ND*nano* Undergraduate Research Fellowship (NURF)
2014 Project Summary

Student name: **Sam O'Mahony**

Faculty mentor name: **Wolfgang Porod and György Csaba**

Project title: **Non Boolean computing using nano-devices**

Briefly describe any new skills you acquired during your summer research:

My research required me to model a neural network of dynamically coupled oscillators. To do this required some complex MATLAB code and a good working understanding of signal processing. Because of this I became much more accustomed to working with MATLAB code and modelling signal and image processing techniques.

I also learned how to run jobs on the campus supercomputer. This required me learning some Linux coding to be able to communicate with the supercomputer through my own PC on the same network.

Practical application/end use of your research:

- Modelling tasks of human cognition (e.g. image recognition) using oscillators akin to neurons in the brain
- Employ clusters of nano-oscillators as cores alongside traditional Boolean logic based cores to compute data heavy tasks at lightning fast speeds.
- Reduced energy consumption for data heavy tasks using this new architecture over a more traditional one.

Project Summary:

There is no computer architecture as powerfully efficient as that of the human brain. Unlike the digital logic employed in even the fastest modern day computers, the brain instead works using analog waveforms to do its number crunching. Humans can recognize an image in no time at all yet, to a computer, such a data intensive task will take considerably longer. Our research is working towards a neurocomputer model which is not victim to the scalability issues of previous neural network models before it. The other main aim that would make this neurocomputer model unique was if the model was able to work with any randomized set of oscillator frequencies – not a set of frequencies that abided by the classic Golomb ruler method (where each oscillator frequency difference is unique). This model moves away from the ubiquitous Boolean logic of today's digital CMOS circuits and towards one composed of analog nano-oscillators.

During my research I created a MATLAB model of this dynamically coupled neural network that was capable of image processing tasks. The model worked well with the randomized set of oscillator frequencies and so was a good result and reason for further research in this topic. A second MATLAB model that closely matched a physical circuit model of the system was also completed. The fact that the model is robust for any set of close oscillator frequencies means that it has a very good chance of being implemented in nano-form. The nano-oscillators under research (Spin Torque Oscillators) tend to be quite noisy in operation and so we hope that this research may lead to these imperfect oscillators working despite this problem and thus being usable to compute the intricate number crunching jobs at hand.

PROJECT ARCHITECTURE AIM:

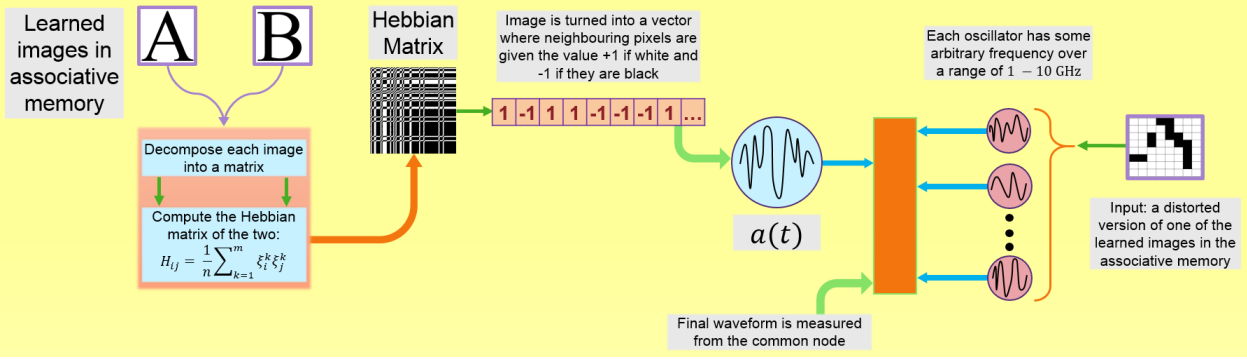

Figure 1: A model of the architecture for the design of this dynamically coupled oscillatory neurocomputer

Publications (papers/posters/presentations):

Poster at the 2014 Summer Undergraduate Research Symposium:
"Non-Boolean computing using oscillators".
Final report: "Simulating Coupled Oscillator Networks"