US Air Force Workshop on

Intelligent Sensory Data Processing and Imaging in Dynamic Battlefield Scenarios

FedEx Institute of Technology
University of Memphis, TN

October 25-26, 2007

Supported by:

FedEx Institute of Technology, Center for Intentional Robotics
Department of Computer Science, University of Memphis
Department of Electrical and Computer Engineering
Tennessee State University, Nashville, TN
US Air Force Research Laboratory,
Sensors Directorate, Hanscom AFB, MA

Workshop Co-Chairs:
Robert Kozma, University of Memphis, TN
Amir Shirkhodaie, Tennessee State University, TN

Foreword by Conference Co-Chairs

Dear Workshop Participants,

We are very glad to have the opportunity to welcome you to our Air Force Workshop in Memphis, at the FedEx Institute of Technology, The University of Memphis, TN. The goal of our Workshop is to bring together researchers from the Air Force Research Laboratory with colleagues from the University of Memphis and from Tennessee State University, Nashville, to discuss recent advances in the field. This workshop creates a forum for interdisciplinary researchers to exchange ideas on research and development in the area of radar, ladar, UV, and imaging sensory data processing, pattern recognition and classification, and information association/correlation and fusion from multi-modality sensors in order to solve long term technological challenges and meet US defense needs in complex warfare scenarios. Recent advances in Ultra-wideband radars, ladar, and imaging systems coupled with biologically-inspired optimization and control algorithms enable achievement of new cutting edge technologies for warfighters acting in dynamically changing environmental conditions, with adversaries hidden behind high level of noise and clutter. The tasks include sensor data acquisition, distributed sensor data processing and fusion, and mobile platforms navigation and control in hostile environment, and the reliable detection and characterization of adversaries.

The program of the workshop includes (i) featured talks by invited speakers from national laboratories and by representatives of the host academia to address recent developments and challenges in this field; (ii) extensive discussions in the form of panel sessions on the opportunities of collaborations and exploring the possibilities of attracting funding through DARPA, AFOSR, and other agencies.

We would like to thank especially to Bert Weijers, Electromagnetic Technology Division, for his continued support of the idea and implementation of the Workshop, and for the participants from AFRL at HAFB and WPAFB, Drs. Atindra Mitra, Ross Deming, Rob Linnehan, Leonid Perlovsky to bring their expertise to the workshop. Prof Peter Erdi from the Henry Luce Center of Complex and Cognitive Systems, Kalamazoo College, provides strong support for cognitive and neural aspects of the activities.

This event could not become a reality without the strong support of the Fedex Institute of Technology, its Executive Director Shaye Mandle, and Lisa Threadgill, Executive secretary. Sponsorships by Chairs of the Computer Science Department, and Electrical and Computer Engineering Department, Profs. Sajjan Shiva and David Russomanno are greatly appreciated. The Organizing Committee members, Dr. Marko Puljic, Mark Myers, Jose Rodriguez, Hima Puppala, and Jaisantosh Ankishetty, from the Computational Neurodynamics Laboratory, volunteered their time and energy to make this event a success. Thanks to all for their efforts.

Thank you to all participants who came and contributed to this event. We really hope that this workshop will give an impetus for fruitful joint research activities in the future.

October 2007, Memphis – Nashville, TN

Robert Kozma and Amir Shirkhodaie
Workshop Co-Chairs

Location of the Workshop

Fedex Institute of Technology
Bellsouth Room
365 Innovation Drive, Memphis, TN 38152

Directions from
Memphis International Airport to FedEx Institute of Technology
From the airport (rental car dealerships) 16 minutes, about 8 miles.

