DMRN+11: DIGITAL MUSIC RESEARCH NETWORK ONE-DAY WORKSHOP 2016

QUEEN MARY UNIVERSITY OF LONDON TUE 20 DECEMBER 2016

Performable Spectral Synthesis via Low-Dimensional Modelling and Control Mapping

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***Abstract*— Spectral modelling represents an audio signal as the sum of a finite number of partials – sinusoids tracked through sequential analysis frames. With the goal of real-time user-controllable synthesis in mind, we assume these observed partials to be correlated functions of time, and that there exists some lower-dimensional set of unobserved forcing functions driving the partials through a set of differential equations. Mapping of these unobserved functions to a user control space provides us with a hybrid approach to synthesis in which mechanistic controls are exposed to the user but the system's behavioural response to these mechanisms is learnt from data.**

I. INFERENCE

Spectral modelling synthesis [1] is capable of accurately reproducing a given audio recording by representing it as the sum of many sinusoids whose behaviour is tracked through time to create 'partials' [2]. In quasi-harmonic sounds, these partials can be thought of as functions of time and are likely to exhibit some shared behaviour.

We consider the maximum amplitude of the analysed partials and keep the most prominent, modelling the rest as a residual. We then assume that these partials are created by some low-dimensional set of forcing functions passing through a system of differential equations. Furthermore, if we choose this set of differential equations to be linear and define a joint Gaussian process prior [3] over the observed functions and the unobserved (latent) functions, we can infer from data both the differential equation parameters and the posterior distribution over the latent functions (Fig. 1). This approach provides a nonparametric way to estimate a low-dimensional representation of a system and its linear relationship to the full system, and is called latent force modelling [4,5].

II. SYNTHESIS

The inference process outlined above provides us with a system of differential equations with fixed parameters, and a low-dimensional set of forcing functions. Resynthesis could be performed by drawing samples from the posterior, but in order to enable performable control of the inferred system we have introduced an additional control mapping stage [6], in which the mean function of the Gaussian process posterior is replaced with some user input.

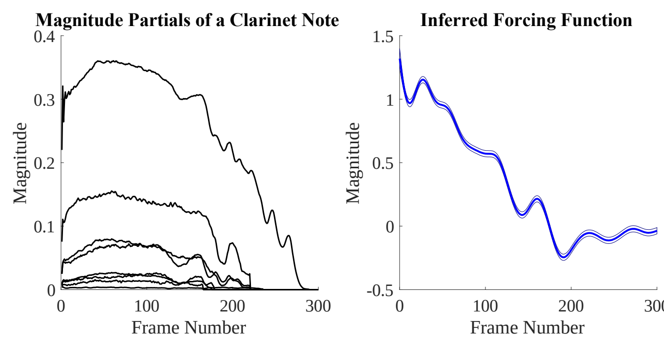

Figure 1. The magnitude over time of the first eight harmonics of a clarinet note (left) and the unobserved forcing function, plus its 95% confidence interval, learnt using the latent force model approach (right).

An experimental approach to defining this control mapping is taken. A performance gesture is recorded using MIDI CC messages which is then scaled and transformed (often by analysing its delta values) until it exhibits similar behaviour to the observed posterior mean. The scaling and transformation used then becomes the control mapping for all future gestures.

Once the control mapping has been defined, the system is implemented in real-time by interpolating frame-level data to obtain sample-level data and applying the learnt mappings to a series of sinusoidal oscillators representing the partials. Implementations are built as VST instruments with MIDI input using C++ and the JUCE framework.

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