2013 YCCSA SUMMER SCHOLARSHIP PROJECT SUBMISSION

This form is for prospective project supervisors to submit their projects to be included in the YCCSA Summer Scholarships Programme for 2013.

It is the purpose of the Summer School that any projects submitted are interdisciplinary in nature.

Date	*28th February 2013*
Main Supervisor's Name	*Dr John Szymanski*
Main Supervisor's Department	*Electronics*
Co-supervisors' name(s) and Departments	*Dr Jez Wells (Music)*
Project Title	*"Sounds interesting!" Complexity within a musical note*
Project Description	*We are used to the idea that complexity is all around us - we see it every time we look up at the clouds or down at the leaves of a plant on the ground. But we still experience complexity with our eyes closed, for every sound that we hear is inherently complex. Musical sounds in particular originate from physical systems (instruments) that have been set into vibrational motion by some brief impulsive input (such as a pluck or strike), or are driven by a sustained input (such as air blown through a mouthpiece or the motion of a bow over a string) or are even driven by a sustained series of near-periodic pulses (such as the glottal airflow in the human voice). These instruments can vary considerably in their design detail, with some involving multiple resonating coupled subsystems, each potentially with inherently nonlinear components. But even if we were to consider just the most basic case of an isolated vibrating string subjected to a single, simple pluck, although repeated plucking of the string will produce a series of sounds that we may perceive as being extremely similar, even a superficial analysis of the time waveforms will confirm that all of the recordings are different in detail. In short, a microphone would never record the same pattern of sound pressure variations twice, showing that the detailed form of vibrations and the resultant air pressure waves exhibit a sensitivity to initial conditions, a characteristic of a complex system.* *This project will investigate complexity within a single musical note, concentrating on developing a better understanding of two main areas. Firstly the very early stages of the note - the so-called "attack" which is very poorly understood and is often (incorrectly) described as noise-like. In fact, the attack is the short period of time during which the system is behaving at its most nonlinear - for the case of the stretched string, for example, immediately after a pluck it takes time for the energy waveforms to propagate along the string from the pluck point to the edges and then to bounce back - in essence, at this early stage standing waves have yet to form.*

	Secondly, however, standing waves will eventually emerge and will begin to dominate the signal as the attack fades. The resulting emergent sound is hence often described as being composed of a series of "partials" with frequencies characterised by the different vibrational modes of these standing waves but, for different reasons, complexity will be playing a role here as well. This can be seen by realising that the motion of a vibrating string is often described by assuming not only that the string is thin, uniformly tensioned, perfectly flexible, and perfectly terminated, but also that the amplitude of the vibrations is in some sense "small" and that the motion is restricted to be both one-dimensional and in a fixed transverse direction. Strictly, all of these assumptions are entirely wrong! More realistically, the equations describing the motion are nonlinear, and if we instead think of the string as able to move more freely, then it can be seen that it can vibrate both up/down and left/right - so that in effect there are two coupled nonlinear oscillators involved in the description of the motion of something as simple as just an isolated string. *The project will concentrate on examining the nature and significance of complexity in both the attack and the sustain/release stages of a musical note. The detailed nature of the note attack is important in that it is already known to play a significant role as an acoustic cue, influencing the way that we perceive the whole sound, while the longer-term nature of the more "harmonic" sustain/release portion of the note is crucial to our perception of pitch, duration and loudness.* *Overall, a better understanding of the role of complexity in both stages of the note production would potentially allow the production of more realistic and satisfying synthesised sounds. The goals of this project are hence to review the current understanding of chaotic dynamics and complexity within the production of a musical note, to carry out numerical simulations, and to use these results to establish priorities for further investigation and research.*
Required skills	*The project would be helped by a familiarity/interest in areas such as:* • *the physics of music and musical instruments;* • *the mathematics of differential equations and chaotic dynamics;* • *audio signal processing;* • *music physical modelling and synthesis.* *Prior knowledge in all of these areas in not required - a significant amount of "on-the-job" learning is expected.* *Familiarity with MATLAB would be required for the numerical simulations.*
Project dates	*Monday, 15 July - Friday, 13 September 2013.*
Other information	
References	*Bilbao, S. (2010), "Percussion Synthesis Based on Models of Nonlinear Shell Vibration", IEEE Transactions on Audio, Speech and Language Processing, 18(4) (May 2010), pp. 872-880* *Fletcher, N.H. (1999), "The nonlinear physics of musical instruments", Rep. Prog. Phys. 62 (1999), pp. 723–764* *Rodet, X. and Vergez, C. (1999), "Nonlinear Dynamics in Physical Models: From Basic Models to True Musical-Instrument Models", Computer Music Journal, Fall 1999, Vol. 23, No. 3, pp. 35-49*

When complete, please email the form to sarah.christmas@york.ac.uk