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**CENTER FOR NEURAL ENGINEERING
AT
TENNESSEE STATE UNIVERSITY**

ANNUAL PROGRESS REPORT

Period: MAY 15, 1992 to MAY 14, 1993

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CENTER FOR NEURAL ENGINEERING

ANNUAL PROGRESS REPORT

Summary

The Center for Neural Engineering comprising of consortium partners: Tennessee State University (TSU), Meharry Medical College (MMC), Accurate Automation Corporation (AAC) and Oak Ridge National Laboratory (ORNL) is presenting first annual report in the format provided by Office of Naval Research for HBCU Science and Engineering Education Programs. A team of seven (7) researchers along with four (4) undergraduate and four (4) graduate students conducted research at the Center. The interaction from consortium partners at AAC and ORNL provided valuable suggestions and assisted the researchers to focussed research. It is envisioned to increase the interaction with AAC and ORNL during summer months and to continue to utilize the vast resources available among consortium partners.

The Center wishes to thank the Board of Directors for their input and Dr. Joel Davis, the technical monitor from ONR for his genuine interest and guidance for the success of the Center and the welfare of the Tennessee State University. The Center is also indebted to Dr. Davis for assisting the Center in receiving two additional grants from DoD, one for students research training in neural networks and the other for purchasing computing equipment.

This report summarizes faculty activities, curriculum changes/enhancement, student activities and facilities supported by this grant. The program objectives for the next year and the interaction with AAC and ORNL are also mentioned.

1 Goals and Objectives

The main objectives of the Center are:

1. To advance the understanding of biologically-motivated neural network systems through inter-disciplinary basic research.
2. To develop the highest quality undergraduate and graduate curricula in neural computing and engineering that will serve as a role model for other institutions.
3. To provide pre-graduate and post-graduate training for students in a nationally and internationally recognized basic and applied research and development environment focussing on critical present and future technologies.
4. To broaden educational and career development opportunities for minorities and women.

The Center plans to address the above objectives through the following tasks:

1. Study the principles and structures of auditory neural system, information and signal processing with emphasis on computational map formation.
2. Develop new neural network algorithms based on the knowledge and models of biological principles in the areas of auditory neural systems, acoustic signal processing and sensory motor control systems.
3. Develop application software tool for fault diagnosis such as helicopter gearbox, acoustic signal classification and intelligent robotics.
4. Conduct workshops and conferences to share results generated by Center.

The specific program objectives for the past year (May 15, 1992 - May 14, 1993) were as follows:

1. Conduct literature survey of neuroscience, and neuroengineering with special reference to biologically motivated neural networks in the areas of auditory and sensory motor control system.
2. Conduct research through experiments in the Meharry Medical College to determine the following:
 - (a) The morphological and neurochemical organization of afferents to the rat auditory cortex.
 - (b) The functional contributions of subcortical projections systems afferent to the auditory cortex in shaping neuronal response patterns relative to feature abstraction and significance.

3. Conduct research on biologically motivated neural networks with applications to robotics. This will lead to the development of neurocontroller based on biological sensory motor control with application to spherical servomotor (joint controller). This objective includes; development of kinematic and inverse-kinematic models of the servomechanism, development of classical controller and development of neurocontroller.
4. Develop a neural network- based system which will produce auditory response similar to the response from a rat's auditory cortex excited by successive pure tones. The data will be collected from the experiment done at Meharry Medical College. A feedforward neural network need to be trained using the firing histogram pattern information with known characteristics parameter set (wavelet transform coefficients) of the input signal.
5. Cascade an adaptive wavelet network and a neural network to implement human audition and perception process and apply it to speaker recognition problem. The constant Q filter bank will be developed by implementing adaptive wavelet transform technique on a wavelet network. At this stage a standard multilayer feedforward neural network will be tested. The input signal will be used here from the human speaker. Upon providing the speaker signal input, the first stage of the system will provide the wavelet parameters to the second stage of a neural network classifier.
6. Develop a wavelet and neural network-based system for feature extraction and classification of various abnormality in the helicopter gearbox data. The data will be provided by the Accurate Automation Corporation of Chattanooga, Tennessee.
7. Develop graduate courses in neuroengineering and neuroscience through the assistance from consortium partners, Accurate Automation Corporation, Meharry Medical College and Oak Ridge National Laboratory.
8. Provide research experience for undergraduate and graduate students in the the area of biological auditory and sensory motor system, neural networks and wavelet transforms and help undergraduate students complete their senior projects.
9. Provide professional development activities for research faculty through the attendance to national meetings, short courses and seminars.
10. Present papers at regional, national and international conferences.

2 Faculty Mentoring Activities At The Center

Dr. Ann Blackshear (biology), Dr. Mohammad Bodruzzaman (elect. engr.), Dr. Satinderpaul Devgan (elect. engr.), Dr. Dhananjaya Marpaka (elect. engr.), Dr. Saleh Zein-Sabatto (elect. engr.) and Dr. Hubert Rucker (physiology) guided four undergraduate (1-biology and 3-elect. engr.) and four graduate students (elect. engr.) on various projects discussed below.

All eight (2 female and 6 male) students are U.S. born Afro-Americans, and all have a GPA of at least 3.0 on 4.0 scale. The undergraduate students are Ms. Nadine Bewry

(biology), Lamar Crowder, Wayne Garrison and Anthony Wilson. The graduate students are Ms. Bridgitte Bundrage, Ronnie Harper, Jaicento Griffith and Richard Griffin. The faculty (mentors) met with the students at least once a week and sometimes more often. The students were trained at Meharry Medical College and Tennessee State University. Dr. Blackshear and Dr. Rucker worked together and jointly supervised the training of Ms. Nadine Bewry.

