Sensor-Controlled Digital Waveguide Model of Vibrating Drum Membrane

The task proposed is to implement the physical model of a drum membrane running in real time on Bela, controlled by a force, acceleration or displacement sensor fitted in a wooden box the size of a small drum. This will serve as a preliminary study for an implement on the acoustic guitar, to be used for percussive interaction. For this application we require real-time interaction at a satisfactory sampling rate, and a model quality that allows expert level percussion playing.

The model will be based on Fontana and Rocchesso's digital waveguide approximation [Fontana 1998]. This paper is the basis for the popular Sound Design Toolkit (SDT) library in C [Baldan 2017]; it also provides solutions to many problems beyond the wave propagation model, such as membrane excitation and air load in a real-world cylindrical drum. There are two reasons that motivate re-implementation from scratch. Firstly, the SDT currently only provides a set "cartoonified" models, where the parameters are tuned to maximise perceptual effect for sound design; our goal on the other hand is to achieve real-world consistency with a physical drum, or at least optimise the perception from the point of view of the percussionist. Moreover, the excitation in the SDT models is event-based, whereas our goal is to implement continuous control from a sensor's signal. We are going to limit the implementation to a circular membrane with an air load.

The project will try to re-use materials I already have with me. Wooden boxes are quite easy to source even under lockdown conditions, and the accelerometer used in Assignment 2 may be re-purposed. Any extra equipment or components will be covered by the AIM grant as this task is part of my PhD project. Below is a provisional task breakdown with time estimates in man-days:

- Review of extra useful sources, especially around sensor mapping to physical quantities in the model. E.g.: is it possible to map the accelerometer to the acceleration/force in the excitation model? (1 day)
- Implement the model in standard C++11 and write a test/simulation harness in Python using Boost.Python, with the same procedure used in Assignment 1. (4 days)
- Build the box and code wrapping the signals on Bela. Record a few seconds of drumming on the surface, process it in the simulation, and plot/listen to effects. Implement any possible mitigation around instabilities in the activation, which seem to be an issue in physical models. A change to a contact piezo transducer may be considered at this stage. (3 days)
- Run the physical model on Bela, initially with very conservative mesh sizes and sampling rate. Increase or decrease precision of the model until we reach a good compromise between real-time operation and sound quality. Optimisation with SIMD intrinsics may be a good tool to use here. (2 days)
- Video shooting and report write-up. (1 day)

Total time allocated: 11 days.

References

[Fontana 1998] Fontana, F. and Rocchesso, D., 1998. Physical modeling of membranes for percussion instruments. Acta Acustica united with Acustica, 84(3), pp.529-542.

[Baldan 2017] Baldan, S., Delle Monache, S. and Rocchesso, D., 2017. The sound design toolkit. SoftwareX, 6, pp.255-260.