ROBOTS AND THE HUMAN

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Robotics is rapidly expanding into the human environment and vigorously staying engaged in its emerging challenges. From a largely dominant industrial focus, robotics has undergone, by the turn of the new millennium, a major transformation in scope and dimensions. This expansion has been brought about by the maturity of the field and the advances in its related technologies to address the pressing needs for human-centered robotic applications. Interacting, exploring, and working with humans, the new generation of robots will increasingly touch people and their lives, in homes, workplaces, and communities, providing support in services, entertainment, education, manufacturing, personal health care, and assistance. The successful introduction of robots in human environments will rely on the development of competent and practical systems that are dependable, safe, and easy to use. This presentation focuses on the efforts to develop human-friendly robotic systems that combine the essential characteristics of safety, human-compatibility, and performance with emphasis on (i) new design concepts and novel sensing modalities; (ii) efficient planning and whole-body robot control strategies; and (iii) robotic-based synthesis of human motion and skills.

In human-friendly robot design, our effort has focused on the development of intrinsically safe robotic systems that possess the requisite capabilities and performance to interact and work with humans. The novel design concept was based on a hybrid actuation approach that consists of biomimetic pneumatic muscles combined with small electric motors. The flexible muscles and the lightweight mechanism allow for human safety, while the electric motors compensate for the slower dynamics and nonlinearities of the pneumatics. This concept was shown to significantly decrease the inherent danger of robotic manipulators, as measured in terms of the reflected mass perceived at the point of impact. Safety can be further enhanced by the addition of robot skin to provide impact reduction and tactile sensing capabilities for advanced sensor based behaviors.

Redundancy is a major challenge in the planning and control of humanoid robots. Inspired by human behaviors, our early work in robot control encoded tasks and diverse constraints into artificial potential fields capturing human-like goal-driven behaviors. To implement such behaviors on robots with complex human-like structures we developed a unified whole-body task-oriented control structure that addresses dynamics in the context of multiple tasks, multi-point contacts, and multiple constraints. The performance and effectiveness of this approach have been demonstrated through extensive robot dynamic simulations and implementations on physical robots for experimental validation. The new framework provides a multi-task prioritized control architecture allowing the simultaneous execution of multiple objectives in a hierarchical manner, analogous to natural human motion.

Initially motivated by the development of human-like skills in robotics, our extensive study of human musculoskeletal system has brought insights and results that proved extremely valuable in human biomechanics. Understanding human motion is a complex procedure that requires accurate reconstruction of movement sequences, modeling of musculoskeletal kinematics, dynamics, and actuation, and suitable criteria for the characterization of performance. These issues have much in common with the problems of articulated body systems studied in robotics research. Building on methodologies and techniques developed in robotics, a host of new effective tools have been established for the synthesis of human motion. These include efficient algorithms for the simulation of musculoskeletal systems, novel physio-mechanical criteria and performance measures, real-time tracking and reconstruction of human motion, and accurate human performance characterization. These developments are providing new avenues for exploring human motion -- with exciting prospects for novel clinical therapies, athletic training, and performance improvement.

Biography of Oussama Khatib

Oussama Khatib received his Doctorate degree in Electrical Engineering from Sup'Aero, Toulouse, France, in 1980. He is Professor of Computer Science at Stanford University. His current research, which focuses on human-centered robotics, is concerned with human motion synthesis, humanoid robotics, haptic teleoperation, medical robotics, and human-friendly robot design. His research in these areas builds on a large body of studies he pursued over the past 25 years and published in over 200 contributions. Professor Khatib has delivered over 50 keynote presentations and several hundreds of colloquia and seminars at institutions around the world. He served as the Director of the Stanford Computer Forum, a corporate affiliate program. He is Co-Editor of the STAR series, the Springer Handbook of Robotics, and has served on the Advisory and Editorial Boards of several journals, as well as Chair or Co-Chair for numerous international conferences. He is a Fellow of IEEE and has served RAS as a Distinguished Lecturer and as a member of the Administrative Committee. Professor Khatib is the President of the International Foundation of Robotics Research (IFRR) and a recipient of the Japan Robot Association (JARA) Award in Research and Development and the IEEE Robotics and Automation Society Pioneer Award.