

Realistic Guitar Modelling using a Dynamical Multibody Approach

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ABSTRACT

Most musical instruments consist on a set of dynamical subsystems connected at a number of constraining locations, through which the vibratory energy flows or tuning can be achieved. Coupling is therefore an essential feature in instrument modelling and, when addressing physically-based synthesis, most modelling and computational difficulties are connected with the manner in which the coupling constraints are enforced. Typically, these are modelled using standard techniques such as Lagrange multipliers or penalty methods, each one with specific merits and drawbacks. In this paper we explore an approach based on the Udwadia-Kalaba (U-K) formulation, originally proposed in the early 90s for discrete constrained systems, which is anchored on analytical dynamics but avoids the use of Lagrange multipliers. Up to now, this general, very elegant and appealing formulation has been nearly exclusively used to address conceptual systems of discrete masses or articulated rigid bodies, namely in robotics. In a recent publication - Antunes & Debut, JASA (2017, in print) - we developed an extension of the U-K formulation to deal with flexible systems modelled through their unconstrained modes. We explored the potential of combining the U-K formulation for constrained systems with the modal description of flexible structures, in order to achieve reliable and efficient computations of the dynamical responses. This modelling approach was shown to be particularly effective, in particular for simulating the transient responses of musical instruments, as demonstrated by computing the dynamical responses of a guitar string coupled to the instrument body at the bridge. In the present paper we further generalize our computational model by incorporating all the guitar strings with both their motion polarisations, as well as the geometrical nonlinear string effects using the Kirchoff-Carrier (K-C) simplified approach. The illustrative results presented highlight the coupling of the various strings and body dynamics through the instrument bridge, and also emphasize the significance of string nonlinearity in the responses of plucked string instruments, which often lead to audible modal coupling terms and frequency gliding effects. The results presented complement extensive work already performed in the past by the authors on guitar string modelling using penalty methods, thus enabling an interesting comparison between the computational efficiency using different modelling techniques.