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Editorial

Special Issue on Human–Robot Interaction (HRI)

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Introduction to Special Issue

Human–robot interaction (HRI) is one of the most rapidly growing research fields in robotics and promising for the future of robotics technology. Despite the fact that numerous significant research results in HRI have been presented during the last years, there are still challenges in several critical topics of HRI, which could be summarized as: (i) collision and safety, (ii) virtual guides, (iii) cooperative manipulation, (iv) teleoperation and haptic interfaces, and (v) learning by observation or demonstration. In physical HRI research, the complementarity of the human and the robot capabilities is carefully considered for the advancement of their cooperation in a safe manner. New advanced control systems should be developed so the robot will acquire the ability to adapt easily to the human intentions and to the given task. The possible applications requiring co-manipulation are cooperative transportation of bulky and heavy objects, manufacturing processes such as assembly and surgery.

This HRI special issue includes papers that undergone a second review process after a selection among the best papers presented in 27th International Conference on Robotics in Alpe-Adria-Danube Region – RAAD 2018, that took place on June 6–8, 2018, at University of Patras, Greece.

As co-located humans and robots have to harmonize with each other's behavior, safety is the main guideline that should be followed by the roboticists. Collision avoidance and detection research[1,2] contributes toward this target and hence improves safety.[3] A collision detection algorithm, without using any external sensor signals, with closed control architecture that is based on repetitive tasks using dynamic time warping is presented by Gordić et al.[1] A modified dynamic time warping method was used that enables measurement comparison with the most similar section of the reference signal efficiently. The potential collision was identified by two decision rules based on the absolute difference between compared matched samples, and the eigenvalues of covariance matrix of matched samples. The method was experimentally validated on Denso VP 6242 and ABB IRB 120 6-axis industrial robots. Abdel-Nasser Sharkawy et al. proposed a method[2] for robot collisions detection and collided link identification using only robot joint position sensors. A multilayer feedforward neural network is designed and trained considering the dynamic decoupling of the manipulator's joints. The KUKA LWR was used to identify controlled collisions during experiments.

Virtual guides are an important tool for HRI, since the motion to complete the task is constrained, to avoid collisions with the environment and simultaneously to improve the dexterity of the system avoiding singular points. A kinesthetic teaching framework that assists the human to program 6D virtual guide constraints using virtual mechanisms and splines is presented by Restrepo et al.[4] The method enables users, without robotics expertise, to create virtual guides by demonstration or modify a portion of the guide by iterative reprogramming. The method is experimentally evaluated with several users in tasks that combine position and orientation constraints, simulating the complexity of some manufacturing tasks such as glue depositing and joint installation (automobile industry), grinding, and polishing.

A unified virtual guides framework is presented by Žlajpah and Petrič[5] that assists operators to perform a cooperative task, where an accurate motion or heavy load manipulation is required and/or

*Please be aware not all papers mentioned in this Editorial are included in this Special Issue. Those included in this issue can be found in the References at the end of the Editorial.

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where human cognitive skills are needed due to the unstructured environment. Their approach is based on admittance control, applied to any position-controlled robot with mounted force/torque sensor at the end-effector and the developed system has been validated by experiments. Virtual fixtures, variable impedance control, and dynamic movement primitives are used synergistically to program a robot by demonstration in order to execute autonomously discrete motion tasks (Papageorgiou et al.[6]). The primitives encode the demonstrated trajectory and synchronize with the current demonstration from the user so that the generated reference motion follows the human's demonstration. The virtual fixtures assist the user in repeating the learned kinematic behavior. The framework is evaluated experimentally for a pick and place task.

A real-time online trajectory generator that constrains translational and rotational magnitude values in a singularity-free formulation is presented by Huber and Wollherr[3] to increase the safety of human–robot collaboration. The method is based on the Magnus Expansion that allows resolving the differential equations on SO(3) with high accuracy. Simulations as well as experiments on a hardware platform show the utility of the method in Human Robot Collaboration contexts.

A framework for cooperative transportation by human and robotic coworkers is presented by Alevizos et al.[7] It is based on a prescribed performance estimator that estimates robustly complex trajectories determined by the human leader. Human effort is reduced by the impedance characteristics adaptation combined with the motion intension estimation, while an adaptive scheme is used to relax the uncertainty in the object dynamics. Multiple robotic coworkers were considered in order to cover transportation tasks involving heavy and bulky objects.

An imitation framework by observation for the speed adaptation of a robot by demonstrated actions of arm motions is presented by Koskinopoulou et al.[8] The described framework has been employed in the execution of a realistic service scenario. An optimal controller based on manipulability for master–slave robotic systems is presented by Torabi et al.[9] The performance of the controller is evaluated via a comparison with two other existing control strategies. Simulation and experimental studies are implemented to validate the performance of the proposed control strategy.

The presented approaches contribute significantly to the scientific research toward the advancement of HRI. Meanwhile, real-world HRI cases, of industrial and service robotics, are limited due to the difficulties of applied effectiveness and readiness of available robotic systems. Thus, the necessity of continuous and qualitative research is of great importance. Therefore, we believe that this special issue on HRI can be an interesting reference on the topics of HRI for the robotics research and development community as well as a source of inspirations for future developments and scientific achievements.

We thank the authors contributed with excellent papers covering challenging topics of HRI. We are grateful to the reviewers for their time and efforts in the evaluation of the papers, and their comments toward improving the quality of the special issue. Finally, we would like to thank the Publisher and Editorial staff of *Robotica* journal and particularly editor-in-chief Prof. Gregory Chirikjian for accepting our proposal and helping the process and publication of this special issue.

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