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GUEST EDITORIAL:

ROBOTICS AND AUTOMATION WITH BIOLOGICALLY INSPIRED INTELLIGENCE

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In the collection of this special issue is a set of 13 research papers selected, after two rounds of reviews, from a total number of 135 submissions. They are included in the special issue of the AutoSoft journal for their non-conventional approach towards engineering applications. Each of the selected papers investigates in a certain aspect into the development of biological inspired methods and their application in robotics and automation. The methods under investigation cover such soft computing techniques as neural networks, fuzzy logical, genetic algorithms, artificial intelligence, and machine learning; and the application areas range from robotics control to manufacturing automation. Together, these papers provide a broad coverage of the different aspects involved in the transfer of technology from lifeforms to engineering applications, including the mimicking of natural methods, imitation of biological mechanisms, and the study of behavioral principles.

The first paper in the special issue presents a focused research project by W. Won et al. on the visual perceptual capability of human-like robot systems. As suggested by the concept of Autonomous Mental Development (AMD), robots can, like human beings, increase knowledge of the surroundings by interacting with their working environment. In analog to the attention mechanism that allows human beings to treat interesting objects differently from other objects, an object-oriented visual attention model is presented in the paper for the proposed officemate system. This paper includes technical details of the proposed methods, and provides discussions as well on strategies to deal with computational complexity. Though the system is not yet functioning at a level close to human behavior, evidence from both indoor and outdoor experiments shows the advantages and potentials of human-like robot systems.

Another inquiry in the nature-mimicking category of technology transfer is presented by Zhong et al. in the next paper. Manufacturing in the computer promises great improvements on affordability, quality, productivity, flexibility, shorter cycle time, and customer relations. From the

technical point of view, this paper develops an approach to enable constraint-based manipulation of virtual objects with a hierarchically structured, constraint-based data model. More importantly, this work reveals not only the easy-to-identify similarity but also the hidden difference between natural methods and their repetition in the practice of manufacturing. While direct object manipulation in natural environment inspires the design of a three-dimensional (3D) human/computer interface that fully explores the creativity of product engineers, the elimination of physical objects in virtual environments can actually go beyond the reality. One typical example is the 3D constraints that are possible in the virtual but do not exist in the natural environment.

In comparison to the first group of two papers that investigates methods to reproduce human behaviors, the second group of nature-imitating papers works on the application of biological mechanisms. The challenges of robotics and automation have stimulated a large number of researchers to recreate the sophisticated and deliberate natural mechanisms in a wide range of engineering applications. Consequently, ten out of 13 papers in this special issue fall into the second category, which are further grouped into two sub-categories of control and automation.

First in the control group is the paper authored by S. Liu et al. After reviewing different types of tracking systems, this paper proposes a control scheme for dynamic tracking of mobile robots. It uses unsymmetrical Gaussian functions to modify the radial basis function neural networks for the handling of uncertainties in robot dynamics. The designed neural network controller works together with a robust compensator, thus providing the anticipated improvement of performance in tracking. A further investigation on the same subject is presented by A. Zou et al. in the following paper. As the focus shifts to plant uncertainties and external disturbances, fuzzy logic becomes the preferred technique for the authors. The proposed design uses the universal approximation property of fuzzy logic systems to deal with uncertainty in plant dynamics, and uses an adaptive compensator to suppress external disturbances and approximation errors. Backed up with experiments, the authors make a special guarantee that all signals in the closed-loop system are uniformly ultimately bounded.

For the tracking of multiple targets, the paper presented by L. Yang et al. discusses a technique based on antenna array and digital signal processing. Similar to weight changing in neural networks, the weighting coefficients of monopulse beams in Digital Beam Forming (DBF) change according to the angle error of signals. Consequently, a system may use monopulse beams to track targets. The capability of this system to track multiple targets, however, relies on the allocation of a DBF monopulse tracking model to each of the targets. Furthermore, when the targeted application area of tracking control changes from mobile robots to robotic manipulators, new challenges have to be dealt with, as discussed by Y. Wang et al. in their paper. As indicated by the title, their paper combines nonlinear robust control theory with neural network design. In the presented design, a neural network is used to identify plant uncertainties, and the effects on tracking performance attributable to the approximation errors of neural network are attenuated to a prescribed level by robust control.

