Fault Tolerance via Endocrinologic Based Communication for Multiprocessor Systems

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Abstract. The communication mechanism used by the biological cells of higher animals is an integral part of an organisms ability to tolerate cell deficiency or loss. The massive redundancy found at the cellular level is fully taken advantage of by the biological endocrinologic processes. Endocrinology, the study of intercellular communication, involves the mediation of chemical messengers called hormones to stimulate or inhibit intracellular processes.

This paper presents a software model of a multiprocessor system design that uses an interprocessor communication system similar to the endocrine system. The feedback mechanisms that govern the concentration of hormones are mimicked to control data and control packets between processors. The system is able to perform arbitrary dataflow processing. Each processing stage within the system is undertaken by a separate group of microprocessors. The flow of data, and the activation of the next stage within the process is undertaken using the bio-inspired communication technique. The desired result is a system capable of maintained operation despite processor loss. The feasibility of the multiprocessor system is demonstrated by using the model to perform a simple mathematical calculation on a stream of input data.

1 Introduction

Biology provides a diverse source of inspiration that reaches across many fields from both artistic and scientific disciplines. Electronic Engineering is no exception.

One of the strongest impetuses for Bio-Inspired Engineering is the assistance it lends to the development of engineering design, especially where solutions via traditional techniques fall short. Such biological based solutions have led to the creation of artificial learning and pattern matching systems based on neural networks [12], as well as self re-configuring systems [3] based on biology’s ability to evolve and adapt.

Of more interest to the area of Reliability Engineering is biology’s ability to maintain operation in the face of adverse conditions. Biology is able to employ
automated fault tolerance, detection and recovery characteristics that enable organisms to remain functional despite injury. It is the desire for electronics to also exhibit these three characteristics that has led to an interest in Bio-Inspired Reliability Engineering.

Both Embryonics [4] and Artificial Immune Systems [5,6] mimic aspects of biological reliability systems. The Embryonic Architecture is capable of removing faulty circuit areas. Reconfiguration via the shifting of functionality to healthy circuitry in redundant areas returns the system to full functionality. Whereas Artificial Immune Systems provide a fault detection and removal mechanism based on the biological self, non-self principle [7].

The ability of biological systems to tolerate and recover from a subsystems death is reliant upon the use of redundancy. This is a common feature present on a number of levels within biology’s structural hierarchy. Society maintains activity through redundancy in individual organisms, similarly organisms can function without certain organs. However, it is the cellular level that utilizes redundancy to the greatest effect.

Cellular biology of higher animals provides the inspiration for the multiprocessor system presented in this paper. A software model of an inter-processor communication system based on biology’s endocrine system is presented, including results that demonstrate the system’s fault tolerant characteristics.

The subject of biological cell signalling is discussed in Section 2. How such signalling can be translated into a useful electronic system is presented in Section 3. The model of the resulting multiprocessor system and operation results are described in Sections 4 and 5 respectively. The paper is concluded in Section 6 with suggestion for further work in Section 7.

2 Cell Signalling

Cells are heavily dependant on signalling mechanisms for survival. The ability for cells to influence each other enables a multicellular organism to maintain a level of homeostasis[1]. Even some unicellular organisms utilise signalling to influence proliferation of other like cells [2].

A variety of different communication systems are employed in higher animals. Each system varies in a number of ways, but especially with regard to range and speed. However, in each case communication is achieved via signalling molecules. Each messenger molecule exhibits a biological signature that determines its recognition by other cells. Target cells recognize messenger signatures through receptors. A receptor-messenger match allows molecules to bind to their target and complete the communication process.

The synaptic signalling process shown in Figure 1 is the most directed messenger based communication system. Nerve cells directly steer their messengers via their connected axons. As the neurotransmitter messengers are released so close to their target, affinity between receptor and messenger can be low. In

\[\text{Homeostasis is the process by which organisms or cells maintain a stable internal equilibrium via physiological changes.}\]