Turn right onto Democrat Rd.
Take the Plough Blvd./Airways North exit
Take the I-240 exit to Nashville (keep right)
Take the Getwell North exit (exit 20B)
Follow Getwell north until it ends at Park Ave.
Turn right/east onto Park Ave.
Drive one block and turn left/north onto Goodlett St.
Cross the railroad tracks to Central Ave.
Turn left/west on Central
Turn left/south on Innovation Drive (you pass Holiday Inn is on the right)
Drive 50 m on Innovation drive.
Parking garage is on the left, please take ticket ($1/hour, max $6/day).
FIT is on the right, just opposite to the Parking garage.

Banquet Dinner Location (Thursday, October 25, 7 pm - 9 pm)
The Grove Grill http://www.thegrovegrill.com/

4550 Poplar Avenue, Memphis, TN 38117
Phone: 901-818-9951
Directions to The Grove Grill
Follow Poplar Avenue toward East
Pass Goodlett Street and continue on Poplar
At the traffic light at Sears turn left
The Grove Grill is just behind Sears

Program

Thursday, October 25, 2007

8:30 – 9:00 Registration, Coffee

9:00 – 9:15 Opening
Shaye Mandle, Executive Director, FedEx Institute of Technology

Session I: Challenges in Sensory Data Processing on the Battlefield
Chair: Robert Kozma (UoM)

9:15 – 9:55 Distributed Sensor Tandems with Intelligent/Robotic Trajectory Diversity
Atindra Mitra (Wright Patterson Air Force)

9:55 – 10:35 Data Association for Multi-Sensor Tracking
Ross Deming (General Dynamics)

Break (10:35-10:45)

10:45 – 11:30 Panel Discussion I
Funding Opportunities in Radar Processing (DARPA)
Chair: Amir Shirkhodaie (TSU),
Panelists: Ross Deming (Antheon), Rob Linnehan (HAFB), Robert Kozma (UoM), Atindra Mitra (WPAF)

Lunch (11:30 – 13:30) Holiday Inn Wilson Hotel

Session II: Advanced Methods of Sensory Data Processing in Distributed Scenarios
Chair: Ross Deming (General Dynamics) and Marko Puljic (UoM and LOC)

13:30 – 14:15 Battlefield Sensor Networking and Data/Information Fusion
Amir Shirkhodaie (TSU)

14:15 – 14:50 A Sneak Peak into the Future of Wireless Sensor Networks from our Limited Vision
Santosh Kumar (UoM)

Coffee Break (14:50 – 15:10)

15:10 – 15:45 Parameter Estimation for Targets Behind Walls
Rob Linnehan (Hanscom Air Force Base, MA)

15:45 – 16:15 Biologically Inspired ATR in Distortion
Khan Iftekharuddin (UoM)

16:15 – 17:00 Panel Discussion II
Funding Opportunities in Intelligent Systems (USAF/IFKA, ARO)
Chair: Robert Kozma (UoM)
Panelists: Ross Deming (Antheon), Khan Iftekharuddin (UoM), Santosh Kumar (UoM), Rob Linnehan (HAFB), Amir Shirkhodaie (TSU), Chrysanthe Preza (UoM), Lan Wang (UoM)

19:00 – 21:30 Reception Dinner
The Grove Grill, 4550 Poplar Avenue, Memph

Friday, October 26, 2007

8:30 – 9:00 Registration, Coffee

Session III: Biological and Cognitive Aspects of Sensing and Decision Making

Chair: Amir Shirkhodaie (TSU)

9:00 – 9:40 Dynamic Logic Neural Fields, Engineering Applications, and the Mind
Leonid Perlovsky (Hanscom AFB & Harvard U)

9:40 – 10:20 From Neurons to Goal-directed Navigation Algorithms
Peter Erdi (Kalamazoo & CRIP, Hungary)

10:20 – 10:50 Learning in Cellular Recurrent Networks with Applications to Image Processing and Nonlinear Optimization
Roman Ilin (UoM)

Break (10:50 – 11:00)

11:00 – 11:30 Neurodynamics and Human Effectiveness
Robert Kozma (UoM)

11:30 – 12:15 Panel Discussion III
Potential Funding in Human Effectiveness and Networks, Semantic Web
Chair: Leonid Perlovsky (HAFB, HU)
Panelists: Peter Erdi (Kzoo), Robert Kozma (UoM), David Russomanno (UoM), Lan Wang (UoM).