There are also two papers in the sub-category of control that are not dealing with robots themselves, but working on methods either to resolve conflicting objectives in multi-sensor fusion as presented by S. Ou et al., or to avoid network congestion as presented by W. Liu et al. When conflicts exist in the mapping of multiple raw streams of sensory data to appropriate actions, S. Ou and the co-authors suggest to associate control actions with costs for a learning control algorithm to balance opposing objectives by minimize costs. Experiment with power management actions shows that not only policies produced by the proposed approach outperform hand-crafted policies, but the learned policies are also more robust in handling unscheduled events. For bandwidth allocation to be proportional fairness and asymptotical stability in network applications, W. Liu and the co-authors suggest heuristic fuzzy rules for a controller to

dynamically adjust algorithm parameters of the Kelly model. A genetic algorithm is then used to optimize the scaling gains of the fuzzy controller. The proposed approach is expected to avoid packet accumulation and improve performance.

The sub-category of automation in this special issue consists of four papers. Planning in a huge searching space has a well-known problem of automation due to high computational complexity. As a practical approach to deal with the complexity problem, the paper presented by C. Park and G. Wang suggests genetic algorithm for global search and Tabu for local search. After introducing a genetic encoding method and a search procedure, it uses the genetic algorithm to obtain a reasonable solution first. Tabu search then helps to improve the solution by changing the path order of each robot in nonshared region, and the priorities in shared region of multiple robots where collisions take places. Another approach, presented in the paper by Y. Gao, shows the advantage of directly imitating the interactions among antibodies and antigen stimulus of immune system. By using the interactions among the antibodies from inter/intra-robot, it designs an algorithm for immune-based static task allocation. The self-reinforcement learning of the antigen stimulus further allows autonomous cooperation among robots without deadlocks.

For more focused investigation on path planning, the paper presented by Y. Fu et al. proposes a method that uses a double-layered fuzzy logic to control both the speed and the turning angle of mobile robots. In particular, it introduces the concept of "virtual target" to help robots escaping from U-shape traps. The presented approach takes advantage of both the robustness of fuzzy logic and the "feel-action" behavior of physiology that utilizes driver's driving experience. Fuzzy logic, in combination with neural networks, also plays an important role in the last automation-related paper on multisensor fusion for path planning with obstacle avoidance as presented by W. Shi et al. This paper uses a precondition network and a conclusion network to match the preconditions and generate conclusions of fuzzy rules respectively. The proposed fuzzy-neural networks allow mobile robots to integrate inputs from multiple ultrasonic sensors for the recognition of environment and to avoid obstacles while planning for motion paths.

The last, but also very important, topic of research is on the study of behavioral principles. As the only one in this special issue that falls into this category, the paper by S. Bensmayl et al. investigates the use of neurophysiological theories for the modeling of cerebro-cerebellar learning in visuomotor transformation. The targeted area of application is on pinch and grip control, but the fundamental principle is based upon two theories of motor control, the Equilibrium Point theory of motor control and the differential neurocontroller theory, and two models of brain structures, the columnar organization of the cerebral cortex and the Marr-Albus-Ito theory of cerebellar learning. The convergence of the learning procedure was proved for human arm reaching movement, and the proposed approach is extended to model the human pinch movement by including biomechanics and muscle properties of the human thumb and index.

All the studies presented in this special issue are supported with experiments, mostly by means of simulation, and a few by theoretical proofs. The Guest Editors hope that the readers will find this special issue interesting and useful for either the included materials or the way that researchers receive inspiration from lifeforms. Special thanks go to the authors and reviewers of all the submitted papers. This special issue would not have been possible without their contribution and hard work. The Guest Editors would also like to express their gratefulness to Professor Mo Jamshidi, the Editor in Chief of the AutoSoft Journal, for his full support.

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