# MTRC-Dream: Music in a Mathematical Environment

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## Introduction

The Media Technology Research Centre of the University of Bath is a grouping of researchers with a general interest in some aspect of Media, mainly in graphics and animation. When it was founded this was part of the School of Mathematical Sciences, but with reorganisations we are now in the Department of Computer Science. A small part of the centre is dedicated to research in aspects of computers and music, a part known locally as DREAM. While our charter emphasises the computational aspects it is significant that the university does not have a music department, nor any department dedicated to arts or humanities. We did enjoy good relationships with the concert organiser until the University decided not to support 'serious' music in any form, and with the local college, and through them have in the past taken part in workshops and other external activities.

## Historical Background

Growing from a mathematical computing group in the university, our main resource is the availability of students. We have had a total of four research students complete their doctorates[8, 21, 25, 4] in this area, with one student currently in his first year. But the other, larger, resource is undergraduates and masters students wanting final year projects. A number of music-related projects are supervised each year, and some of these have led to public outputs [20, 19, 18]. In particular the Rosegarden[24] notation editor and sequencer for GNU/Linux originated as a linked pair of undergraduate projects, and is still being developed by ex-students with others. In order to provide musical inputs we have identified a number of visitors and others living in the vicinity; the involvement of the associates is critical to the work of the centre. A feature of the University of Bath which we have embraced eagerly is that being in a rural area, we look to world-wide communities for cooperations. Our most widely known work has been in maintenance and development of MIT Csound[6]; this is probably the largest single consumer of time. It has brought us into contact with a number of interesting users in 5 continents (no one in Antarctica yet!). We are also involved in commercial music technology. Despite living within a mathematical environment, and having only mathematicians as students, we have generated a small number of compositions, and produce CDs of them. These tend to emphasise algorithmic techniques, but not exclusively.

## Facilities and Projects

The physical presence of the grouping is in two rooms, connected by a window, The inner room is a small purpose-built sound-proof studio, which is equipped with:

Dual boot Linux/Windows Intel machine with M-Audio Audiophile sound card
iMac with CD-RW
Mixing desk Behringer 2642A
Pair Genelec 1029A Studio Monitors
Subwoofer Genelec 1091A
Headphones Beyer DT100
MIDI synthesiser (old)

MIDI Fader box
Flying Cow ADC/DAC Converter

to which we may add a pair of Genelec 2029A monitors when needed. These additional monitors are normally used in an office.

The outer room is larger, but has no sound treatment. We are in the process of installing a network of Silicon Graphics machines in this area to provide a general work facility for the studio. We hope to develop this into an open access facility for the local community. While we may observe the process of composition for research purposes, in exchange composers can get easy access to the best facilities available. Longer term we are also creating a national open access electro-acoustic research facility[22], and also independently to provide a home for the Composers' Desktop Project[13].

# Current Research

We are mainly a research facility. In this section we outline the recent research areas.

### Physical Modelling

The largest area of late has been in physical modelling of plucked strings and drums. With strings we have been developing a wavelet-based pitch detection algorithm[17], and work on this continues. We used the extended Kalman filter method to determine the model parameters for a guitar[25] to complete the model. With drums we have investigated the waveguide methods, and in particular the linking of the membrane vibration to the air[3]. This work has been extended into consideration of material modelling [2, 1]. Work is continuing with comparisons with finite difference schemes for drums.

### Sonification

We are starting projects with other parts of the Faculty of Science, in particular with the sonification of data from ultra-sound scanning for medical physics. The project considers the non-linear effects of sound passing through amniotic fluid, and we are developing methods for hearing the way in which the sound waves change from harmonic to square waves. This is work in progress.

### Software

The largest body of software currently being developed is the revised Csound. This reconstruction of the original system involves areas of software engineering and compiler construction, as well cooperation with a widely distributed developer and user community.

We are also working with commercial interests in SAOL and related technologies.

### Agents and Performance

The most active area at present is to continue the work of [16] in conjunction with the Agent research group in Bath. Using the redeveloped Csound mentioned above we are constructing a framework to investigate the agent approach to composition and performance modelling. At present one student is working in thsi area, and another one is due to start soon.

### Sound Morphing and Spectral Space

In a recent project, supported by funding from the UK Arts and Humanities Research Board, we have created a real-time streaming implementation of the phase vocoder, identifying the changes required to be made to the "classic" Dolson/Moore algorithm to support streaming over arbitrarily long periods of time, and other changes to promote efficient real-time performance on multiple platforms. In addition to implementations on Macintosh, Windows and Linux platforms, we also have a basic working implementation on the Analog Devices SHARC dsp processor. A significant output from this project was the addition of streaming phase vocoder opcodes to Csound, through the definition of a new Csound signal type, enabling a variety of real-time cross-synthesis and other transformations to be designed.

In parallel with work on the phase vocoder, we are investigating techniques for morphing sounds using both real-time and interactive tools as well as the more common offline techniques. We regard the perceptual issues in sound morphing as of the greatest importance. Even using the most modern techniques, morphs especially between similar sounds can be, to the unprepared ear (and especially in the absence of supporting visual cues), indistinguishable from cross-fades, or may simply be accepted as a single sonority. We consider unbiased listening tests to be essential to the process of identifying morphing recipes (between both similar and widely dissimilar sounds) that are spontaneously identified as such, whether in narrative or abstract contexts. The Centre is also the host to the Windows port of SNDAN[5, 9], work funded by the UK Sonic Arts Network.

### File formats

A further outcome of the phase vocoder work was the development of the first fully portable streamable file format for phase vocoder analysis data, based on the new Microsoft format WAVE_FORMAT_EXTENSIBLE; the format is known as PVOC_EX[10], and is supported by Csound. Adaptations of CARL pvoc, incorporating some elements of the Moore vocoder such as oscillator back resynthesis, have been published as fully working demonstrators of the new format [12], which is a fully open format free for anyone to use. We have identified several further signal types that require portable and streamable file formats; for example we have developed a preliminary format for Ambisonic B-Format audio data[10], currently supported by the freely available CDP Multi-Channel Toolkit[11]. We seek similar formats for control data, including multi-dimensional data such as coordinate positional data for surround sound applications.

## Music Projects

Although a research facility we retain personal interests in music. A CD of early music from members of the Bath School of Mathematical Sciences[23] was produced in 1998.

More recently we organised a composition competition after ICMC2000, and Following the Door Concert[14] at ICMC Havana in 2001 a CD[7] of the concert and other pieces was produced in the studio in association with Alta Sounds. In the same spirit at ICMC 2002 in Göteborg a similar concert to the Havana one was presented, based on a sample of a street market in Havana[15]. We are now running a third project from street sounds in Göteborg.

Members of the studio continue personal interests in composition and performance.

## Student Projects

Over the years we have seen student projects in a wide variety of areas. Some have already been mentioned, but algorithmic dance music, improvisation and accompaniment have featured, as well as user interfaces to Csound and sound editing. Most of these projects do not go sufficiently far to warrant publication, but the educational value is high, and students find working with sound fun. Student projects are just starting in sonification, composition and gamelan, and projects in wavelets and beat detection are ongoing,

These projects are backed up by one final year course on *Music and DSP*, which is enjoyed by many students, but is usually considered hard.

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