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Measurements and sound synthesis of a guitar string re-excitation

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Abstract: One of factors that have an impact on the sound of a guitar is a state of its string at the moment of its excitation. When a string is excited while still vibrating, such phenomenon is referred to as re-excitation. It is known to affect the sound of an instrument, and therefore it is sometimes implemented in sound synthesis methods based on physical-modelling, but its nature has not been well-studied due to practical problems in measuring real instruments' behaviour in controllable, repeatable environment. The paper presents results obtained with a unique test stand equipped with a guitar-playing robot designed for measurement purposes. The stand facilitates a precise control over amplitude, location and time of excitation, which allows to carry out the research on re-excitation. One of the most flexible approaches to physical modelling applied in sound synthesis is the finite difference method. Therefore the measurements are compared to FD string models in order to fine-tune settings of the experiment, and ultimately, to verify behaviour of particular models.

Keywords: physical modelling, finite difference method, sound synthesis, guitar, robot

1. Introduction

Sound synthesis based on physical modelling methods attempts to identify and simulate phenomena related to sound production. Of primary concern are these that allow to control parameters responsible for perceivable sound effect – either related to instrument itself, or its excitation. For the purpose of simplification and efficiency, sound synthesis often assumes that an instrument does not vibrate during excitation. Only relatively recent concatenative and physical modelling synthesis methods allow to model re-excitation, ie. implement dependence of sound characteristics on the vibrations of a string at the moment of its excitation (Fig. 1). However, such modelling requires relevant experimental data. Therefore a laboratory stand equipped with a guitar playing robot has been developed. The robot (Fig. 2) excites a string at a precise moment of time, at specified location, with adjustable and repeatable amplitude [1] facilitating a degree of control over phase and harmonics.

Various finite difference schemes have been applied to model a guitar string, starting with a frequency-dependent damped stiff string [2]:

$$\frac{\partial^2 u}{\partial t^2} = \gamma^2 \frac{\partial^2 u}{\partial x^2} - \kappa^2 \frac{\partial^4 u}{\partial x^4} + 2\sigma_0 \frac{\partial u}{\partial t} + 2\sigma_1 \frac{\partial^3 u}{\partial t \partial x^2} \tag{1}$$

where u represents displacement, γ is a cumulative material parameter, κ controls stiffness, σ_0 and σ_1 are responsible for damping. Output of a model was used for initial setting of spatial and temporal parameters of excitation in test stand. In turn, results of measurements were used to adjust model parameters and to verify behaviour of its elements.

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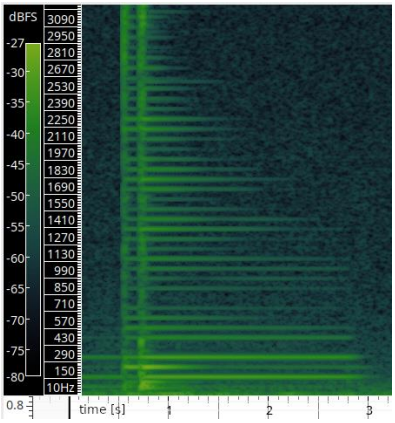

Fig. 1. Spectrogram of a recording of re-excited guitar string

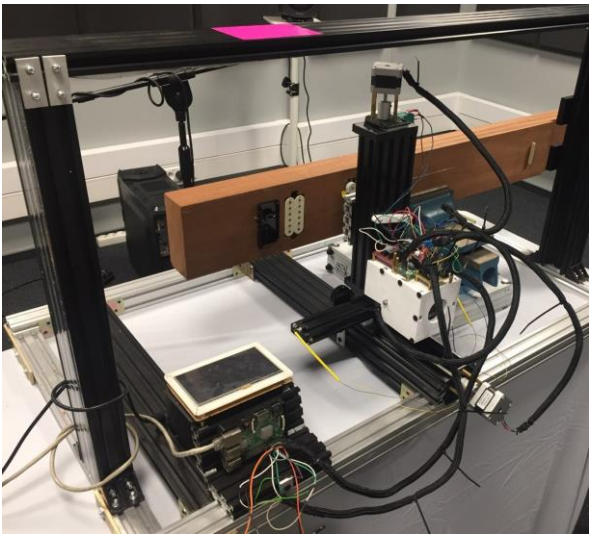

Fig. 2. The stand with a guitar-playing robot in configuration with a simplified electric guitar

References

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