

INSTITUTIONAL INFRASTRUCTURE IN SUPPORT OF COMPUTER AND SOFTWARE ENGINEERING WITH SPECIAL FOCUS ON HUMAN-COMPUTER INTERFACE RESEARCH AND INFORMATION PROCESSING

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INTRODUCTION

The vision of the NSF-CATE center at FIU is to foster a cross-disciplinary research and educational program as a catalyst for our undergraduates and graduates alike to train and develop their creative thinking by bringing in synergy the fields of applied information processing, human/brain-computer interfaces, and neuroscience. In the merging of these technologies, we see a productive ground for the development of new methodologies and scientific discovery that (1) will meet the impending needs in neuroscience as we elicit both the functional mapping of the brain, and the causality of key brain disorders; and (2) perform Human-Computer Interface (HCI) research that address effectively the issue of *Universal Accessibility*, focusing on visual impairment and motor disability. Applied information processing (in relation to analysis and interpretation of signals and images), neuroscience (in terms of brain functional mapping and neurorehabilitation and cognitive issues), and human/brain-computer interface research (as assistive or augmentative real-time systems) are inextricably linked. New developments in the field of applied information processing may yield new insight into key physiological aspects of neuroscience, which in turn, can elicit new research directions and new theoretical developments in support of system design with augmented viability. The interplay between science and engineering is hence at its best by bringing together new theoretical findings into the practical realms of medical science. Experimental results, as observed through clinical means or through system design evaluations and feasibility studies serve as means to redefine or re-evaluate our theoretical premises; just as learning more about the workings of the human brain will serve to spawn theories that can expand our potential for new scientific/engineering discovery. It is important to note that the strong collaboration we have secured with our industry partners entails student internships, clinical rotations, joint faculty appointments, shared use of modern equipment and infrastructure, all serving in an integrated environment apt to secure the success of our students' educational and research careers all the way to the Ph.D. level.

AREAS OF FOCUS AND RESEARCH SPONSORS

With the infrastructure provided by the CATE center, students are now afforded to carryout their work and training in the following research areas:

Research Areas

- Image-Signal Processing and Computer Vision
- Assistive Systems and Human-Computer Interfaces
- Brain Research and Neurorehabilitation
- Biomedical Applications: Flow Cytometry and Confocal Microscopy
- Robotics for Motion Planning and Automated Guidance
- Parallel and Distributed Computing

Research Sponsors

- The National Science Foundation (NSF)
- The Office of Naval Research (ONR)
- Miami Children's Hospital
- Beckman-Coulter Inc.

Research Funding and Publications

The CATE center has to this date secured close to 6 million dollars in federal funding. The CATE center submits 8 to 10 proposals and generates 15 to 25 publications annually.

INDUSTRY PARTNERS

- Miami Children's Hospital
- Beckman-Coulter Inc.
- Intelligent Hearing Systems
- Miami Lighthouse for the Blind

HUMAN CAPITAL

Faculty

Malek Adjouadi, Armando Barreto, Ana Pasztor, and Gustavo Roig

Faculty Research Associates

Melvin Ayala, Ph.D. -- Areas of Expertise: Neuro-control and Neural Networks.

Ilker Yaylali, M.D., Ph.D. -- Area of Expertise: Neuroscience and EEG brain research

Student Support for the 2002-2003 Academic Year

Graduates - (25):

(a) Ph.D. Students (6):

Female Students (2): Cai Weiting, Ph.D. candidate; Monica Dezulueta, Ph.D. candidate

Male Students (4): Patricio Vidal, Ph.D. candidate; John Riley, Ph.D. candidate; Navarun Gupta, Ph.D. candidate; Marc Rossman, Ph.D. student

(b) MS Students (19):

Female Students (7): Natasa Mirkovic; Mercedes Cabrerizo; Kirenia Nunez; Ann Zhong, Anaelis Sesin, Dalila Landestoy and Maria Tito

Male Students (12): Mark Rossman, Celso Duran; Alejandro Simon; Manuel Docurro; Craig Mackay; Pablo Fernandez, Mourad Michel, Sriman Lingala, Miguel Alonso, Wissarut Yuttachai, Maroof Choudhary, and Carlos Ordonez.

