Madison Hanberry Triad Computing 3 – 23 – 16

* Note: I will be supplementing my talk with a slide-show presentation. *

Objective and Motivation

In modern computer processors, binary logic governs all operations to some extent, and it has done so for virtually every electronic computer thus far. This has worked well enough, but there are limits to reducing every operation to an array of ones and zeros. It is likely that one would find higher-bit operations (ternary, etc …) to be desirable in many situations. In particular, ternary operations could prove useful. Still, current semiconductor-based architectures are inherently binary, so implementations of higher-bit operations that are not powers of two would be impractical. As a solution to this problem, we have been researching novel constructs which do not have the same restrictions.

Solution and rationale

There were many options which could be explored, but in the end we decided that the nano-magnetic triad was the most compelling. In particular, we found that the shape of a triad gives the construct a useful magnetic anisotropy – That is, it has three axes of stable magnetization. Herein lies the potential for higher-bit operations, namely ternary operations. From here, we explored ways in which we could get these triads to interact with one another to perform logic operations.

Simulation Environment

– *Preliminary Information* –

In order to model how an arrangement of triads would behave, we had to consider the interactions between each electron spin within the structure. These interactions manifest themselves as electron spin-torque, and this can be modeled mathematically using the Landau-Lifshitz-Gilbert equation, or *llg equation*.

– *Implementation* –

There exist programs to drive the simulation of micro-magnetic interactions, all of which rely on the *llg* equation. Ultimately, NMAG was chosen to implement our simulations because its interpretations of model surfaces are done using finite element generation, which is ideal for out structures. In addition,Netgen was used to create solid meshes of our triad arrays, and MayaVi was used to visualize the datapoints produced by NMAG.

Testing Procedure

Several arrays of triads were tested to observe whether or not they would behave in a way that could be conducive to logic operations. To get a general idea of how each structure would behave, they were all subjected to a hysteresis simulation routine. The results of this routine showed us how each structure would act when subjected to various initial magnetizations, and also how each structure would relax out of those initial magnetizations. From these tests, four formations were found to produce interesting relaxation states in the triads: shamrock, clover, tessellated clover, and buckle formations. We took these four structures, reconstructed them using triads of varying side-length, concavity, and material parameters, and then subjected them to the same tests as before to see which variety of triad produced the most stable relaxation state.

Results and Conclusion

* Final testing is still under way. These results are subject to elaboration.*

It was found that each formation offered a unique relaxation state which varied in a predicable way given a structure's initial magnetization. In addition, triads with a higher concavity to side-length ratio provided more stable results. Given this outcome, it would be feasible to construct a processor using triad arrangements as logic gates. More work needs to be done to develop a logic system that would be conducive to the use of these gates, and the interpretation of the magnetization states as data will also need to be developed further.