Modelling string vibrations with unilateral impacts in fretted musical instruments through the modal Udwadia-Kalaba approach

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Abstract. Following our previous work on the Udwadia-Kalaba (U-K) dynamical formulation as applied to musical instruments, we explore here the possibility of modeling the vibro-impact string motions in fretted instruments. The frets, distributed along the fingerboard, are modelled in terms of auxiliary oscillators intermitently coupled to the string allowing different types of contacts. Illustrative numerical simulations are presented by considering a fretted monochord.

Introduction

The nonlinear interaction of a vibrating string against an obstacle has recently called for a large body of research for simulation and sound synthesis of stringed musical instruments. For modelling contact, most of the methods presented so far adopt a penalty approach together with sophisticated discretization methods [1, 2, 3], or numerical techniques from nonsmooth contact dynamics [4]. Alternatively, the present authors demonstrated that reliable simulations of flexible systems involving point-constraints, either linear [6] or intermittent [7], can be carried out by using the Udwadia-Kalaba equation [8], which expresses the dynamics of the constrained system through a single dynamical matrix equation including constraints. Following our efforts in musical instrument simulation, this work places the focus on the implementation of the string nonlinear impact interactions with the multiple frets of a guitar within the modal U-K framework.

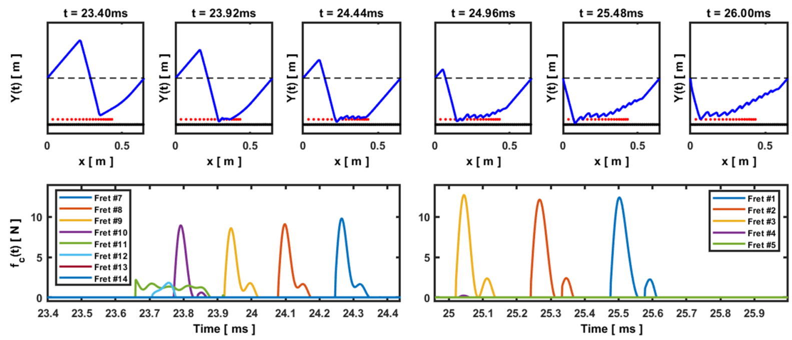

Figure 1: Computed snapshots of string motion against a set of 19-fret (distributed to allow chromatic playing) on a fingerboard together with the computed contact forces.

Results and discussion

The contact force is computed at each time step from the string modal motion and its calculation includes a condition of constraint release when the contact force changes from compression to traction. To deal with the spatial extent of the system, we keep track of the current contact configuration, and update the constraint matrix whenever a contact is detected or released. Because constraints are applied at the acceleration level, an accumulative drift can be observed in the computed motion and special care has been taken in the numerical integration by implementing the constraint violation elimination technique [9]. Figure 1 presents simulations results, where patterns in the contact force are highlighted, that seem quite realistic as are the resulting sounds.

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