Undergraduates - (21)

Female Students (7): Christine Bedia; Anaelis Sesin, Dalila Landistoy, Grettel Frias, Suzie Diaz, Karen Santiago, Yania Arencibia.

Male Students (14): Eddy Caballero, Luis Arencibia, Michael Valdes, Walter Tisher, Jay Joseph, Gary Charles, Daniel Rodriguez, Leonardo Letourneaut, Christian Cousinet, Pedro Pena, David Salinas, Charles Suero, Ricardo Valdes, and Daniel Sanchez.

Student Recruitment and Retention for the 2002-2003 Funding Period

In an unprecedented effort, the CATE center has recruited and supported the following number of students, with some students being retained from their REU experience all the way to the Ph.D. program:

Ph.D. Students (10):

Female Students (6): Monica Dezulueta, Mildred Zabawa, Danmary Sanchez, Mercedes Cabrerizo, Natasa Mirkovic, and Ann Zong

Male Students (4): Mark Rossman, Navarun Gupta, Miguel Alonso and Feng Gui

MS Students (18):

Female Students (3): Maria Tito, Anaelis Sesin, and Dalila Landistoy

Male Students (11): Celso Duran, Alejandro Simon, Eddy Caballero, Michael Valdes, Pablo Fernandez, Mourad Michel, Sriman Lingala, Miguel Alonso, Maroof Choudhary, Carlos Ordonez.

Undergraduates (7):

Female Students (2): Christine Bedia (Webmaster), Grettel Frias

Male Students (5): Jay Joseph, Gary Charles, Charles Suero, Ricardo Valdes, and Daniel Sanchez.

Conferral of Degrees for the 2002-2003 Funding Period

Ph.D. Degrees (3):

- John S. Riley: Statistical Anal. & Optimal Classification of Blood Cell Populations Using Gaussian Distributions.
- Patricio J. Vidal: A Mathematical Resolution to Log Transformations and the Binning Effect In Applied Processing of Data in Flow Cytometry.
- Cai Weiting, "Wavelet Domain Motion Estimation and Compensation for Video Compression", Department of Electrical and Computer Engineering

Master Degrees (13)

- Marc Rossman: Using Single Photon Emission Computed Tomography Brain Images to Localize Epileptic Foci
- Carlos Ordonez: Development of a 3-D Sound Guidance System for Blind Navigation in Virtual Environments.
- Eyhab Al-Masri: A practical System for Hands-Off Computer Interaction Based on EMG / Eye Gaze Tracking.
- Ricardo Romero: A DSP-Based Detector of Nonstationary Periodically Structured Signals
- Natasa Mirkovic: 3-D Source Localization of Epileptic Foci Integrating EEG and MRI Modalities.
- Manuel Doccuro: Three-Dimensional Autostereoscopic Imaging by Computer Based Holography Techniques
- Miguel Alonso Jr.: On-screen Pre-deblurring of Digital Images Using the Wavefront Aberration Function of the Human Eye to Improve Computer Access for the Visually Impaired.
- Wissarut Yuttachai, "Wavelet-Based Compression of Electrocardiogram Records Using the Minimum Description Length Criterion
- Craig Mackay: Real-Time Motion Tracking of Objects in a Human-Computer Interface.
- Maroof Choudhury: Multi-Sensor Sonar Sys. for Indoor Range Measurement as a Navigational Aid for the Blind
- Mercedes Cabrerizo: A Topographic Methodology to Interpret Activity Changes In The Human Brain as a Function of an Auditory- Comprehension Process
- Kirenia Nunez: Analysis of EEG Signals in Time Domain for the Understanding of Auditory and Comprehension Activities.
- Ann Zhong: Multidimensional Pattern Recognition and Classification of White Blood Cells Using Support Vector Machines.

