning process. To observe mental learning processes of a human, the authors propose a new method for visualizing them by the reflection subtask for human to be aware of the goal finding process in continuous learning with invisible mazes. The two-layered task is introduced. First layer is the main task of continuous learning designing the environmental mastery task to accomplish the goal for any environment. Second layer is the reflection subtask to make clear the goal finding process in continuous learning. The reflection cost is evaluated to analyze it.

Chapter 20 is titled "Designing the Learning Goal Space for Human Toward Acquiring a Creative Learning Skill." This chapter introduces the way to design the learning support system toward acquiring a creative skill on learning. There are two research goals. One is to establish designing the creative learning task and the other is to make clear the human sense of creativity.

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