Dr. Rucker's laboratory was selected as a consortium (subcontractor) laboratory. The laboratory had ongoing research programs in which biological data was collected with potential utility in the development of new neural networks. In addition, we are interested in modeling of information processing in the auditory cortex. Two Tennessee State students, Wayne Garrison and Nadine Bewry, participated in the collection of neurophysiological data during the past year. These activities took place on a weekly basis. Mr. Garrison's senior project was partially based on data collected in this laboratory.

Dr. Zcin-Sabatto supervised the senior project of Ronnie Harper during Fall '92 in collaboration with Accurate Automation Corporation. Ronnie had worked during summer '92 at AAC and his project at AAC developed into a senior project. During spring '93 Ronnie (as a graduate student) was trained and assigned to a project in sensory motor control. Ronnie built and trained a neural network to mimic the behavior of a proportional-controller. His neurocontroller was implemented in the simulation of the servomechanism control system and the results were found to be satisfactory. During the school year 1992-93 Sabatto also supervised Anthony Wilson (undergraduate). His research activities were in the area of active vision. His senior project titled "Design of a vision system for dynamic object tracking using neural networks". In this research Anthony Wilson developed a method for image decomposition captured by a camera. Then a neural network was used to generate the necessary commands for the movement of a robot hand to track the target object. It was determined that the neural network can generate a corresponding output for the object's coordinates based on the preprocessed input vectors. Anthony Wilson completed his senior project in April of '93 and graduated in May '93 with a BS degree in electrical engineering.

Dr. Bodruzzaman supervised two undergraduate and one graduate students. They are Wayne Garrison, Lamar Crowder and Richard Griffin respectively. Garrison and Crowder finished their senior projects on time and graduated in May 1993. Griffin will continue to work in this area towards his Master's degree. These students developed their projects in the area of auditory responses, auditory classification of speech, and modeling of cochlear processes respectively. Garrison was helped by Dr. Rucker in getting the experimental data from auditory response of rat. Crowder was helped by Bodruzzaman in our digital signal processing lab in collecting speech data using SUN Workstation. A paper has been published in the SPIE International Conference Proceedings in which Crowder was one of the co-author.

Dr. Marpaka in consultation with Dr. Reinhold Mann and Dr. Charles Glover of ORNL monitored the progress of Ms. Bridgette Bundrage and Jaicento Griffith on the projects provided by Mann and Glover. Bundrage worked on the research project titled "Neural network-based multi-target tracking system." Initial literature search on this project is partially completed. Development of mathematical model for non-linear dynamical tracking system and solution of tracking system is being pursued and design of self-organization

neural network architecture for target tracking problem is under investigation. Griffith's project is titled "Optimization of information flow using multiple-sensor neural network information filtering system". Both Bundrage and Griffith along with Marpaka are scheduled to spend their summer at ORNL.

Dr. Ann Blackshear served as a co-mentor, along with Dr. Rucker, for Ms. Nadine Bewry, a sophomore biology major. Nadine spent the first semester of the 1992-93 academic year in biology laboratory, where she learned general laboratory techniques and how to various laboratory experiments. She also learned how to write experimental protocols and record data. During this period, she was also exposed to the process of planning and implementation of laboratory experiments. During the second semester, Nadine worked in Dr. Rucker's laboratory. There she participated in neurophysiology experiments on sensory processing in the auditory cortex of the rat. While a publication did not result from these studies, a manuscript is expected to be generated by Fall'93.

3 Faculty Research Highlights

3.1 Research Activities of Dr. Hubert Rucker

Dr. Hubert Rucker conducted research in following areas:

3.1.1 Patterns of Response Plasticity in the Receptive Field of the Rat Auditory Cortex after Conditioning

The specific aim of these studies was to characterize the patterns of response plasticity in receptive fields of the auditory cortex of rat after conditioning. During conditioning, acoustic stimulation was paired with rewarding medial forebrain bundle (MFB) stimulation. Twenty-one neuronal multi-unit clusters isolated in the non-primary auditory cortex of urethane anesthetized were characterized with regard to their frequency receptive fields. Neuronal activity was recorded after tone presentations from 4 kHz to 28 kHz (increments of 4) at 80 dB to establish a baseline. After establishing the baseline, neuronal activity was recorded and characterized after sensitization and after conditioning. Prior to sensitization training, neurons exhibited increased firing at best frequency (BF) and decreased firing at other frequencies. After sensitization, there were either a generalized increase in neuronal firing throughout the frequency receptive field or no significant changes in firing from baseline. After the conditioning training, the receptive fields were analyzed for changes in neuronal activity at BF and at the conditioned stimulus (CS) frequency. After conditioning, approximately 48% (8/18) neurons exhibited a decrease in neuronal firing at BF with an increase in firing at CS frequency. There were differences in the incidence of increase neuronal firing at CS frequency with decreased BF if the CS frequency came before rather than after the BF. Approximately, 37% (3/8) demonstrated an increased CS frequency firing with decreased BF firing when the CS frequency was before the BF; while, 63% (5/8) exhibited the same response patterns when the CS frequency was after the BF. When the BF and the CS frequency were the same (3/3), there were no significant changes in the receptive field profile;

increased firing remained at best frequency. Overall, the CS exerted significant effects on neuronal firing at that frequency. 67% (12/18) of neurons exhibited an increase in neuronal firing at CS; while, 11% exhibited a decrease in firing. However, the CS caused no significant changes in 22% (4/18) of neuronal firing at that frequency. These results are interpreted to indicate that plasticity of information processing, herein represented as frequency receptive field alterations, can occur in a context-specific manner in the rat auditory cortex.

