Self-Sensing Transducers for Tactile Interaction with Digital Musical Instruments

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***Abstract*— The haptic instruments presented use a novel method of self-sensing to provide bidirectional tactile interaction. A single voice coil transducer can be used for exciting resonant synthesis models while simultaneously providing vibrotactile feedback to the musician.**

***Index Terms*—** vibrotactile, self-sensing, haptics, tactile

I. INTRODUCTION

Exciter-resonator instrument design – where a resonant synthesis model uses an audio-rate excitation input from an acoustic pickup or microphone – is already a well established practice for digital instrument designers [1]. Within the tactile domain, this interaction tends to be unidirectional, as the introduction of vibrotactile haptic feedback creates a feedback loop that can become unstable when vibrations are picked up by the input sensor [2]. While such feedback loops can create interesting musical outcomes, the control and reduction of this feedback loop can enable a wider variety of interactions. In the instrument designs presented, seen in Figure 1, a single voice coil transducer is used as a sensor and vibrotactile actuator simultaneously. Impedance modelling is used to reduce unstable feedback.

II. SELF-SENSING

Previous research has introduced a technique that utilises a single voice coil transducer as both a sensor and actuator simultaneously [3]. This system enables sensing of audio-rate percussive hits (with the voice coil acting as a dynamic microphone) alongside sensing the amount of damping applied to the transducer by measuring changes in its electrical impedance, all with simultaneous vibrotactile feedback.

Feedback from the actuation signal to the sensed input signal is cancelled by modelling the transducer's impedance with digital filters. By applying this filter model to the actuation signal and subtracting the modelled signal from the sensed input signal, the feedback is reduced. While this technique gives the option of reducing feedback to avoid instability, the imperfections of the technique (or reduction of the cancellation) can also lead to interesting self-oscillations. This is particularly notable when combined with a synthesis model containing non-linear or chaotic elements, where sonic outcomes can be more complex than simple single-frequency unstable feedback.

Figure 1: Haptic feedback instrument interfaces that each use a single voice coil transducer for both sensing and actuation.

The amount of force applied to the voice coil transducer can be sensed through changes in the electrical impedance of the transducer. The level of the peak in impedance at the transducer's resonant frequency is inversely proportional to the mechanical damping and applying pressure to the transducer increases the mechanical damping. This change in impedance is measured and mapped to a synthesis parameter.

III. INSTRUMENT DESIGNS

The various instrument designs presented use a range of resonant percussive synthesis models. Different interface physicalities are also presented – with a hand bell instrument alongside a tabletop percussion instrument. A video demonstrating the instrument designs can be found here: https://youtu.be/VulRuykdWx4

IV. REFERENCES

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