approaches at the workshop, and we experimented with these systems, and compared their performance and ease of use.

The first system had three 64x64-neuron AER receiver chips and six 8-bit microcontrollers (MicroChip PIC16C55). These microcontrollers work in parallel, with one pair computing the X and Y addresses for each receiver chip. The throughput was 3M addresses per second; this rate supports an incoming address-event rate of 83K with a fan-out of 5. This system was rather slow because the microcontrollers operated at only 5MIPS, and about 10 instructions where executed to perform the handshaking protocol and to add the offset to the address. The system was also difficult to use, as we had to modify programs written in assembly language to implement new projective fields.

The second system had four 64x64-neuron AER receiver chips and five 64k X 16 EPROM chips. However, this prototype only supported a single outgoing address per receiver chip for each incoming address. We designed and started building a memory-based system that supported projective fields at the workshop. The new design uses an EEPROM to store the projective field mapping and a microcontroller to perform the handshake protocols and to sequence through several locations in the EEPROM for each incoming address. We completed the program for the microcontroller as well as the address mapping for the EEPROM. Further debugging of the hardware and software will continue between Hopkins and Boston University.

7.5.11 Cochlea to 1D Receiver and to Koala Robot

Participants: A. Andreou, D. Klein, P.Verschure

(See also the Neurobots workgroup)

The goal of this project was to interface a silicon cochlea to a 1D address-event receiver chip, and to a small mobile robot (Koala). In spite of our late start, we managed to build and debug a circuit board. Unfortunately, it took longer than any of us expected to connect one of the available microphones to the chip. As a result, we could not test the board on Koala. The project will be continuing and completed in the Baltimore/Washington area between the Hopkins and the University of Maryland groups.

In conjunction with the 1D-retina to Koala interface, this project provides an interesting opportunity to perform the coordinate transformations required for multimodal sensor fusion by rerouting address-events. These opportunities will be explored in the coming year and we will have more to report and evaluate at next year's workshop.

7.5.12 Neuronal Networks on Silicon Cortex (SCX)

Participants: E. Niebur and A. Whatley

Niebur proposed using the SCX to emulate a small neuronal circuit in which relative timing of neuronal events is important.

The underlying idea is that the time structure of neuronal spike trains on the scale of a few milliseconds can be used to transmit information which is complementary to the more commonly-used average spike rate code. This technique increases the used bandwidth of the neural information transmission channels significantly. In particular, E. Niebur and C. Koch suggested that the location of the focus of selective attention might be coded in the temporal structure. In two papers (Niebur, Koch and Rosin, 1993; Niebur and Koch, 1994) they showed that a simple neuronal circuit consisting of mutually inhibitory interneurons will suppress unattended stimuli in the presence of attended stimuli. The interneurons are

capable of decoding the incoming temporal information (either oscillations or synchronicity in their input). All neurons are implemented as biologically plausible variants of simple integrate-and-fire neurons.

The SCX project was planned to implement two groups of neurons on two different chips. On chip 1, a simple time structure was modulated on a subset of the neurons which were designated to code for the attended stimulus. The other neurons on this chip responded to "unattended" stimuli, which is coded by the same average spike rate they would produce in the presence of an attended stimulus but without the additional modulation. On chip 2, the above-mentioned circuit is used to separate attended from unattended stimuli.

After some brief period of familiarization with SCX host commands (aided by the documentation previously written by Whatley) and with the architecture of the particular Multi-Neuron Chips (MNCs) available for use at the workshop, Niebur was able to generate a command file that could be read by the SCX host software to configure the SCX in the required way to emulate a small, prototype version of the circuit to be studied. In doing so, he became the first user of the SCX system from outside its originating lab. A. Whatley assisted in taking data from the neuronal circuit implemented, and this data was then analyzed off-line by Niebur. This analysis showed no significant correlation between the firing of the neurons that were expected to be correlated. This may have been because no attempt had at that point been made to tune the synaptic weights in the circuit to obtain the desired behavior. Further investigation was not attempted during the workshop, but could be pursued in the case that either Niebur visits the Institute of Neuroinformatics in Zurich where the SCX project is based, or the SCX host software is developed to the point at which the SCX can be controlled, and data gathered, across the internet (in a manner analogous to the way in which Jonghan Shin, based at Caltech, is presently able to use the single silicon neuron test setup in Zurich). This is a possible future development of the SCX project, though considerable development effort will be required.

Even if no further progress is made on studying the particular neuronal circuit used in this project on the SCX system, the experience of having an independent end-user, Niebur, work with the SCX has been a valuable one. The lessons learned about the level and type of documentation required, and about the kinds of functions an end-user wants to perform should help towards Whatley's stated interest in "Making the SCX system into a usable platform for others to use...".

7.6 Active Vision Workgroup

Orgnizers: Brian Scassellati and Matt Marjanovic

Scassellati and Marjanovic brought an active vision system developed as part of the Cog Project at the MIT AI Lab (see figure 16). The system consists of four degree-of-freedom, four color camera head for input and output, and a network of eight TI C40 DSP's for computation.

The intent of the lab was to give participants some hands-on experience with a functional and capable active vision system. Brian and Matt developed a number of basic visuomotor tasks as examples of system capability and algorithmic possibility, and participants were encouraged to expand upon these examples and develop tasks of their own. Sample tasks included subtraction-based motion detection, saccading to motion, smooth pursuit tracking, vergeance, and pixel-level visual adaptation.

With the powerful, general computational hardware available, some participants discovered that the vision system was a useful testbed for digital simulation of algorithms which