3.1.2 The Effect of Chronic Ethanol Ingestion on Mid-Latency Auditory Evoked Potentials

The purpose of this study was to determine the effects of chronic ethanol ingestion on the Na and Pa components of mid-latency auditory evoked potentials (MLAEPs). Male Sprague-Dawley rats (N=24) were given 10% ethanol in drinking water for ten months and MLAEPs were obtained and compared to age-matched controls given tap water. Data were obtained for varying frequencies (4,8,16,24,32 KHz) and intensities (65, 75, 85 dB SPL). Ethanol treatment was seen to increase the Na and Pa latencies in all cases (ranging 8.5 - 12 ms). A significant decrease in the amplitudes of Na and Pa was observed at 4, 8, and 16 KHz. The Na-Pa interpeak intervals at 4, 8 and 16 KHz were also significantly shortened. These findings suggest that chronic alcohol consumption may bring about structural and/or neurochemical alterations in substrates for cortical information processing. MLAEP's may be useful for evaluating the degree of pathology and cortical cognitive deficits, and therefore complement the information provided by BAEP's and long- latency evoked potentials.

3.2 Research Activities of Dr. Ann Blackshear

Dr. Blackshear collaborated with Dr. Rucker on his research project. She also trained Nadine Bewry a sophomore biology major in neurophysiology, conducting experiments on sensory processing of auditory cortex of rat. Nadine will spent summer 1993 at Cold Spring Harbor laboratory at Long Island, New York to gain experience in Molecular biology.

3.3 Research Activities of Dr. Saleh Zein-Sabatto

Dr. Zein-Sabatto in this part of the research concentrated on the subject of sensory motor control with application to spherical servomechanism. The research started with comprehensive literature survey during Summer of '92. The findings of the survey were documented in a technical report. During the Fall of '92 and Spring of '93 the following research activities were conducted:

- Initiated two concept models for a three-degree-of- freedom (3DOF) servomechanism.
- Developed a kinematic model for the first concept model of the 3DOF servomechanism.
- Developed a dynamic model for the first concept model of the 3DOF servomechanism.

- Developed a classical controller for the first concept model of the 3DOF servomechanism.
- Wrote a Matlab code for the simulation of the above developed models.
- Started development of 3D-graphical model for the first concept model of the 3DOF servomechanism.
- Started development of physical prototype (Laboratory Model) for the first concept of 3DOF servomechanism.

Initial simulation results showed that both the kinematic and inverse-kinematic model performed satisfactorily. Providing two rotational angles, the kinematic model of the servomechanism was accurately able to compute the position and orientation of a coordinate frame attached at the tip ($d=10$ inches) of the servomechanism. Inversely, the inverse-kinematic model was also able to compute the required rotational angles for servomotors I & II for any desired position and orientation within the reach of the servomechanism.

A dynamic model was developed for the first concept model of the spherical servomechanism. A block diagram model and an equivalent closed-loop transfer function were obtained for the purpose of design and simulation. The above model developments are necessary for neural network implementation in sensory motor control.

The first step in the neural network developments was to design and implement classical controllers to control the servomechanism. A proportional (P) and a proportional-derivative (PD) controllers were designed and implemented. Then neural networks with standard back-propagation training algorithm were simulated and trained to mimic the behavior of the P and PD-controllers. It was shown that the trained neurocontrollers were able to learn behavior of the classical controllers and perform satisfactorily in response to a general (arbitrary) input commands defined by the user.

The above two steps set the stage for the development of more sophisticated, biologically motivated neural networks based on sensory motor control.

3.4 Research Activities of Dr. Mohammad Bodruzzaman

Dr. Bodruzzaman conducted research in following areas:

3.4.1 Neural Network-Based Auditory Response

A neural network and an adaptive wavelet network-based auditory system has been designed to mimic neuronal firing patterns in the auditory cortex of a rat's brain. The auditory response data were obtained from rat experiment as provided Dr. Rucker of Meharry Medical college. An adaptive wavelet network (cochlea network) generates wavelet features of the original acoustic signal to correspond to the biological auditory signals which are transmitted along the auditory nerves to the auditory cortex. A two layer feed-forward neural network was used for modeling the auditory cortex which generates similar responses as the neuron

firing pattern in the auditory cortex in response to the input stimulus. Although the data were insufficient, an average firing pattern as obtained from the rat's auditory cortex was used to create the training pair for the input stimulus signal of 1kHz to 32kHz in the interval of 4kHz. The final system network (both cochlea and cortex network) produced a training error of less than 5%. Due to the training data set being small (only 6), the testing error for the system was 34%. In order to decrease error it is recommended that more data be collected in small increment of input frequency.

3.4.2 Wavelet and Neural network-Based Auditory Tuning for Speaker Recognition

An adaptive wavelet network (wavenet) and neural network (neural-net) has been implemented to model human auditory system for speaker recognition. This is an attempt to cascade a wavelet network and a neural network for feature extraction and classification respectively. The wavenet is to mimic the audition process by extracting a wavelet basis function for the speech data generated by each individual speaker and the neural net for mimicking the perception of the human brain process by classifying and recognizing the speaker. The human speech data were collected using SUN Sparcstation's sound tool. It has been observed that the same word uttered by the same person has different waveform at different times and this difference can be characterized by some time domain dilation in the waveform similar to the dilation effect on a wavelet function. The speech waveforms of the word "blue" uttered by five different male students were used. We collected nine samples for each speaker. The adaptive wavelet filter coefficients that lead to the best 1-2 approximations for each speaker are extracted. Seven of the nine wavelet filter coefficient sequences that were obtained for each speaker were then used to train the neural network, while the remaining part are stored as testing data. The training error in root mean square was less than 5% and the testing success rate was almost close to 100%.

