Guest Editorial

Introduction to the Focused Section on Biomimetics and Novel Aspects in Robotics

This issue presents a collection of 11 papers covering the themes of novel sensing and actuation, human–robot interfaces, mobile robots, and biomimetics. These represent the focus of the ten robotics sessions organized at the IMECE 2005. We believe that this Special Issue will provide a compilation of the most recent developments in these topics and will be an important source of information for researchers.

Two papers in this focused section examine novel sensing and actuation that form the basis for future high-performance robotic and mechatronic systems. There is a tremendous interest in self-sensing and self-regulating robotic and mechatronic systems. Odhner and Asada present a method for using thermoelectric devices (TEDs) together with a low-order estimator to achieve feedback control of a SMA Actuator array. In measuring the local temperature difference via the Seebeck effect and regulating the temperature via the Peltier Effect, such TEDs would not require other external temperature sensors, enabling the production of large yet compact TED-driven SMA actuators arrays. In addition, current self-powered robots require energy self-sufficiency and a power density that is beyond the current state of the art in battery technology. Fite and Goldfarb present a novel actuator, which employs flow of a liquid monopropellant over catalyst packs into the respective sides of a double-acting cylinder to provide power. Their paper presents detailed actuator design with a pair of proportional injector valves, a force controller, and subsequent energetic characterization of resulting actuator.

Two papers in this focused section discuss the advances in the state of the art in creating novel multimodal haptic user interfaces with emphasis on enhanced performance and passivity by mechanical system design or by control. Gao and Book examine the use of passive electromagnetic brakes to create dissipative haptic interfaces with enhanced motion redirection and force control. The paper focuses on a quantitative examination of the role of topology (serial or parallel), the system configuration, and redundancy in actuation for improving two-sided steerability of such systems. In most teleoperation/haptic manipulation, bidirectional interaction of human users tends to be highly asymmetric, with sensitivity to high bandwidth accelerations but a significantly smaller actuation bandwidth. With this observation, Tanner and Niemayer examine the creation of a control architecture that provides a natural ability to scale and shape the high-frequency content independent of the low-frequency force feedback and in doing so provides the ability to enhance perception and performance with the given tasks at the user interface while maintaining guarantees of passivity associated with wave variables.

Three papers in this focused section examine the use of mobile robots and mobile robot collectives in various unstructured terrains. Reina et al. note that ignoring slip, sinkage, and other wheel-terrain dynamic interactions is the principal cause of loss of odometric accuracy and other tractive performance in most mobile robot localization schemes. Hence, they implement a multimodal sensor-fusion approach which uses a new camera-based visual-sinkage estimator to provide deterministic detection of slip and sinkage especially on unpaved rough terrains. The other two papers focus on issues pertaining to modular mobile robot collectives to cooperatively achieve tasks not possible by individual robots alone. Huang et al. consider the automated deployment and maneuver of safety cones used in highway maintenance work zones focusing on the use of a heterogeneous group of simple inexpensive robots with minimal sensors. They present the development and experimental verification of a tracking-based localization method for the sensor and computationally limited robot collective following a more sophisticated leader in a desired formation over long distances. Tang et al., in contrast, examine cooperative payload transport by robot collectives in an “Army of Ants” approach. A systematic procedure was developed to analyze the mobility and disturbance rejection capabilities at the payload based on the architecture, interconnection, and actuation of the constituent individual mobile agents and validated on a hardware-in-the-loop test bed.

Four papers examine novel mechanical component and designs for realization of various biomimetic robotic systems—from integration of structure, sensing, and actuation in a monolithic compliant gripper; to a novel “design-for-control” autonomous biped; to a lower extremity exoskeleton for assistive walking; and design of flapping wing mechanisms to permit micro aerial vehicles (MAVs) to hover. Dollar and Howe describe the realization of novel single-piece compliant robotic graspers by shape deposition manufacturing (SDM) that mimic the integrated structural, sensing, and actuation functionality of the human hand. The paper presents the detailed design, fabrication, and staged validation of such integrated designs with elastomeric flexures, structural elements, and embedded sensor and actuator components within the polymeric matrix that provide enhanced robustness over conventional assembled prototypes for grasping in unstructured environments. Agrawal and Fattah take the unique approach of designing a planar biped such that its dynamic equations of motion are nearly linear by judicious placement of counterweights within the system. The resulting
system may be treated as nearly linear with nonlinear perturbations, which tremendously simplifies the development of nonlinear feedback-linearized controllers. Zoss et al. focus on the design architecture of Berkeley’s Lower Extremity EXoskeleton (BLEEX)—a powered leg exoskeleton that shadows the operator’s movement to enhance the overall load-carrying capabilities in rough, unstructured, and uncertain terrains. Various aspects of the design selection, in terms of sizing and placement of articulations and actuators for enhanced performance, are validated in the first-of-a-kind untethered energy-autonomous exoskeleton prototype. Finally, McIntosh et al. examine creation of a flapping wing design for an ornithopter/MAV to enable them to produce some of the basic insect wing motions. The paper discusses development and experimental validation of a compact light-weight mechanism to achieve such coordinated wing motions about two orthogonal axes confirming the availability of adequate lift for such flapping wing MAVs to hover.

We hope readers will find this focused section on Biomimetics and Novel Aspects in Robotics interesting and informative. As our editorial work comes to an end, we would like to express our deep appreciation to all the authors who supported this focused section by contributing papers. We are also grateful to all the reviewers for their service and commitment to the journal through rigorous reviews, timely response to the tight schedule, and above all, insightful and constructive comments that helped shape the final outcome. Last but not least, our sincere appreciation goes to the Editor-in-Chief, Prof. R. C. Luo, for his vision, support, and valuable advice throughout this process.

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