



## Key lectures



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**Oussama Khatib** received his PhD from Sup'Aero, Toulouse, France, in 1980. He is Professor of Computer Science and Director of the Robotics Laboratory at Stanford University. His research focuses on methodologies and technologies in human-centered robotics including humanoid control architectures, human motion synthesis, interactive dynamic simulation, haptics, and human-friendly robot design. He is a Fellow of IEEE. He is Co-Editor of the Springer Tracts in Advanced Robotics (STAR) series and the Springer Handbook of Robotics, which received the PROSE Award for Excellence in Physical Sciences & Mathematics. Professor Khatib is the President of the International Foundation of Robotics Research (IFRR). He has been the recipient of numerous awards, including the IEEE RAS Pioneer Award in Robotics and Automation, the IEEE RAS George Saridis Leadership Award in Robotics and Automation, the IEEE RAS Distinguished Service Award, the Japan Robot Association (JARA) Award in Research and Development, and the IEEE Technical Field Award.

### Ocean One: A Robotic Avatar for Oceanic Discovery

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#### Abstract

The promise of oceanic discovery has intrigued scientists and explorers for centuries, whether to study underwater ecology and climate change, or to uncover natural resources and historic secrets buried deep at archaeological sites. The quest to explore the ocean requires skilled human access. Reaching these depths is imperative since factors such as pollution and deep-sea trawling increasingly threaten ecology and archaeological sites. These needs demand a system deploying human-level expertise at the depths, and yet remotely operated vehicles (ROVs) are inadequate for the task. A robotic avatar could go where humans cannot, while embodying human intelligence and intentions through immersive interfaces. To meet the challenge of dexterous operation at oceanic depths, in collaboration with KAUST's Red Sea Research Center and MEKA Robotics, we developed Ocean One, a bimanual force-controlled humanoid robot that brings immediate and intuitive haptic interaction to oceanic environments. Teaming with the French Ministry of Culture's Underwater Archaeology Research Department, we deployed Ocean One in an expedition in the

Mediterranean to Louis XIV's flagship *Lune*, lying off the coast of Toulon at ninety-one meters. In the spring of 2016, Ocean One became the first robotic avatar to embody a human's presence at the seabed. This expedition demonstrated synergistic collaboration between a robot and a human operating over challenging manipulation tasks in an inhospitable environment. Tasks such as coralreef monitoring, underwater pipeline maintenance, and offshore and marine operations will greatly benefit from such robot capabilities. Ocean One's journey in the Mediterranean marks a new level of marine exploration: Much as past technological innovations have impacted society, Ocean One's ability to distance humans physically from dangerous and unreachable work spaces while connecting their skills, intuition, and experience to the task promises to fundamentally alter remote work. We foresee that robotic avatars will search for and acquire materials in hazardous and inhospitable settings, support equipment at remote sites, build infrastructure for monitoring the environment, and perform disaster prevention and recovery operations- be it deep in oceans and mines, at mountain tops, or in space.