IMAGE PROCESSING SENSORS FOR AUTONOMOUS VEHICLES, ROBOTICS AND REMOTE SENSING: NEUROVISUAL FUSION ARCHITECTURE FOR AUTONOMOUS OBJECT DETECTION

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Image Processing Sensors for Autonomous Vehicles, Robotics and Remote Sensing
Research Concentration Areas: (1) Investigate information processing of vertebrate and invertebrate retinae; and (6) Understand the biological algorithms underlying sensor fusion, both within and between sensory modalities.

Title: *Neurovisual Fusion Architecture for Autonomous Object Detection*

While the accomplishments in the field of image processing have been staggering and continue to knock down traditional barriers, understanding of even the most fundamental neurovisual processing interface in humans continues to elude researchers. It is evident that new interdisciplinary research directions are needed to understand visual processing and to develop new theoretical models that can be validated and used in machine intelligence applications. The objective of this research proposal is to assemble a cross-disciplinary team of scientists, depicted in Table 1, to address topics (1) and (6) stated above. The conceptual block diagram of our proposed research activities along with the responsible research units/universities is illustrated in Figure 1.

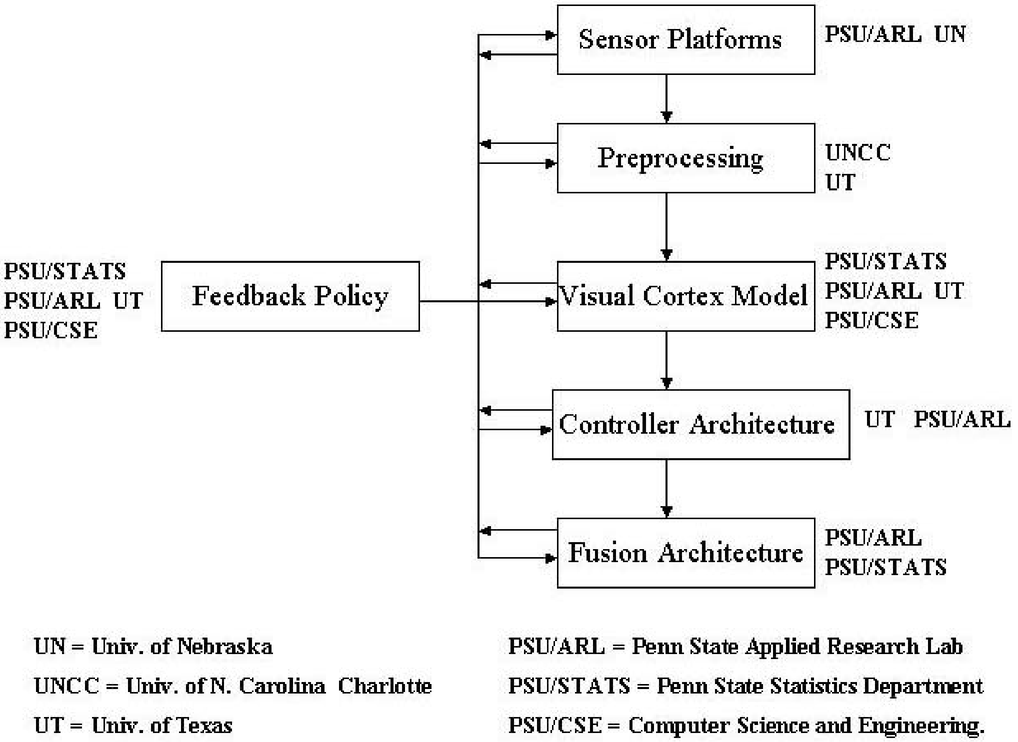

Figure 1. Conceptual Block Diagram of Proposed Research Plan

In Fig. 1, we propose a neurovisual system that approximates the information processing capabilities of the retina and that possess the properties of sensor/platform independence. The **Sensor Platforms** block is a subsystem that will be developed to interface sensor scenarios of interest in to the visual cortex processing system. Both simulated and experimental scattering models from a variety of natural surface and volume targets as well as artificial targets will be developed in different spectral regimes. These will include microwave, millimeter-wave, near-infrared and mid-infrared spectral regimes, using radar as well as lidar remote sensing systems. Robust multisensor fusion methodologies, especially as they apply to neurovisual systems, will be investigated and tested. Environments will be developed for static, dynamic, occluded and low SNR situations of interest. In addition, the results for single sensor cases have the capability to be extended to stereo as the **Visual Cortex Model** block supports this capability.