Lunch (12:15 – 14:00) Holiday Inn Wilson Hotel

14:00 – 15:00 Overview Panel and Recommendations
Co-Chairs: Amir Shirkhodaie and Robert Kozma
Panelists: Ross Deming (Antheon), Peter Erdi (Kzoo), Khan Iftekharuddin (UoM), Leonid Perlovsky (HAFB, HU), Vasile Russ (UoM), David Russomanno (UoM). Rob Linnehan (HAFB), Robert Kozma (UoM), Shaye Mandle (FIT), Atindra Mitra (WPAF), Chrysanthe Preza (UoM), Lan Wang (UoM).

15:00 – 18:00 Excursion to Graceland (Elvis Presley) and Memphis Downtown

18:00 – 21:00 Memphis Barbecue and Beale Street Blues

Thursday, October 25, 9:15 – 9:55 am

Distributed Sensor Tandems with Intelligent/Robotic Trajectory Diversity

Atindra K. Mitra
Air Force Research Laboratory
Sensors Directorate
Wright-Patterson AFB, Dayton, OH 45433

Abstract

A number of significant sensor geometries for distributed information exploitation in challenging and embedded environments are discussed. These categories of novel geometries are formulated based on several years of recent sensors research at AFRL that is focused on future UAV and multi-platform UAV/UGV robotics applications. These new system-of-systems concepts were originally denoted as position-adaptive radar in urban environments and position-adaptive radar for thru-wall sensing. Through a number of tiers of recent sensor development efforts, these concepts have been generalized to formulate a number of futuristic concepts that include “collapsing and closing” UAV swarms, position-adaptive RF sensors implemented as integrated/distributed aperture systems, exploitation of UAV systems with trajectory perturbations, joint RF/EO tandems, and position-adaptive sensors for chem/bio sensing.

This presentation provides a basic outline of these novel concepts along with discussions that illustrate exploitation potentials for the design of advanced information gathering and processing systems for future applications. A limited set of simulation results are included to illustrate the efficient waveform processing potential that is integrated within these system-of-systems concepts.

Thursday, October 25, 9:55 – 10:35 am

Data Association for Multi-Sensor Tracking

Ross Deming and John Schindler
Consultants for General Dynamics IT, Inc.
and
Leonid Perlovsky
Air Force Research Laboratory

Abstract

A new approach is described for combining range and Doppler data from multiple radar platforms to perform multi-target detection and tracking. In particular, azimuthal measurements are assumed to be either coarse or unavailable, so that multiple sensors are required to triangulate target tracks using range and Doppler measurements only. Increasing the number of sensors can cause data association by conventional means to become impractical due to combinatorial complexity, i.e., an exponential increase in the number of mappings between signatures and target models. When the azimuthal resolution is coarse, this problem will be exacerbated by the resulting overlap between signatures from multiple targets and clutter. In the new approach, the data association is performed probabilistically, using a variation of expectation-maximization. Combinatorial complexity is avoided by performing an efficient optimization in the space of all target tracks and mappings between tracks and data. We present results computed using experimental single-sensor data, as well as synthetic multi-sensor data.

Thursday, October 25, 1:30 – 2:15 pm

Battlefield Sensor Networking and Data/Information Fusion

Amir Shirkhodaie, Ph.D., Professor
Center of Excellence for Battlefield Sensor Fusion
Department of Mechanical and Manufacturing Engineering
Tennessee State University
3500 John A. Merritt Blvd., Nashville, TN 37209
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Abstract

Battlefield information superiority is crucial for transforming the US military forces to the next generation of network centric warfare. The future US Future Combat System program calls for a multi-year major transformation of military operations and capabilities to provide knowledge superiority in the battle space, multi-sensor information fusion, deployment of new mobile sensor devices (including autonomous and semi-autonomous robotic sensors, use of individual soldiers as sensor systems, and integration of national and local resources). Such a concept is aimed at making the military forces more effective in dynamic anywhere/anytime conflict situations and leveraging information and knowledge to increase the effectiveness of military forces while reducing casualties.

