The Changing Picture of Nonlinearity in Musical Instruments: Modeling and Simulation

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The standard model of the functioning of a musical instrument, namely that of a linear resonator (such as a string, acoustic tube, bar, membrane or plate) subject to a nonlinear excitation mechanism (such as a hammer, bow, or lip/reed) is a powerful one indeed. Such a formalism, through the application of the apparatus of linear system theory to the resonator, leads not only to ease in terms of analysis of the instrument as a whole, but also to efficient simulation designs, where the resonator may be modelled in terms of modes, or travelling waves, or in an input- output sense. In the past 20 or so years a more detailed picture of the resonator has emerged, involving nonlinear refinements to the model of the resonator, and leading to various perceptual effects: pitch glides in strings and membranes, phantom partial generation in strings, crashes in plate/shell based percussion instruments, brassiness in high-amplitude brass instrument playing, and finally, effects due to distributed collision as in the case of the sitar and snare drum. The range of phenomena to be investigated is thus greatly increased—and yet simulation becomes a much more challenging undertaking. In this talk, unifying features of (and distinctions among) such nonlinearities are discussed, particularly with regard to the problem of simulation, in the context of both model validation and physically-based sound synthesis.