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The CAM-Brain Machine (CBM): An FPGA Based Tool for Evolving a 75 Million Neuron Artificial Brain to Control a Lifesized Kitten Robot

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Abstract. This article introduces the "CAM-Brain Machine" (CBM), an FPGA based piece of hardware which implements a genetic algorithm (GA) to evolve a cellular automata (CA) based neural network circuit module, of approximately 1,000 neurons, in about a second, i.e., a complete run of a GA, with 10,000s of circuit growths and performance evaluations. Up to 65,000 of these modules, each of which is evolved with a humanly specified function, can be downloaded into a large RAM space, and interconnected according to humanly specified artificial brain architectures. This RAM, containing an artificial brain with up to 75 million neurons, is then updated by the CBM at a rate of 130 billion CA cells per second. Such speeds should enable real time control of robots and hopefully the birth of a new research field that we call "brain building." The first such artificial brain, to be built in 2000 and beyond, will be used to control the behaviors of a life sized robot kitten called "Robokitty."

Keywords: evolvable hardware, artificial brain, neural networks, genetic algorithm, kitten robot

1. Introduction

This article introduces the "CAM-Brain Machine" (CBM) (Korkin et al., 1997), a Xilinx XC6264 FPGA (Xilinx, Inc., 1996) based piece of hardware that is used to evolve 3D cellular automata based neural network (Rumelhart and McClelland, 1986) circuit modules at electronic speeds, that is in about a second per module. 65,000 of these modules can then be assembled into a large RAM space according to humanly specified artificial brain architectures. This RAM is updated by the CBM fast enough (130 billion CA cell updates/sec) for real time conrol of robots. Four of these CBMs have already been or are about to be delivered (the first to de Garis's previous lab, ATR in Kyoto, Japan, the second to Belgium's Lernout and Hauspie speech processing company, the third is to be delivered to STARLAB in June 2000, and GENOBYTE will have its own also in June 2000).

The CBM is the essential tool in the "Artificial Brain (CAM-Brain) Project" (de Garis, 1994; de Garis et al., 1998; website http://Foobar.starlab.net/∼degaris/journal.html), which at the time of writing (Spring 2000), has been running for 7+ years. Although the focus of this article is on the functional principles and design of the CBM, a certain background needs to be provided so that the motivation for its construction is understood.

The basic (and rather ambitious) aim of the CAM-Brain Project as first stated in 1993 was to build an artificial brain containing a billion artificial neurons by the year 2001. The actual figure in 2000 is maximum 75 million, but the billion figure is still reachable if we really want. The Brain Builder teams at STARLAB and GENOBYTE are hoping that the CBM will revolutionize the field of neural networks (by creating neural systems with tens of millions of artificial neurons, rather than just the conventional tens to