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WAVE-BASED MOTION CONTROL OF FLEXIBLE SPACE SYSTEMS

Abstract

Wave-based control is a relatively new way to design motion control systems for under-actuated flexible mechanical systems. It has several attractive properties, including robustness to un-modelled system dynamics, robustness to non-ideal actuator behaviour, and reduced sensing requirements. It seamlessly integrates motion control of under-actuated flexible systems with active vibration damping, in a generic, easy-to-implement, way. The main idea is to consider the actuator as launching a mechanical "wave" into the system, that is, launching a disturbance that propagates through the system. Sooner or later the effects of the disturbance find their way back to the actuator, where they are detected and absorbed. To implement the controller, no detailed system model is needed. Neither do modes of vibration need to be measured or estimated. Instead, the interaction between the actuator and the part of the system to which it is attached is monitored and resolved, in real time, into counter-propagating mechanical waves, entering or leaving the system at the actuator-system interface. This resolving is done using two measurements, which can be processed through low-order transfer functions, in a simple way. The actuator controller decides on a launch "wave", to which it adds the measured returning wave, and their sum becomes the control law for the actuator. For rest-to-rest motion, for example, the launch wave should have a net displacement of half the target displacement. In the absence of external disturbances, the addition of the measured returning wave to the actuator's motion moves the system the second half of the target displacement, while absorbing all vibration. The returning wave sees a matched mechanical impedance at the actuator and is absorbed out of the system. The implementation does not have to be perfect. Within reasonable limits, as the actuator performance falls, the degradation of control performance is remarkably gradual. Wave-based control has been successfully applied to flexible robots, cranes, and materials handling, among many other fields. But it is particularly well-suited to space applications, including attitude control of large space structures and debris control using elastic tethers. Currently a wave-based toolbox is being developed under a contract with ESA where the main application is robust control of launchers with significant structural flexibility and sloshing of on-board liquid propellant. Previous ESA contracts applied wave-based control to models of the planned International X-ray Observatory and to the DELIAN robotic arm for planetary rovers. The technique will shortly be space-tested on a 2-unit cubesat.