HUMAN CAPITAL- RETROSPECTIVE

The CATE center since its inception has financially supported the following students:

- 4 Postdoctoral graduates (1 female and 3 Males).
- 62 graduates (14 Ph.D.s and 48 MS students with 33 Males and 29 Females): 5 obtained the Ph.D. degree (2 females, 3 males), and 39 obtained their MS degree (18 females and 21 males).
- 71 undergraduate students (35 females and 36 males): 67 obtained their BS degrees (32 females, 35 males).

RESEARCH CONTRIBUTIONS

Research Findings

Wavelet Domain Motion Estimation and Compensation for Video Compression: A Sub-decimation decomposition method based on the symmetric-extended wavelet transform (SWT) approach was developed in this research direction. The results yielded better compression in terms of both low bit rate and high signal to noise ratio. Most importantly, this research has also led to making the Wavelet domain motion estimation and compensation shift invariant for optimized video compression.

Statistical Analysis and Optimal Classification of Blood Cell Populations Using Gaussian Distributions: A new figure of merit is developed to measure the similarity (or dissimilarity) of Gaussian distributions through a novel concept that measures the percentage of data overlap. The derivations are expanded to provide a generalized mathematical platform for determining an optimal separating boundary of Gaussian distributions in multiple dimensions. Another approach considered in this same line of research consisted in making use of Support Vector Machines in a neural network algorithm that allowed for optimized linear decision functions to separate in an optimal fashion blood cell subpopulations that otherwise experienced overlap.

A Mathematical Resolution to Log Transformations and the Binning Effect In Applied Processing of Data in Flow Cytometry: A new mathematical approach was developed to overcome the effect of a data processing phenomenon known as 'histogram binning' inherent to flow cytometry data. The filtering of the binning effect successfully preserved the statistical content of the original data. The mathematical approach introduced in this research endeavor is so appealing that a patent application has been filed.

Modeling of Head-Related Transfer Functions for Interactive Customization of Binaural Sound Systems: In this research, initial steps were successful in enabling the customization of generic HRTFs to each intended listener so that the realism of the 3-D sound rendering process can be achieved. The realism in the 3-D sound rendering process can serve as a navigational tool in a human-computer interface system to help persons with visual disability.

Deconvolution of Computer Images for Useful Viewing By Partially Sighted Users: In this research, preliminary results have been achieved for a computer display that implements the pre-compensation of the images viewed by a partially sighted user through deconvolution with a Point Spread Function (PSF). This "pre-compensated" image

shown on the computer screen is then usefully viewed by the subject through his /her blurry PSF approximation. This research is driven by the fact that the emulation of common eye conditions, such as astigmatism, defocus and spherical aberration through convolution of an image with distorted PSFs can be demonstrated in vision research

3-D Auto-stereoscopic Imaging by Computer Based Holography Techniques: This work establishes for the first time at FIU a hardware system for generating physical holograms from computer stored digital images. A physical optics laboratory setup was established and used to conduct multiple conventional holography experiments. A more appealing technique for real-world object imaging, the graphical approach, is implemented in this research work. A procedure is also established by which this technique can be expanded to produce fully three-dimensional static holograms of real-world objects.

New Research Directions

This 2002-2003 academic year, we have consolidated our efforts and have worked on a comprehensive program to establish a research/educational environment in support of persons with disabilities. We have sought funding and continue to do so to build the foundation for such a program. This research front is supported by scientific/experimental evaluations and feasibility studies where theoretical findings and prototype designs are valued in terms of their practical implications and societal impact they yield. The development and design of 'Assistive Systems' in this research endeavor are to yield improvement in access and functional capabilities of individuals with disabilities within the realm of real-world practicality.