Dr. Harold Szu of Naval Surface Warfare Center was consulted several times regarding implementing the wavenet architecture. Although the system shown here is applied to speaker recognition problem this can also be applied to any domain where feature extraction and classification is needed. Wavelet filter coefficients, as a feature set, are dynamic coefficients which can be adaptively adjusted using an adaptive wavelet network based on the time varying input signals. In this work, the wavelet features are fed to a feedforward neural network for classification purposes. The neural network training and testing results seem to be very promising, and a larger test will be pursued.

A part of this work has been reported in the senior project of Lamar Crowder. A paper has also been published in the SPIE International Conference Proceedings, held in Orlando, FL., May 14, 1993. This paper was co-authored by Crowder (TSU student), Dr. Harold Szu and Dr. Brian Telfer of Naval Surface Warfare Center. The paper was presented by Dr. Harold Szu and received a full house appreciation for the work done at TSU (as commented by Dr. Harold Szu).

We are continuing the same research over this summer and going into more depth of the problem area. Richard Griffin will continue to work on this area and help in acquiring more data from Dr. Rucker's laboratory.

3.4.3 Neural Network-Based Fault Diagnosis of Helicopter Gearbox

Bodrutzamman spent half day on November 6, 1992 and another half day on February 15, 1993 at Accurate Automation Corp. in Chattanooga. There, he discussed and wrote some programs for them in the area of Wavelet transformation for the analysis of helicopter gearbox vibration data. He brought helicopter gearbox data from the AAC and loaded them on the SUN Sparcstations in Signal Processing Lab. Some preliminary analysis has also been done. The results are promising. The wavelet transform technique has been used on normal and various abnormal helicopter gearbox data and some good results have been obtained in classifying the various vibration data.

3.4.4 Other Neural Network-Based Research Activities

Besides the above mentioned work Bodruzzaman has also done some research in the area of text dependent speaker recognition using cepstral coefficient-based neural network, signal recovery from noise using neural network, efficient algorithm development for multi directional search learning for multilayer feedforward neural network, neural network-based modeling of chaotic dynamics and neural network-based nonlinear deconvolution. All these works have been published in conference proceedings and journals.

3.5 Research Activities of Dr. Dhanajaya Marpaka

Dr. Marpaka in conjunction with Dr. Charles Glover of ORNL guided a graduate student Bridgitte Bundrage to develop an artificial neural network tracking algorithm. This algorithm is currently being used to reconstruct charged particle tracks. It involves nonlinear dynamic systems.

3.6 Research Activities of Dr. Satinderpaul Devgan

Dr. Devgan sent letters to ninety nine (99) institutions that offer course related to our areas of interest in neuroscience/neuroengineering. He surveyed their course offerings and their faculty for the development of our curriculum in neural computing and engineering. He also examined the course offerings by TSU and MMC in the area of neuroscience. This information was used in preparing the tentative curriculum that is been reviewed by the participating faculty. Eventually this program may be offered as a concentration under the existing Masters of Engineering Program.

4 Faculty Publications

1. Pirch, J.H., Turco, K., and Rucker, H.K., " A role for acetylcholine in conditioning-related responses of rat frontal cortex neurons: microiontophoretic evidence." Brain Res.586:19-26, 1992.

2. M. Bodruzzaman and M. J. Malkani, "Neural network modeling of neuromuscular signals." Proceedings of International Symposia on Information Sciences (ISKIT '92), Iizuka, Fukuoka, Japan, July 12-15, 1992.
3. M. Bodruzzaman and M. J. Malkani, "Chaotic neural networks and their possible application to biological system modeling." Proceedings of 2nd International Conference on Fuzzy Logic and Neural Networks (IIZUKA '92), Iizuka, Fukuoka, Japan, July 17-22, 1992.
4. M. Bodruzzaman, X. Li, C. Wang and S. S. Devgan "Neural network modeling of chaotic systems." Proceedings of Canadian Conference on Electrical and Computer Engineering (CCECE '92), Ontario, Canada, September 1992.
5. C. Wang, M. Bodruzzaman, and X. Li, "Multi-directional search learning algorithms for multilayer feedforward neural network," - submitted to the IEEE Transaction on Neural Networks. November 1992.
6. M. Bodruzzaman, X. Li, K. Kuah, L. Crowder, M. Malkani, H. Szu and B. Telfer, "Speaker recognition using neural network-based adaptive wavelet transform," Proceedings of SPIE International Conference '93, Orlando, FLA, April, 1993.
7. M. Bodruzzaman, K. Kuah, T. Jamil, C. Wang and X. Li, "Parametric feature-based voice recognition system using artificial neural network," Proceedings of IEEE Southeastcon '93, Charlotte, NC, April, 1993.
8. X. Li, M. Bodruzzaman, C. Wang and J. A. Cadzow, "Signal recovery using neural networks," Proceedings of IEEE Southeastcon '93, Charlotte, NC, April, 1993.
9. M. Bodruzzaman, X. Li, and C. Wang "Modeling of chaotic dynamics using artificial neural network," - submitted to the Journal of Chaos, Solitons and Fractals, Pergamon Press, January 1992.
10. X. Li, M. Bodruzzaman, M. Malkani, H. Szu and B. Telfer, "Neural network-based nonlinear blind deconvolution," - in press, Proceedings of World Congress on Neural Networks (WCNN), Portland, OR, July 1993.
11. M. S. Zein-Sabatto and M. Bodruzzaman, "A Neural Network Classifier for Recycling Process." Proceedings of IEEE Southeastcon '93, Charlotte, NC, April, 1993.
12. M. S. Zein-Sabatto, M. Malkani and H. K. Ruckur, "Neuro-control system for biologically motivated servomechanism." International Joint Conference on Neural Networks, IJCNN '93, Nagoy, Japan, Oct. 25-29, 1993 (in process).
13. S. Devgan, M. Malkani, M. Bodruzzaman and H. Rucker, "Graduate Program in Neural Engineering." Proceedings of ASEE Frontiers in Education , November 1993. (Paper accepted for presentation and publication)