Multi-sensor data fusion is applicable to a number of emerging technologies of interest to Department of Defense (DoD) including: automated target recognition and tracking, battlefield surveillance, guidance and control of autonomous vehicles, and battlefield situational awareness. The two main challenges that the DoD within the fusion arena today are: the lack of explanation of how fusion processes support operational missions; and how effectively and efficiently the command control can steer direction of fusion from variety of sensors and human observers providing nonstop data and information about evolving battlefield events. The fusion can be defined as a process or a set of processes transforming observational data into more detailed and refined information, knowledge, and understanding. The value of fusion is not a matter of being able to accomplish individual pieces of the process using automation or cognitive means but figuring out how to best combine the two to achieve the required result in a net-centric holistic fashion. The application of fusion impacts several operational imperatives and spans all echelons in the military forces.

A fully functional sensor network can perform many military-related intelligence missions in synchronization and harmony with human agents in the battlefield. A typical sensor network may consist of many ad-hoc sensor network clusters where each cluster is comprised of many energy stingy micro-sensor nodes with limited communication, computation, and processing power capacity. Efficient, robust, and secure management of data trafficking in such power sensitive networks is highly critical.

This lecture focuses mainly on identification of data and information requirements and describes the research effort of the Center of Excellence for Battlefield Sensor Fusion in the area of sensor networking, intelligent surveillance system for urban terrain, multi-target tracking, and automated multi-modality sensor data and information fusion.

Thursday, October 25, 2:15 – 2:45 pm

Parameter Estimation for Targets Behind Walls

Robert Linnehan[a], Robert Kozma[b], John Schindler[c],
David Brady[d], Leonid Perlovsky[a]

[a]Air Force Research Laboratory/Sensors Directorate,
Hanscom AFB, MA;
[b]University of Memphis, TN
[c]General Dynamics, Hanscom AFB, MA;
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Abstract

The ability to identify and localize targets within buildings using exterior sensors will offer superior advantages to the military and law enforcement communities. The benefit of determining the building's interior layout prior to entry or targeting is also apparent. Recent experiments have shown RF sensors are an appropriate technology to perform non-invasive detection and estimation through walls. Regardless of the data collection method, it is a seemingly insurmountable challenge to unravel information of the building interior and properly associate and discriminate returns from targets within. Wall parameter ambiguities (the thickness and electrical properties), multipath reflections, clutter, measurement noise, and other electromagnetic phenomena pose significant challenges to developing robust imaging techniques with synthetic aperture radar (SAR).

In the present work we demonstrate the potential to mitigate these challenges using an adaptive, model-based approach to iterative maximum likelihood estimation.

Thursday, October 25, 2:45 – 3:15 am

A Sneak Peak into the Future of Wireless Sensor Networks from our Limited Vision

Santosh Kumar
WiseManet Laboratory
Department of Computer Science
University of Memphis, Memphis, TN

Abstract

Wireless sensor network, by virtue of proving in-situ sensing combined with intelligent collaborative processing at the point of collection itself together with wireless communication, are enabling numerous novel applications such as remote health monitoring, environmental monitoring, precision agriculture, and enhanced surveillance. In this talk, I will present three main applications that we are currently working on – AutoSense, AutoWitness, and Intrusion Detection.

AutoSense aims to revolutionize behavioral sciences research by enabling reliable and real time quantification of personal exposure to addictive substances and psychosocial stress as experienced by human subjects in the field. AutoWitness will help law enforcement agencies in recovering stolen objects/assets. For intrusion detection, we are developing theories and algorithms that can be used for efficient deployment and affordable maintenance of wireless sensor networks deployed for perimeter security such as international borders.

