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Novel Microsatellite Control System

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Abstract
We are developing extremely simple yet quite capable analog pulse-coded neural networks for "smaller - faster - cheaper" spacecraft attitude and control systems. We will demonstrate a prototype microsatellite that uses our novel control system to autonomously stabilize itself in the ambient magnetic field and point itself at the brightest available light source.

Summary
The current trend in spacecraft is "smaller - faster - cheaper" but it is not known just how small, fast, and cheap satellites can be built and still perform useful work. However, it is clear that a major engineering paradigm shift is required in order to move beyond the very highly evolved and optimized space systems that are currently available. In particular, the paradigm of anticipating every possible anomaly and engineering the appropriate anomaly mitigation has proven to be unfeasible - we just cannot anticipate everything that can go wrong, especially in space. We need engineering solutions that respond to unanticipated events in non-catastrophic ways. In other words, rather than designing systems primarily to perform work and expecting them to survive all anticipated circumstances, we should design systems that automatically attempt to survive all circumstances and then try to extract useful work from them.

Using this new paradigm, we are developing extremely simple yet quite capable analog pulse-coded neural networks for a variety of advanced robotic applications that include spacecraft attitude and control systems. The basis of these control systems is a two transistor "neuron" that produces control pulses. These neurons can be configured singly or can be combined in pairs or in hexagonal rings to produce central pattern generators. Our experience with legged robots have shown these simple systems are extremely reliable, robust to faults, and capable of surprising emergent behaviour such as self assembly and synergistic collective behavior. The hexagonal ring central pattern generator in a four legged crawling robot can, for instance, reproduce the walking and running motions observed in living quadrupeds.

Systems such as robots and spacecraft are immersed in their environment. Environmental feedback into these systems is unavoidable, even without sensors. Often the actuators themselves act as effective environmental
sensors. For example, a spacecraft that is oriented using magnetic torque coils will respond to the magnetic variations induced by geomagnetic storms, even if it has no magnetometer for sensing the ambient field. Instead of designing systems that withstand their environment, we are engineering systems that RELY ON their environment. The actuators and sensors coupled to the environment feed back into the control system by controlling the control pulse timing relationships. Often the sensor and actuator can be combined into a single unit, simplifying and ruggedizing the design.

This approach has produced another unexpected result - the sensor fusion problem becomes trivial. Inputs from multiple sensors combine directly and naturally. There is no need for interpolation or decimation to handle temporal mismatches and relative importance is assigned directly by specifying the sensor voltage relationships. Our prototype spacecraft control system uses gradients in the magnetic field as sensed by the magnetic torque coils to stabilize itself and simultaneously uses light gradients from a photosensor pair to orient the spacecraft toward the brightest light source.

We will demonstrate a prototype microsatellite that uses our novel control system to autonomously orient itself in the ambient magnetic field and point itself at the brightest available light source. This is a first step toward defining a minimum useful microsatellite design of the future and is relevant to all areas that use spacecraft platforms.

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