5 Faculty Presentations

1. M. Bodruzzaman and M. J. Malkani, "Neural network modeling of neuromuscular signals." International Symposia on Information Sciences (ISKIT '92), Iizuka, Fukuoka, Japan, July 12-15, 1992.
2. M. Bodruzzaman and M. J. Malkani, "Chaotic neural networks and their possible application to biological system modeling." 2nd International Conference on Fuzzy Logic and Neural Networks (IIZUKA '92), Iizuka, Fukuoka, Japan, July 17-22, 1992.
3. M. Bodruzzaman, X. Li, C. Wang and S. S. Devgan "Neural Network Modeling of Chaotic Systems." Canadian Conference on Electrical and Computer Engineering (CCECE '92), Ontario, Canada, September 1992.
4. M. Bodruzzaman, X. Li, K. Kuah, L. Crowder, M. Malkani, H. Szu and B. Telfer, "Speaker recognition using neural network-based adaptive wavelet transform," SPIE International Conference '93, Orlando, FL., April, 1993.
5. M. Bodruzzaman, K. Kuah, T. Jamil, C. Wang and X. Li, "Parametric feature-based voice recognition system using artificial neural network," IEEE Southeastcon '93, Charlotte, NC, April, 1993.
6. X. Li, M. Bodruzzaman, C. Wang and J. A. Cadzow, "Signal recovery using neural networks," IEEE Southeastcon '93, Charlotte, NC, April, 1993.
7. M. S. Zein-Sabatto and M. Bodruzzaman, "A neural Network Classifier for Recycling Process," IEEE Southeastcon '93, Charlotte, NC, April, 1993.

6 Faculty Self Improvement Activities

Dr. Blackshear and Dr. Rucker attended the Annual meeting of the Society for Neuroscience, Nov 24 -30, 1992, Anaheim, California.

Dr. Bodruzzaman and Dr. Zein-Sabatto attended IJCNN'92 held in Baltimore, July 1992 and Dr. Bodruzzaman attended Dr. Harold Szu's tutorial on "Wavelet and Neural Network".

Dr. Bodruzzaman and Dr. Zein-Sabatto attended IEEE Southeastcon'93 held in Charlotte, NC, April, 1993. Both served as a Technical Chairman of two of the sessions on Neural Networks.

Dr. Zein-Sabatto attended the 1993 IEEE International Conference on "Robotics and Automation", Atlanta, GA. May 2-7 1993.

All TSU researchers and at times a few undergraduate and graduate students attended a series of two hour weekly seminars throughout the Summer 1992 and the Academic year 1992-93 on Neuroscience offered by Dr. Rucker. He used the text book titled "Principles of Neural Science," edited by Eric Kandel, James Schwartz and Thomas Jessell. Every seminar was generally followed by a general discussion of the topics covered.

All TSU researchers attended a series of five lectures on "Statistical Neural Networks" by Dr. Muhammad A. Majid a visiting scientist during Summer 1992.

These lectures were held in The College of Engineering and Technology on TSU campus.

7 Visiting Faculty

Three distinguished researchers Drs. John Caulfield, Jeffrey Johnson and Harold Szu presented seminars on neural networks. Drs. Charles Glover (ORNL), Reinhold Mann (ORNL), Aliana Maren (ACC), Richard Saeks (AAC), Charles Thompson (AAC) and Kevin Priddy (AAC) presented lectures on neural networks as part of first structured graduate level course on "Artificial Neural Networks". The course was coordinated by Dr. Bodruzzaman. TSU faculty Drs. Bodruzamman, Marpaka and Zein-Sabatto delivered the first four lectures followed by four lectures each by ORNL and AAC scientists and engineers respectively. The course was attended by eight students and TSU faculty members. Each lecture was of 2 1/2 hours duration. The distinguished research lecture activities are described below:

7.1 Distinguished Research Lecture Seminars:

Dr. Harold Szu, Information Science Group Leader at Naval Surface Warfare Center presented a seminar on September 22, 1992 on "Agenda for Next Generations Intelligent Neuro-computing". A theory of dynamical architects in the context of classical NN was presented. A video presentation showing live neural network formation on a VLSI chip with time-lapsed video microscope was also presented to both the students and the faculty members.

Dr. H. John Caulfield University Eminent Scholar at Alabama A&M University presented a seminar on "The Why of Optical Neural Networks" on October 20, 1992. He discussed the advantages of optics including 4th order parallelism, quantum mechanical processing, use of fanin to consume complexity and also addressed molecular computers.

Dr. Jeffrey D. Johnson a Research Scientist at Wright Laboratory, Wright Patterson Air Force presented a seminar on "Neural Networks for Prediction and Control on October 22, 1992. The problem of formulating a decision policy in an environment that supplies delayed, minimally-descriptive reinforcement feedback was addressed.

8 Other Faculty Activities

The Center for Neural Engineering conducted a five day very successful tutorial based workshop on Fuzzy-Neuro Systems, May 23-27, 1993 at Tennessee State University. This National Science Foundation funded workshop was attended by 32 engineering faculty from 13 Historically Black Colleges and Universities (HBCU) and 2 Minority Institutions (MI). The participating universities were:

Alabama A&M University

Central State University

Florida A&M University
Hampton University
Howard University
Morgan State University
Norfolk State University
North Carolina A&T state University
Prairie View A&M University
Southern University
Texas A&I University (MI)
Tennessee State University
Tuskegee University
University of District of Columbia
University of Puerto Rico at Mayaguez (MI)