Furthermore, the joint collaboration between FIU and Miami Children's Hospital has multiple projects encompassing hardware and software development in neurophysiology, functional imaging and MR imaging towards the creation of real-time design environments that will permit the accuracy and safety, manifolds beyond what is available today. MCH has allocated resources towards academic enhancement over and above the allocation of funds for routine clinical care. The resources include commitment of physicians and Ph.D.s who are Members of MCH's Brain Institute, capital equipment, and allocation of dedicated technical personnel for enhancing neurological care. MCH and the MCH foundation have also initiated a Brain Trust as a fund-raising drive to support multiple goals and provide the supervisory/administrative oversights for its goals. With all these commitments, students from FIU are finding an environment most suitable for cross-training and multidisciplinary research where computer science, information technology and engineering know-how meets the practical demands of neuro-rehabilitation and the need of real-time assistive systems that can help children with disabilities.

PUBLICATIONS

Journal Publications

1. M. Adjouadi and M. Ayala, "Making Waves Useful", IEEE Potentials, pp. 6-11, Vol. 22, No. 1, Feb. 2003.
2. M. Adjouadi, D. Sanchez, M. Cabrerizo, M. Ayala, I. Yaylali, P. Jayakar, and A. Barreto, "Interictal Spike Detection Using the Walsh Transform", IEEE Transactions on Biomedical Engineering, 2003 (3rd review).
3. N. Mirkovic, M. Adjouadi, "3-D Source Localization of Epileptic Foci Integrating EEG and MRI Data", to appear in Brain Topography, 2003.
4. M. Adjouadi, M. Cabrerizo, M. Ayala, I. Yaylali, and P. Jayakar, "Design and Implementation of Orthogonal Operators in the Analysis of Epileptogenic Data", IEEE Trans. on Signal Processing, 2003 (2nd review).
5. C. Alacaci and A. Pasztor, "Effects of Flawed State Assessment Preparation Materials on Students Mathematical Reasoning: A Study", Journal of Mathematical Behavior, Elsevier Science, 21, pp. 225-253, 2002.
6. M. Alonso and A. Barreto, "Real-Time Computer Station for the Teaching of Adaptive Signal Processing", Computers in Education Journal, Vol. XIII, No.1, pp. 2 – 9, .2003.
7. A. Pasztor, "Experiencing mathematics", Journal of the Academy for the Art of Teaching, Vol. X, No. 1, 2003.

Conference papers

1. M. Adjouadi, M. Cabrerizo, K. Nuñez, M. Ayala, I. Yaylali, P. Jayakar, D. Sanchez, "Interictal Spike Detection Using the Walsh Transform", Proceedings of the GSPx & International Signal Processing Conference (CD), ISBN: 1009129, [online]: <http://www.gspix.com>, Dallas, TX, USA, March 31-April 3, 2003.
2. M. Adjouadi and M. Ayala, "Improving Epileptiform Activity Recognition by Means of Energy Criteria", Proceedings of the GSPx & International Signal Processing Conference (CD), ISBN: 1009129, [online]: <http://www.gspix.com>, Dallas, TX, USA, March 31-April 3, 2003.

