Session Overview
Physical Human-Robot Integration and Haptics

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Machines and robots in the near future will share environments, and often come directly in touch with humans. This is to happen in several applications domains, including domestic applications (domotics), entertainment, assistance, cooperative manipulation tasks, teleoperation, human augmentation, haptic interfaces and exoskeletons. Physical Human-Robot Interaction (pHRI) poses many challenges, which can be summarized by the dichotomy *safety vs. performance*. The first and foremost concern, indeed, is that the robot must not hurt humans, directly nor indirectly, in regular operations nor in failures. Second, the machine is expected to perform swiftly and effectively its tasks in the service to humans.

As a consequence of this priority inversion, machines interacting with humans have different requirements than those currently met in industrial robots: while accuracy is less demanding, safety of operations is a must. Furthermore, the definition of *performance* is to be rethought, being sometimes the machine intended for quite different tasks than conventional industrial robots.

This session was designed to explore the safety and performance aspects of pHRI. The first paper, *A Unified Passivity Based Control Framework for Position, Torque and Impedance Control of Flexible Joint Robots* by Alin Albu-Schäffer, Christian Ott and Gerd Hirzinger, discusses how to effectively control a high-performance robot arm designed to minimize risks of impact with humans by reducing its inertia, and allowing joint compliance. Compare this with the traditional approach of controlling stiff and heavy arms so as to appear compliant, and consider the degree of fault tolerance of the two approaches.

The focus of three papers in this session was on design and control of high-performance haptic devices. Here, performance is to be intended at a broader, "system" level than coventionally done in robotics: indeed, the system includes both the machine and the human. The goal of haptics is that of stimulating tactile perceptions of the operator so as to provide a realistic and compelling sensation of being in touch (literally) with a remote or virtual environment.

In *Wave Haptics: Encoderless Virtual Stiffnesses*, by G. Niemeyer, N. Diolaiti, and N. Tanner, the difference between specifications of a haptic interface from those of classical servomechanisms is considered. Accordingly, a control scheme that exploits some physical behaviours of the actuation system, rather than counteracting them by imposing the controller authority, is shown to provide definite advantages. In *Reality-based Estimation of Needle and Soft Tissue Interaction for Accurate Haptic Feedback in Prostate Brachytherapy Simulation*, by J. T. Hing, A. D. Brooks, and Jaydev P. Desai, an interesting application to medical training is reported where the need for an objective interaction performance evaluation is preheminent. Finally, in *Haptic Virtual Fixtures for Robot-Assisted Manipulation*, by J. J. Abbott, P. Marayong, and A. M. Okamura, it is shown how software-generated force and position signals are applied to human operators to improve the safety, accuracy, and speed of robot-assisted manipulation tasks.