All the TSU researchers participated in the planning , organization and the implementation of this workshop. Drs. James Bezdek (West Florida Univ.), Kim Blackwell (ERIM), Joel Davis (ONR), Madan Gupta (Saskatchewan Univ), Yashvant Jani (Togai InfraLogic), Robert Lea (NASA), Robert Pap (AAC), Francoise Pin (ORNL), and Kan Thangavelu (United Technology) provided the instructions. Pap and Pin's participation provided the consortium support and Davis participation reinforced the commitment of the Office of Naval Research to the success of this Center. Bezdek and Jani taught the participants the basics of Fuzzy Logic the first three days through theory and laboratory simulations of both hardware and software tools. They also introduced the fundamentals of neural networks, which was reinforced by Blackwell through the design of artificial neural networks from neurobiological principles. Davis put the icing on the cake through his presentation on what a neuroengineer should know about neuroscience. Pap introduced neurocontroller, its practical applications to defense industry and led the participants to the fundamentals of Fuzzy-Neurocontroller. Thangavelu explained application of fuzzy controllers in elevators and Lea discussed the commercial and defense applications of fuzzy logic and the involvement of NASA Johnson Space Flight Center in this technology. On the final day Gupta introduced the topic of fuzzy- neural systems and its application to pattern recognition. Pin explained fuzzy decision making with application to robotics. He showed the successful application of fuzzy controller in the navigation of an automobile in a parking lot. The workshop ended with a panel discussion on curriculum development and research opportunities in this exciting technology. The evaluation from the participants speak very highly about the depth of the knowledge possessed by the instructors, and their interaction with the participants both in the class and outside the class. There was a consensus effort on the part of participants to develop some joint proposal in this area. The Center hopes to pursue this new challenge.

8.1 Participation in proposals

The Center faculty participated actively in submitting proposals to various agencies as follows:

1. "Research Training Opportunities in Neural Engineering" under FY 92 ASSERT submitted to DoD for \$ 212,257 —FUNDED
2. "Research Training Opportunities in Neural Engineering" under FY 93 ASSERT submitted to DoD for \$ 231,696 —NOT FUNDED
3. "Robust Integrated Neurocontroller for Complex Dynamic Systems", Drs. Zein-Sabatto (PI), Marpaka (Co-PI) submitted to NASA for \$ 562,698 —FUNDED (effective June ,1993)
4. "On-Line Intelligent and Integrated Health Monitoring System for Aircraft Structures", Drs. Bodruzzaman (PI), Devgan (Co-PI), Malkani (Co-PI) submitted to NASA for \$ 995,000 - PENDING TECHNICAL REVIEW
5. "Conditioning related acetylcholine release", submitted to National Institute of Mental Health , Dr. Rucker (PI)
6. "Computation Facility for Neural Network Research", Drs. Devgan (PI), Bodruzzaman (Co-PI) and Zein-Sabatto (Co-PI) submitted to DoD under Research Instrumentation Program Infrastructure for HBCU for \$ 259,700 —PENDING TECHNICAL REVIEW

9 Faculty Recruitment

Postdoctoral position in the Center was advertised in March 1993 issue of IEEE Spectrum. About 40 applicants have responded and their applications are being reviewed.

Advertised in April 1993 issue of IEEE Spectrum for Research Assistants to pursue Master of Engineering degree at TSU, with research opportunities in Neural Engineering at the Center.

Announcements for the above positions were also sent to many graduate schools in the nation, graduating seniors and sister HBCU institutions. They were also given to the participants at the Fuzzy-Neuro workshop held at TSU, May 23-27, 1993. As a result one graduating senior Tim Robinson from Morgan State University has applied for admission. In addition Carolyn Keaton from Morgan State University and Talisman Barrett from Norfolk State University have expressed their interest in pursuing graduate studies at TSU. Both Carolyn and Talisman are expected to graduate in December 1993. All three applicants are US born African Americans. They are recommended by the faculty at the Fuzzy Neuro workshop.

Announcements will also be placed at other conferences that we attend.

10 Curriculum Changes and Enhancements

Dr. Rucker offered Advanced Neurophysiology course at Meharry Medical College during Spring '93 semester. This course utilizes a systems approach to central nervous system function including sensory systems, motor control systems and higher cognitive functions. This course was attended by all four of our research assistants, Bundrage, Griffith, Griffin and Harper along with Dr. Rucker's Ph.D students. This course was highly interactive and the students were asked to make presentations on many topics from the course.

TSU will offer a first course in Artificial Neural Networks in Fall '93 semester. This course will be team taught by Drs. Bodruzamman and Marpaka with introductory lecture by Rucker. This course will be supplemented with guest lecturers from consortium partners and other experts in the fields as needed. This course will be open to all students in the Master of Engineering Program at TSU.

It is anticipated that Drs. Blackshear and Rucker along with other colleagues in the Speech Audiology Department at TSU will offer an introductory course in neurobiology to meet the special needs of our research assistants.

Dr. Devgan has almost completed a curriculum for a concentration in Neural Engineering and Computation in the Master of Engineering program.

11 Programs for Students

11.1 Recruitment Activities

We recruit the students to conduct research in the Center for Neural Engineering as follows;

1. Announcement is posted on the College bulletin Board for graduating seniors with a GPA of at least 3.0 out of possible 4.0 to apply with a copy of transcript and a letter expressing their interest to conduct research at the Center. A student must agree to complete senior project at the Center and that a student must set aside at least a block of three hours to conduct research.
2. Outstanding juniors are also being looked upon as potential candidates to generate a pipeline.
3. Undergraduate students are exposed to the field of neural networks through distinguished lecture series program.
4. Demonstrations are being set up in the Center to motivate the student in this technology.
5. Recruitment poster and related literature is sent our sister HBCU/MI institutions to recruit graduate students.
6. Announcement are placed at the national NSBE and SWE conventions.

