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Understanding and exploiting natural dynamics for highly dynamic motion of underactuated robots

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Humans and animals are capable of overcoming complex terrain challenges with graceful and agile movements. One of the key ingredients for such complex behaviors is motion coordination to exploit their natural dynamics. Sports performers coordinate their action in many different ways to achieve their goals. Coordination is a key feature in highly dynamic maneuvers ranging from the graceful, precise action of an ice dancer to the explosive, physical power of a triple jumper. Lizard coordinates its tail swing to stabilize its dynamic motion over rough terrain. Cheetah can rapidly accelerate and maneuver during the pursuit of its prey by the coordinating of the motion of its tail. Understanding and emulating these motions is one of the long-standing grand challenges in robotics and biomechanics with possible applications in rehabilitation, sport, search-and-rescue, environmental monitoring and security. Despite the existence of powerful tools such as nonlinear trajectory optimization, they are usually treated as black boxes that provide local optimal trajectories. We introduce the Dynamical Coupling Map (DCM), a novel graphical technique, to help gain insight into the output trajectory of the optimization and analyze the capability of underactuated robots. As examples of dynamic maneuvers, the DCM analysis is demonstrated on the swing-up motion of a simplified model of a gymnast on high bar as well as a vertical jump for a high-dimensional humanoid robot with arms swing. The DCM shows graphically and intuitively the pivotal role of exploiting the natural dynamics in order to exceed their physical capacity which is dictated by the input torques limits. We also extend the current posteriori analysis to exploiting the natural dynamics as a priori for guiding motion generation of highly dynamic maneuvers.

Biography

Ziad Zamzami is currently a PhD candidate at the Sorbonne Universités-University of Pierre and Marie Curie (UPMC) in Paris, France and a Member of the Institute of Intelligent Systems and Robotics (ISIR). He holds a Master's degree in Advanced Systems and Robotics (SAR) from the UPMC. He holds a BSc and MSc in Material Science and Mechanical Engineering from the University of Mulhouse, France in the framework of the joint double degree program with the French University of Egypt. He has participated in several projects including; Fast Autonomous Rover SysTem (FAST) project funded by the French National Research Agency (ANR) and more recently on the FRAUDO Project in partnership with the French Atomic Energy Commission (CEA) and the French Defense Research Projects Agency (DGA). His research interest includes motion planning, trajectory optimization, underactuated robotics and multibody dynamics.

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