For additional information on each of these projects, please visit http://www.cs.memphis.edu/~santosh/WiseManet.

Thursday, October 25, 3:45 – 4:15 pm

Biologically-Inspired Dynamic ATR in Distortion

Khan M. Iftekharuddin

Department of Electrical and Computer Engineering
Director, Intelligent Systems and Image Processing Lab
Institute for Intelligent Systems, The University of Memphis, TN

Abstract

The objective of this talk is to investigate biologically inspired computational models for automatic target recognition (ATR) for distorted targets. The premise of this work can be characterized by a novel direction of thinking outside of the usual machine vision paradigm that primarily involves a working set of algorithms based on known engineering principles. Contemporary knowledge of the biological visual system is analyzed to draw insights and thereby to re-think dynamic ATR in distortion.

http://umdrive.memphis.edu/iftekhar/faculty/iftekhar.htm

Friday, October 26, 9:00 – 9:45 am

Dynamic Logic, Neural fields, Engineering Applications, and the Mind

Leonid I. Perlovsky
Air Force Research Lab., 80 Scott Rd.,
Hanscom AFB, MA 01731
Tel. 781-377-1728; e-mail: Leonid.Perlovsky@hanscom.af.mil

Abstract

Dynamic logic and neural fields are mathematical techniques describing aspects of the functionality of the mind: concepts, emotions, instincts, imaginations, intuitions. All of these are inseparable from perception and cognition. I first explain a scheme for reducing combinatorial complexity often encountered in the past attempts at designing "intelligent systems," and then discuss engineering applications (model-based pattern recognition, control, data mining, fusion, financial predictions, Internet search engines); and present some results suggesting orders of magnitude improvement in classical detection and tracking in noise.
The last part of the talk moves to future research directions: roles of beautiful, music, sublime in the mind, cognition, and evolution. I relate dynamic logic to the knowledge instinct, which drives the mind to understand the world, and argue that instinct is even more important than sex or food. This mathematical modeling of the mind and cultures can be used to improve mutual understanding among peoples around the globe and reduce tensions between cultures.

Dr. Leonid Perlovsky is Visiting Scholar at Harvard, Principal Research Physicist and Technical Advisor at the Air Force Research Lab. He leads Semantic Web project and other research programs. From 1985 to 1999, as Chief Scientist at Nichols Research, a $0.5 B high-tech organization, he led the corporate research in intelligent systems, neural networks, and sensor fusion. He served as professor at Novosibirsk and New York Universities; participated as a principal in startups developing tools for text understanding, biotechnology, and financial predictions. His company predicted the market crash following 9/11 a week before the event, detecting activities of Al Qaeda traders, and later helped SEC looking for these guys. He delivered invited keynote plenary talks and tutorial lectures around the globe, published more then 280 papers, 10 book chapters, a monograph "Neural Networks and Intellect," Oxford University Press, 2000 (currently in the 3rd printing) and 2 books with Springer in 2007.
Dr. Perlovsky organizes conferences on Computational Intelligence, Chairs IEEE Boston Computational Intelligence Chapter, leads IEEE NNTC Task Force

on “The Mind and Brain,” serves as Associate Editor for IEEE Transactions for Neural Networks, Editor-at-Large for “Natural Computations,” and Editor-in-Chief for “Physics of Life Reviews.” He received several National and International Awards, including the Distinguished Member Award, IEEE Boston Section, 2005; Charles Ryan Memorial Basic Science Award, AFRL 2007; Gabor Award for Engineering Achievements in Neural Networks, International Neural Network Society 2007; and McLucas Award, the USAF 2007 (the highest AF scientific award).