7. The college also participates in Science and Engineering graduate recruitment fairs.

11.2 Summer Educational/Enrichment Programs

Although the College does not offer any summer courses, the opportunities are available to send the students to attend conferences and or short courses depending on the availability of funds. Efforts will be made to encourage students to attend enrichment programs offered by defense agencies.

11.3 Research Opportunities and Internships

All research assistants are provided the opportunity to work half time (20 hours per week) during the school year and full time (40 hours per week) during summer. Undergraduate assistants can work a maximum of 10 hours per week during academic year and full time during summer. During the academic year research can be done at TSU and or MMC.

Due to our unique teaming arrangement, the student are provided the opportunity to spend either full or part summer at our consortium partners TSU, MMC, ORNL and AAC. Thus proving a variety of experience to the student to enhance his professional development. This could lead to a challenging Master's thesis and a journal article.

Students attending at Meharry Medical College are exposed to basic electrophysiological techniques associated with the recording of bio-electric events from live animals to include protocol development, animal surgery, instrumentation, analysis as well as ethical and humane considerations. This program could be enhanced by pairing students on a long term basis with Ph.D. level neuroscience students working in this laboratory.

11.4 Mentoring Programs

Each research assistant is provided a TSU faculty member as a mentor. The mentor meets with the student at least once a week or more as the need be. During summer months a student could have two mentors if he is spending summer at consortium partners facility. However a TSU faculty member will be his primary thesis advisor and this should be made clear to consortium partners. Otherwise a problem could develop.

12 Facilities and Equipment

The grant did not provide any funds to purchase equipment to conduct research. Fortunately Bellcore had donated 12 SUN 2 terminals to TSU. They were donated to the Center located in room 240 of the College of Engineering and Technology. Sun microsystems donated a server, and memory boards were purchased at the suggestion of local sun representative. However it was discovered to our dismay that the terminals could not handle graphics. It was too

slow. This was brought to the attention of Program Monitor, and he approved our request to purchase 3 486-based PC's at a cost of \$ 5000.00, so that the undergraduate students could use them and complete their senior project on time. In the mean time faculty and students used SUN sparc 4 workstations in the Intelligent Signal Processing Lab (funded by Air Force) located in adjoining room. Since then we have submitted a proposal to DoD to provide funds to purchase SUN workstations for TSU and MMC. Funds have also been requested for the development of Sensory Motor Control Systems lab in the Center at TSU.

During the last contract period, Meharry Medical college purchased a CSI dual channel spectrum analyzer which will allow continuous waveform analysis of EEG data. This will enhance MMC's ability to follow changes in cortical processing on a chronic and less invasive basis.

13 Specific Program Objectives for Next Year

It is envisioned that with a greater interaction among consortium partners a well focused research will be conducted leading to quality research, quality curriculum and journal articles. The specific objectives of various researchers are listed below:

13.1 Goals of Dr. Rucker:

1. To generate 3 peer reviewed papers from current work.
2. To present work at 2 national symposia.
3. To mentor 2 students in biomedical data gathering.
4. To develop a model of cortical auditory processing based on primary data which includes bias weights representing diffuse cortical afferents.
5. To study state dependent acetylcholine release in cortex.
6. To offer the Advanced Neurophysiology course again in the Spring '94 semester.

13.2 Goals of Dr. Blakshear:

Working in collaboration primarily with Dr. Rucker, Dr. Blakshear's goals are as follows:

1. To continue increase knowledge of neural networks and auditory cortex simulation, as well as increase interactions with other faculty in the program.
2. To increase participation in the research activities on the role of Ach in associative conditioning in the auditory cortex. These studies are expected to result in the generation of a manuscript.

3. To participate in the development and instruction of a basic neurobiology course in the neural networks program.
4. To mentor one undergraduate student.

13.3 Goals of Dr. Bodruzzaman

Dr. Bodruzamman will interact with Dr. Rucker at Meharry Medical College and Dr. Priddy of Accurate Automation Corporation, and to some extent with Dr. Mann and Dr. Szu of Oak Ridge National Laboratory and Naval Surface Warfare Center respectively. His specific goals for next year are as follows:

1. Generate 2 refereed and 3 conference papers with consortium partners from current works.
2. Mentor 2 undergraduate students in generating and supervising their senior project in the area of auditory neural network.
3. Mentor 2 graduate students in generating and supervising their Master's thesis in the area of auditory neural network.
4. Develop neural network-based model for the auditory cochlea.
5. Teach graduate level neural network course (EE525) in the fall of 1993.
6. Coordinate with Dr. Rucker in developing auditory neural network.
7. Coordinate with Engineers of Accurate Automation Corp. in developing wavelet and neural network-based helicopter gearbox data analysis system.
8. Coordinate with Dr. Harold Szu of Naval Surface Warfare in developing wavelet-neural network model.
9. Present papers at the IEEE-INNS Conference '94.
10. Present papers at the WCNN Conference '94.
11. Present papers at the SPIE Conference '94.
12. Present papers at the IEEE Southeastcon '94.
13. Actively participate in recruiting Post Doc research associate for the Center.

13.4 Goals of Dr. Marpaka

Dr. Marpaka will interact with Drs. Glover and Mann of Oak Ridge National laboratory. His specific goals for next year are as follows:

1. Interact with Dr. Mann to develop neural network architecture for optimization of information flow using multiple-sensor neural network information filtering.
2. Spend part of summer 1993 at ORNL in Dr. Mann's Center for Engineering Systems Advanced Research group to conduct research in item 1.
3. Mentor 2 graduate and undergraduate students.
4. Publish at least two major journal papers in conjunction with consortium partners.

