CPS: Breakthrough: Collaborative Research: Cyber-Physical Manipulation (CPM): Locating, Manipulating, and Retrieving Large Objects with Large Populations of Robots

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Project Details

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Abstract: This project develops the theory and technology for a new frontier in cyber-physical systems: cyber-physical manipulation. The goal of cyber-physical manipulation is to enable groups of hundreds or thousands of individual robotic agents to collaboratively explore an environment, manipulate objects in that environment, and transport those objects to desired locations. The project embraces realistic assumptions about the communication, computation, and sensing capabilities of simple individual robots, leading to algorithmic solutions that intrinsically leverage population size in favor of complex agents. Cyber-physical solutions for locating, grasping, and characterizing objects require tools based on distributed computational geometry, while the tasks of planning a path, initiating motion, and controlling the trajectory require tools from decentralized control and consensus. The project lays the theoretical and algorithmic foundations of cyber-physical manipulation, and proves the feasibility of the concept experimentally in hardware tests with up to 100 individual robots. The project uses the problem of manipulation as a stage on which to explore the deeper cyber-physical issue of information asymmetry; the difference in the state of the world as perceived by different agents in the system due to differences in their history of observations, and limitations in their communication capabilities. The object retrieval problem studied in this project is an elemental building block for enabling more complex cyber-physical manipulation tasks. It provides crucial algorithmic components for numerous applications of broad societal benefit, including automated construction (in which hundreds or thousands of robots fabricate large, complex structures), autonomous emergency response (in which large teams of robots find and retrieve incapacitated human survivors after a disaster), and automated environmental cleanup (in which robots secure a dangerous environment by removing debris or hazardous substances). Furthermore, distributed algorithms for multi-agent systems are of broad scientific relevance beyond the realm of cyberphysical systems. The natural world is, in its algorithmic essence, decentralized at many levels. Hence, any advancement in the understanding of how groups of individual agents collaborate to accomplish a coherent task will have broad scientific ramifications. The project has a robust educational and outreach program. One aspect is a hands-on curriculum for robotics outreach activities, called the 'Cyber-Physical Manipulation Lab.' Using a custom-designed robot platform, this educational module introduces the theory and practice of cyber-physical systems to young students to attract them to STEM subject areas

at an early age. Results of the project are also incorporated into several graduate and undergraduate level courses at Rice University and Boston University.

CPS Domains Platforms Control Robotics CPS Technologies Foundations