Friday, October 26, 9:45 – 10:30 am

From Neurons to Goal-directed Navigation Algorithms

Péter Érdi

Center for Complex Systems Studies
Kalamazoo College, Kalamazoo, MI and
Department of Biophysics Biophysics
KFKI Research Institute for Particle and Nuclear Physics
Hungarian Academy of Sciences, Budapest, Hungary

Abstract

It is known for about thirty years that certain spatial information, namely the location of the rat, is encoded in the hippocampus. "Place cells" seem to combine rate are phase code. Recent findings [Hafting et al 2005] suggested that certain cells ("grid cells") in entorhinal cortex show a multiple firing locations, and correspond to the vertices of a triangular grid. These triangles tessellate the environment in hexagonal patterns. Functionally, position, distance and direction seem to be integrated in the dorsocaudal medial part of the entorhinal cortex. It seems to be plausible that the brain uses both "dead reckoning" and "map-based" navigating algorithms. Also navigation and memory are related. A framework of an integrated hippocampal model and preliminary simulation results are presented.

The work is being done within the framework of European Integrated Project (IST-027819) ICEA since January 2006. ICEA (Integrating Cognition, Emotion and Autonomy) is a four-year project on bio-inspired cognitive robotics and embodied cognition.

Thanks to the members of the Hungarian team (Péter Eros, Tamás Kiss, Zoltán Somogyvári, Balázs Ujfalussy.)

Friday, October 26, 10:30 – 11:00 am

Learning in Cellular Recurrent Networks with Applications to Image Processing and Nonlinear Optimization

Roman Ilin
Department of Computer Science
The University of Memphis

Abstract

Cellular Simultaneous Recurrent Neural Network (SRN) has been shown to be a function approximator more powerful than the feed-forward multilayer perceptron (MLP) architectures. This means that the complexity of MLP would be prohibitively large for some problems while SRN could realize the desired mapping with acceptable computational constraints. Cellular network architectures are especially efficient in hardware implementation and have widespread applications in image processing.

The speed of training of complex recurrent networks is crucial to their successful application. The present work improves the previous results by training the network with Extended Kalman Filter (EKF). We implemented a generic Cellular SRN toolbox and applied it for solving two challenging problems: a subset of the connectedness problem relevant to image processing applications and the 2D maze navigation. The implications of the results are discussed.

This is a join work with Robert Kozma (UoM) and Paul J. Werbos (NSF).

Friday, October 26, 11:30 – 12:00 am

Neurodynamics and Human Effectiveness

Robert Kozma
Computational NeuroDynamics Laboratory
Department of Computer Science
The University of Memphis

Abstract

Air Force guidelines state that new challenges require warfighters to have flexible, game-winning capabilities that permit precise, measured responses with acceptable risk. AF strategic directions are focused on helping the information warrior think, decide, and act in new ways, on reducing decision times and improving decision quality through improved human-system interfaces and processes, and on protecting all airmen in all offensive and defensive environments. Such strategic goals can be achieved by advancing cognitive modeling, task critical information portrayal, and decision support technology.

The Computational Neurodynamics Laboratory has accumulated thorough expertise in experimental methodology of brain monitoring based on electro-encephalogram (EEG) measurements. We collaborated on the development and evaluation of a novel experimental methodology to monitor cognitive activity based on scalp and intracranial recordings. The proposed mechanism of hemispheric neurodynamics-based identification of frequent cortical phase transitions opens new avenues to study human cognition, decision making, and action selection. Dynamic logic-based image-processing methodology provides the required competitive edge in challenging tasks with dynamically changing environments, having high level of noise and clutter. Our results suggest that phase structures in the human scalp EEG relating to cognition may be readily accessible with standard equipment. In particular, commercially available, non-intrusive equipment has been tested, based on high-density scalp EEG array evaluation. This approach for brain-computer interfaces has the potential of applications for various warfighter scenarios, both in training and in-flight, as well as for supporting persons with disabilities.

This work is in collaboration with Dr. Walter J Freeman, Division of Neurobiology, UC Berkeley, and Dr Don Tucker, Electrical Geodesics Inc, OR; and with CND Lab members Mark Myers, Jose Rodriguez, and Hima Puppala.