13.5 Goals of Dr. Zein-Sabatto

Dr. Zein-Sabatto will interact with Mr. Chad Cox of Accurate Automation Corporation and Dr. Francoise Pin of ORNL. His specific goals are as follows:

1. Spend some time at AAC to interact with Chad Cox on Robotics project(s) at AAC
2. Read literature to collect data either from MMC or other medical college on sensory motor system.
3. Continue the development of neurocontrol systems based on actual biological sensory motor control with application to spherical servomechanism with the data obtained in item 2.
4. Mentor 3 undergraduate and graduate students.
5. Publish journal articles jointly with AAC.
6. Apply for patent on joint controller.

PART II

14 Information About Seniors in The Program

During Fall '92 semester four electrical engineering seniors participated in the Center for Neural Engineering. They conducted research on various topics under the supervision of faculty mentors. Their research generated into senior projects.

The names of the students, their major field of study, the name of faculty mentor, name of the graduate school and or employer upon graduation is listed below;

1. Name of Student: Ronnie Harper

Major field of study: Electrical Engineering

Faculty Mentor: Dr. Seaks (AAC), Dr. Zein-Sabatto

Date of Graduation: December 1992

Name of Graduate School: Tennessee State University

Name of Employer:

Project Title: The design of Neural Network for Motor Controller Selection

2. Name of Student: Lamar Crowder

Major field of study: Electrical Engineering

Faculty Mentor: Dr. Bodruzamman

Date of Graduation: May 1993

Name of Graduate School:

Name of Employer: Delco Electronics (GM)

Project Title: Design of Neural Network Based Auditory System for Speaker Identification

3. Name of Student: Wayne Garrison

Major field of study: Electrical Engineering

Faculty Mentor: Dr. Bodruzamman (TSU) Dr. Rucker (MMC)

Date of Graduation: May 1993

Name of Graduate School:

Name of Employer: International Paper

Project Title: Design of Neural Network-Based Model for Auditory Cortex of Rat.

4. Name of Student: Anthony Wilson

Major field of study: Electrical Engineering

Faculty Mentor: Dr. Zein-Sabatto

Date of Graduation: May 1993

Name of Graduate School: Georgia Tech.

Name of Employer:

Project Title: Design of a Vision System for Object Tracking Using Neural Networks

15 Additional Data

All the students in this program participated in the Fifteenth Annual University-Wide Research Day, open for all students and faculty at TSU Campus on March 23, 1993. We are pleased to announce that Ronnie Harper ranked the first place among the graduate students presentation and Anthony Wilson ranked the third place among all the undergraduate student presentations. Thus bringing reputation and visibility for the Center among TSU campus community.

16 Interaction With Oak Ridge National Lab

In addition to attending Center meetings and various telephone conversations, ORNL participants Drs. Charles Glover and Reinhold Mann provided a very valuable assistance and constructive suggestions for the growth of the Center. Some of the most note-worthy contributions are:

1. Glover and Mann gave 4 lectures on neural networks during Fall '92 semester at TSU. Each lecture was of 2 1/2 hours duration.
2. Dr. Pin participated in planning of Fuzz-Neuro workshop at TSU May 23-27, 1993 and gave a presentation on also participated in panel discussion on May 27, 1993.
3. Dr. Mann and his colleagues provided extensive information on capital equipment to start a sensory-motor control lab. at TSU.
4. Ms. Bridgitte a graduate research assistant is working with Glover on her Master of Engineering thesis.
5. Dr. Marpaka will spend about a month at ORNL to perform research this summer.

17 Interaction With Accurate Automation Corp.

Like ORNL partners there has been considerable interaction with Richard Saeks, Bob Pap and his colleagues at AAC. Some of the most note-worthy activities are:

1. Ronnie Harper spent summer 1992 at AAC working on Hopfield based neural network for motor controller. This work was accepted as a senior project. Ronnie graduated in December 1992 and joined the Center as a graduate assistant. Ronnie also presented his work at AAC at TSU research day and won the first place among all the graduate student presentations.
2. Drs. Aliana Maren, Kevin Priddy, Richard Saeks and Chuck Thompson presented four (4) lectures on neural networks during fall '92 semester at TSU.
3. Mr. Bob Pap Participated in planning a workshop on Fuzzy- Neuro Systems at TSU May 23-27, 1993. He also gave a presentation on fuzzy-neuro controller with practical application to DoD projects.
4. Dr. Bodruzamman is interacting with Dr. Kevin Priddy on the application of wavelet technique to helicopter problem. He will spend time this summer at AAC to interact actively on this project.
5. Dr. Zein-Sabatto has been exchanging information with Chad Cox at AAC on robotics project. He also will spend time at AAC this summer to get actively involved in this project.

Hopefully interactions with AAC and ORNL will assist TSU faculty in making use of the resources available at consortium partners, which will lead to quality research, quality curriculum and most important produce quality students.

	Number of students enrolled at school (by year)						Number of students enrolled in ONR Program (by year)				Number of students graduated Aug. '92&May '93		Number to Graduate or Professional School	
	FALL 1992										Total		Total	
	1	2	3	4	1	2	3	4	Total	ONR	Total	ONR	Total	ONR
Major Discipline (Science & Engineering)														
Fr. Soph Jr. Sr.														
Biology	81	41	59	72		1			21		6			
Chemistry	13	6	17	16					10		4			
Computer Science	63	38	60	67					18					
Engineering	322	142	127	244				3	47	3	7		2	
Mathematics	11	5	14	14					6					
Physics			2	1					2					
Totals for science and engineering	490	232	279	414		1		3	104	3	17		2	

Table 1 - Enrollment Data

Class Year	Mean SAT (ACT) for all Freshman	Mean SAT (ACT) for ONR Freshman	Mean GPA for all students	Mean GPA for ONR students	Mean GRE (all students)	Mean GRE (ONR students)
1 1992	19	N/A	2.74	N/A	N/A	N/A
2						
3						
4						

Table 2 - Academic Performance Data