3. N. Mirkovic, M. Adjouadi, I. Yaylali, P. Jayakar, "3-D Source Localization of Epileptic Foci Integrating EEG and MRI", Proceeding of the IASTED International Conference on Modeling and Simulation, pp. 209-215, ISBN: 0-88986-337-7, Palm Springs, CA, USA, February 24-26, 2003.
4. M. Rossman, M. Adjouadi, N. Mirkovic, M. Ayala, P. Jayakar, I. Yaylali, "An Integrated Approach to Localize Epileptic Foci Using Relative Spect Subtraction", Proceeding of the IASTED International Conference on Modeling and Simulation, pp. 222-228, ISBN: 0-88986-337-7, Palm Springs, CA, USA, February 24-26, 2003.
5. M. Ayala, M. Adjouadi, "An Optimized Artificial Neural Network Approach for Epileptiform Activity Recognition", Proceeding of the IASTED International Conference on Modeling and Simulation, pp. 342-347, ISBN: 0-88986-337-7, Palm Springs, CA, USA, February, 2003.
6. A. Simon, M. Adjouadi, "Implementation of a High Impedance Solid State Relay for Interfacing a Robotic Platform to a Computer", Florida Conf. on Recent Advances in Robotics, Dania Beach, FL, USA, May 2003.
7. M. Cabrerizo, M. Adjouadi, I. Yaylali, P. Jayakar, K. Nunez, "A New Algorithm for the EEG Functional Brain Mapping Based on an Auditory-Comprehension Process ", SCI 2003 - The 7th World Multiconference on Systemics, Cybernetics and Informatics, Orlando, Florida, USA, July 2003.
8. A. Sesin, M. Adjouadi, "A Calibrated Real-Time Eye Gaze Tracking System as an Assistive System for Persons with Motor Disability", SCI 2003 - The 7th World Multiconference on Systemics, Cybernetics and Informatics, Orlando, Florida, USA, USA, July 2003.
9. N. Zong, M. Adjouadi, "Multidimensional Pattern Recognition and Classification of White Blood Cells Using Support Vector Machines", SCI 2003 - The 7th World Multiconference on Systemics, Cybernetics and Informatics, Orlando, Florida, USA, July 2003.
10. C. Weiting, M. Adjouadi, "Wavelet-based Video Compression Using Multiresolution Motion Estimation and Compensation", 9th International Conference on Distributed Multimedia Systems, Florida International University, Miami, Florida, USA, September 2003.
11. C. Weiting, M. Adjouadi, "Video Compression Analysis Based on Fast Motion Estimation Algorithms", International Conference on Computer, Communication and Control Tech., Orlando, Florida, USA, July 2003.
12. A. Simon, M. Adjouadi, A. Sesin, C. Mackey, M. Rossman, M. Ayala, "Implementation of a .NET Distributed Computing Cluster using XML Web Services", 9th International Conference on Distributed Multimedia Systems, Miami, Florida, USA, September 2003.
13. C. Ordonez, N. Gupta, and A. Barreto, "Sound Spatialization as a Navigational Aid in Virtual Environments", Proceedings of the 6th World Multiconference on Systemics, Cybernetics and Informatics, Orlando, FL, pp. III-297 – III-302, July 2002.
14. N. Gupta, C. Ordonez, and A. Barreto, "Improved Localization of Virtual Sound by Spectral Modification of HRTFs to Simulate Protruding Pinnae", Proceedings of the 6th World Multiconference on Systemics, Cybernetics and Informatics, Orlando, FL, pp. III-291 – III-296, July 2002.
15. R. Romero and A. Barreto, "Real-Time Development Of A DSP-Based Ringing Detection And Warning System", Proceedings of the 6th World Multiconference on Systemics, Cybernetics and Informatics (SCI 2002), Orlando, FL, pp. III-356 – III-361, July 2002.
16. M. Choudhury and A. Barreto, "Design of a Multi-Sensor System for Indoor Range Measurement as a Navigational Aid for the Blind", Biomedical Sciences Instrumentation, Vol. 39, pp. 30-35, 2003.
17. Alonso M., and Barreto A., "Digital Image Processing for Pre-compensation of Higher-Order Aberrations of the Human Eye", Biomedical Sciences Instrumentation, Vol. 39, pp. 99 - 104, 2003.
18. C. Li, J. Zhai, and A. Barreto, "Digital Signal Processing Methods for the Evaluation of Blood Volume Pulse Waveform Changes due to Exercise", Biomedical Sciences Instrumentation, Vol. 39, pp. 163 - 168, 2003.
19. N. Gupta, A. Barreto, and C. Ordonez, "Spectral Modification of Head-Related Transfer Functions for Improved Virtual Sound Spatialization" Proc. IEEE International Conference on Acoustics, Speech and Signal Processing, pp. II-1953-1956, Orlando, Florida, May 2002.

Patents

1. P. Vidal, J. Riley and M. Adjouadi, "Statistical Probability Distribution-Preserving Accumulation of Log-Transformed Data", Invention submitted for International Patenting by Beckman-Coulter Corporation
2. M. Adjouadi and M. Ayala, "Neural Studio - A Software Package as a Teaching/Research Tool in Artificial Neural Networks" (presently under preparation for submission).