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Editorial

Special Issue on Wearable Robotics: Dynamics, Control and Applications

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While initially conceived for human motion augmentation, wearable robots have gradually evolved as technological aids in motion assistance and rehabilitation. There are increasing real-world applications in industrial and medical scenarios. Though efforts have been made on wearable robotic systems, e.g. robotic prostheses and exoskeletons, there are still several challenges in kinematics and actuation solutions, dynamic analysis and control of human-robot systems, neuro-control and human-robot interfaces; ergonomics and human-in-the-loop optimization. Meanwhile, real-world applications in industrial or medical scenarios are facing difficulties considering effectiveness.

Following the open call launched on April 3, 2018, we guest editors collected 23 submissions; after a rigorous and careful reviewing process, finally 13 papers were selected to be included in this Special Issue. Content of the accepted papers spans from novel solutions for upper-limb or lower-limb exoskeletons, to wearable systems in industrial or medical scenarios.

Natali et al. presented the design of a soft modular lower limb exoskeleton within the XoSoft EU project to improve person's mobility. The study analyzed the human–exoskeleton energy patterns by way of the task-based biological power generation. The resultant assistance, in terms of power, was 10.9%±2.2% for hip actuation and 9.3%±3.5% for knee actuation. The control strategy improved the gait and postural patterns by increasing joint angles and foot clearance at specific phases of the walking cycle.

Wang et al. proposed a passive lower extremity exoskeleton with a simple structure and a light weight. During walking, pulling forces are generated through Bowden cables by pressing plantar power output devices by feet, and the forces are transmitted to the exoskeleton through a crank-slider mechanism to enable the exoskeleton to provide torques for the ankle and knee joints as required by the human body during the stance phase and the swing phase. When walking with the proposed exoskeleton at a speed of 0.5 m/s, it can save the most metabolic cost, reaching 13.63%.

Ercolini et al. introduced the latest prototype of the NEUROExos, which is a novel generation of upper-limb exoskeletons. The proposed prototype extends the field of application to assistance in activities of daily living. Experimental results showed that the NEUROExos devices exhibited clinically relevant performance in terms of reliability, safety, and effectiveness, thus laying the foundation for future development and clinical validation studies.

Zeiaee et al. studied the problem of optimizing the kinematic structure of an eight degree-of-freedom upper-limb rehabilitation exoskeleton. The problem was formulated as a constrained multi-objective optimization using a dexterity index. A novel method for solving inverse kinematics problem was used. The optimization results were used in the development of the second generation of Texas A&M upper-limb exoskeleton.

Cao et al. presented a lower-limb exoskeleton actuated by pneumatic muscle actuators. The system aims to assist either the elderly for muscle strengthening by conducting walking activities or the stroke patients during a rehabilitation training program. A global parameters optimization algorithm was proposed to automatically calculate the pre-defined object function and attain the most applicable parameters. Experimental studies were conducted and the results indicated the effectiveness of the proposed method.

Guo et al. discussed the issue of human–machine interaction which may potentially distort natural human motions if the artificial mechanisms overload the articular surfaces and constrain biological joint kinematics. The equivalent articular geometry is constructed from the beam deformations driven by knee motions, where the continuous deformations are estimated with strain data from the embedded sensors. Both simulated analysis and experimental validation are presented to justify the proposed method.

Aprigliano et al. investigated the effectiveness of a robot-mediated strategy aimed at promoting balance recovery after multidirectional slippages. The study tested the effectiveness of our robot-mediated strategy while older adults were asked to manage multidirectional slippages. Results showed that the assistive strategy is effective at promoting balance recovery in the sagittal plane, for both perturbing paradigms.

Ophaswongse et al. introduceed a novel active-assistive torso brace called Wheelchair Robot for Active Postural Support (WRAPS). It consists of two rings over the hips and chest connected by a 2RPS-2UPS parallel robotic device. The performance of WRAPS was evaluated in seated healthy subjects. The design of WRAPS suited well the subject's anthropometrics while supporting the weight of the torso. It indicateed the potential applicability of WRAPS to promote active-assistive trunk mobility in people who cannot sit independently because of trunk dysfunction.

Huo et al. discussed the control of an active ankle foot orthosis for paretic patients. The study introduced an adaptation interaction method to the basic proxy-based sliding mode control (PSMC) with an online adaptation of the proportional, integral and derivative parameters. A gait phase-based ankle reference generation algorithm was proposed to adjust the joint reference trajectory in real time. The experiments using the proposed system show better tracking results with respect to basic PSMC while guaranteeing the safety.

Mo et al. proposed a hierarchical safety control strategy for exoskeleton robots based on maximum correntropy Kalman filter and bounding box to ensure safe operation. Accurate joint angle prediction was obtained by filtering out non-Gaussian impulsive noise based on maximum correntropy criterion. The safety evaluation of the exoskeleton robot operation was realized according to the collision detection results of the hierarchical bounding box.

Emonds et al. established rigid multi-body system models with 14 bodies and 16 degrees of freedom in the sagittal plane for one unilateral transtibial amputee and three non-amputee sprinters. The motions of the amputee athlete and the non-amputee reference group were compared by computing characteristic criteria. The evaluation of the numerical results has shown that the amputee athletes applies larger torques and mechanical work in the arm joints than the non-amputee athletes.

Lou et al. proposed an inertial measurement unit (IMU)-based gait phase detection system for stroke patients. The experimental results showed that the system can be used to detect the gait phase of stroke survivors, which has been verified on five stroke survivors. All recognition accuracy results were above 96.5%, and detections were about 5–15ms in advance of time. In addition, using only one IMU can also give reliable recognition results.

Hong et al. designed a novel three-degree of freedom sensorized remote-center-of-motion (RCM) ankle module. The ankle exoskeleton was designed using two revolute-revolute-revolute spherical chains. The intersecting point of the rotation axes of all revolute pairs becomes the rotation center of the ankle mechanism. compared to the ankle mechanism with offset center of rotation, the proposed RCM ankle is applicable for sensing wearer's ankle motion and reducing mechanical interference to wearer's natural ankle motion.

We would like to thank all authors who submitted original papers to this special issue. We also would like to show our appreciation to reviewers who brought helpful comments. Finally, our thanks also go to the journal Robotica, particularly Prof. Chirikjian, for the approval of this successful special issue.

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