The **Preprocessing** block will utilize existing techniques and pursue new strategies related to invariant operators and operators representative of visual cortex function. The specific areas that will be addressed are the commutative groups of translation, scaling, and rotation transformations, and operators known to be representative of early vision function such as multiresolution Gabor functions.

The **Visual Cortex Model** block will utilize the LISSOM family developed at the University of Texas at Austin, which is a set of neural network models that simulate the development and function of the human visual cortex. LISSOM is based on the Self-Organizing-Map algorithm, which produces brain-like maps efficiently. LISSOM also uses Hebbian learning (for calculating connection strength between neurons) and lateral connections (for reducing redundant neuron activity) to achieve a very biologically compatible model. In order to utilize LISSOM, it must be first trained to form brain-like maps. There may be several maps that form a hierarchy of increasingly sophisticated representations. In the first map, neurons are sensitive to short line segments oriented at different angles. Further up the hierarchy, LISSOM can be trained to detect simple shapes, such as squares or circles. The LISSOM code is efficient and runs natively on a Linux platform. The image input is an M by N matrix of numbers that represent gray level values, and the output may be an M by N matrix with the numbers representing correlation to the location of the object being detected. LISSOM represents a worthy model of the visual cortex that can take input from the preprocessor, and output processed data to the controller architecture.

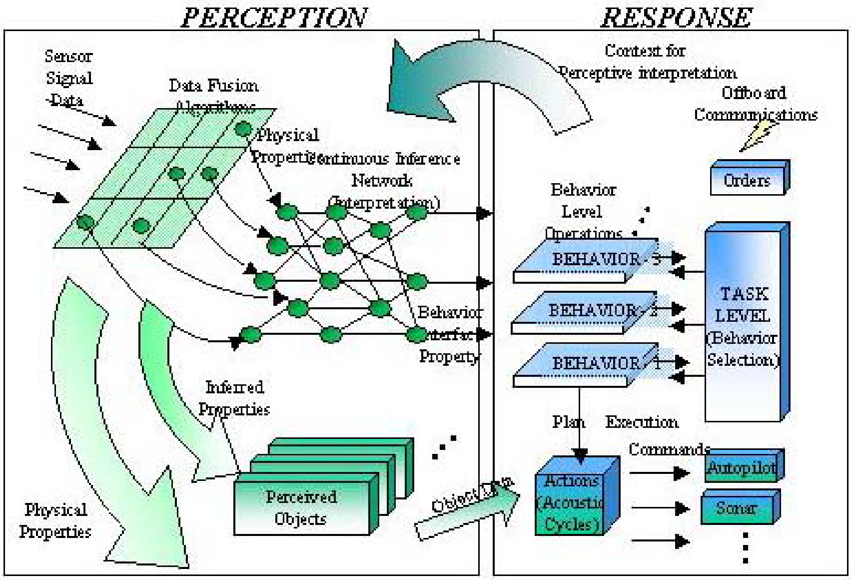

Figure 2. Intelligent Controller Architecture

The **Controller Architecture Block** (see Figure 2) is composed of two main layers; a Perception layer and a Response layer. The Perception layer builds an internal representation of the external world as viewed through the onboard sensors and signal processing. This layer is built on a hierarchical pattern recognition design using a continuous inferencing network (CINET). This network is used to make inferences from the data as well as for fusing information over sensors and time. The Response layer consists of a response execution engine, a task manager, and a collection of independent Behaviors. Each Behavior requests control when its associated Behavior Interface Property triggers it or it is ordered to execute. The Task Manager prioritizes the Behaviors requesting control and grants control to the one with the highest priority.

