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Applications of passivity theory to the active control of acoustic musical instruments

Edgar Berdahl[a], Guenter Niemeyer[b] and Julius Smith[a]
[a]Stanford Univ., Center for Computer Research in Music and Acoustics (CCRMA), Dept. of Music, Stanford, CA 94305-8180, USA
[b]Stanford Univ., Mech. Eng., Bldg. 530, Stanford, CA 94305, USA

The dynamic behavior of any acoustic musical instrument can be modified by closing a feedback loop around even a single sensor and actuator. The ultimate goal is to make the acoustics of the instrument programmable by way of a digital feedback controller, while the instrument retains its tangible form. In this talk, we describe a class of controllers that are applicable to passive acoustic musical instruments, and we present sound examples from laboratory experiments on a vibrating string. First, we briefly introduce positive real functions. Next, we design positive real controllers allowing the quality factor and resonant frequency of instrument modes to be individually controlled. Because positive real controllers are passive, they are stable if the instrument is passive. This means that neither a full instrument model nor complete state measurements are required. Finally, we describe a class of simple passive nonlinear controllers that can emulate various kinds of friction, stiffening and softening springs, etc. Passivity of these controllers follows from the local passivity of the controller components. Controller parameters may often be tweaked so that the controllers are no longer passive but still perform useful functions, such as bowing emulation.