

TITLE: Kinematically Redundant Robots: The Promise of Human-Like Dexterity

ABSTRACT: The vast majority of robots in use today operate in very structured environments, e.g., in factory assembly lines, and possess only those limited motion capabilities required to perform specific tasks. While these robots can outperform humans in terms of speed, strength, and accuracy for these tasks, they are no match for the dexterity of human motion. Part of a human's inherent advantage over industrial robots is due to the large number of degrees of freedom in the human body. Articulated, i.e., jointed, motion systems that possess more degrees of freedom than the minimum required to perform a specified task are referred to as kinematically redundant. In an effort to mimic the dexterity of biological systems, researchers have built a number of kinematically redundant robotic systems, e.g., anthropomorphic arms, multi-fingered hands, dual-arm manipulators, and walking machines. While these systems vary in their appearance and intended applications, they all require motion control strategies that coordinate large numbers of joints to achieve the high degree of dexterity possible with redundant systems. This talk will discuss the issues that arise when designing such strategies, frequently drawing on the use of the singular value decomposition, including the characterization of redundancy, the quantification of dexterity, and the development of efficient and numerically stable motion control algorithms that simultaneously optimize multiple criteria.

TITLE: Designed to Fail: Robotic Systems That Gracefully Degrade in Performance

ABSTRACT: Operations in remote or extremely hazardous environments, e.g., in space, underwater, or in nuclear/chemical waste sites, are frequently performed by robotic devices. Unfortunately, the very nature of these environments makes the probability of a failure in the mechanical or electronic hardware of the robot more likely. Because by definition the operating environment precludes the intervention of a human to repair or retrieve the device, fault tolerance becomes a critical issue. By fault tolerance it is meant that damage to any portion of the robotic system, such as the mechanical actuators, control electronics, sensors, etc., will not render the system uncontrollable. A damaged fault tolerant system can be operated, albeit in a somewhat degraded capacity, to complete the assigned task or at a minimum to retrieve the robotic device without compromising the working environment. This presentation will focus on two approaches for designing failure tolerant robotic systems. The first is to develop software that can control robots of an arbitrary design to achieve maximum fault tolerance. This would allow the use of conventional manipulators to their maximum capability, regardless of the extent of the damage to the device. The second is to design robotic arms with kinematic redundancy that maximizes the dexterity and maneuverability of the arm after the occurrence of a fault.