The goal of the **Fusion Architecture Block** is to continuously ingest multi-source data, dynamically filter the data against user criteria (e.g., target type, geographical area, number of types of data sources, etc.), and associate and correlate the data to produce a prioritized target list with target identification, a fused geo-location, and its supporting pedigree of message support. Two important problems associated with the fusion process are (*i*) the identification of areas (clusters) with exceptionally high response and (*ii*) the determination of whether the high response can be attributed to chance variation (false alarm) or is statistically significant. The spatial scan statistic will be used for detection and evaluation of these clusters. Three basic properties of the scan statistic that will be researched for this task are the geometry of the area being scanned, the probability distribution generating responses under the null-hypothesis of chance variation, and the shapes and sizes of the scanning window.

The **Feedback Policy Block** will essentially be a bi-directional communications hub that interfaces to all existing processing blocks. This specific subsystem will accept prioritized command inputs from the Controller and Fusion Architectures and provide parameter updates to based on evidential reasoning to the subsystem processing engines.

In addition, each specific processing block will be numerically analyzed for complexity, parallelism and efficient processing arithmetic mapping. The goal of this analysis will be to derive the optimal processor/processing mapping such that an efficient chip implementation of the system architecture could be realized at the sensor interface.

In conclusion, we feel we have proposed an innovative solution to an extremely difficult problem by assembling a cross-disciplined team of researchers with diversified talents that encompass all aspects of a neurovisual imaging system. The unique aspects of this system is the cross-platform, cross-sensor adaptability of the system.

Table 1. MURI Team Members

Name	**Affiliation**	**Expertise**	**Role**
Dr. Richard L. Tutwiler 814-863-2188 rlt@tasha.arl.psu.edu http://www.arl.psu.edu/areas/image/image.html	Penn State Applied Research Lab	Image Analysis, Pattern Recognition, High Frequency Medical Ultrasonics, RF/Digital Electronics	PI
Dr. Joseph P. Stitt 814-863-0682 jstitt@psu.edu http://www.personal.psu.edu/faculty/j/p/jps120/	Penn State Applied Research Lab	Image Analysis, Data Fusion, High Frequency Medical Ultrasonics, RF/Digital Electronics	CO-PI
Dr. James Stover 814-863-4104 jjs5@psu.edu http://www.arl.psu.edu/areas/gcav/gcav.html	Penn State Applied Research Lab	Intelligent Controller Architectures	CO-PI
Dr. Jesse L. Barlow 814-863-1705 barlow@cse.psu.edu http://www.cse.psu.edu/~barlow/	Penn State Department of Computer Science and Engineering	Numerical Linear Algebra, Least Squares and Eigenvalue Computation, Numerical Computation in Signal and Image Processing.	CO-PI
Dr. Ganapati .P. Patil 814-865-9442 gpp@psu.edu http://www.stat.psu.edu/%7Egpp/index.htm	Penn State Department of Statistics	Inferential geoinformatics, change detection and accuracy assessment, spatial scan statistics	CO-PI
Dr. Thomas P. Weldon 704-687-4391 tpweldon@uncc.edu http://wws2.uncc.edu/tpw/	Univ. of North Carolina at Charlotte Department of Electrical and Computer Engineering	Mixed-signal VLSI, image processing, medical imaging, radio systems, and communication systems, and ground penetrating radar	CO-PI
Dr. James A. Bednar 512-495-9973 jbednar@cs.utexas.edu http://www.cs.utexas.edu/users/jbednar/index.html	University of Texas at Austin Department of Computer Science	Biologically realistic computational modeling of the human visual system	CO-PI
Dr. Ram Narayanan 402-472-5141 rnarayanan1@unl.edu http://doppler.unl.edu/	University of Nebraska-Lincoln Department of Electrical Engineering	–Remote sensing system development and testing, Reflectance and scattering models	CO-PI