Center for Embedded Systems (CES)
Request for Proposals Template – YEAR 6

DUE: Monday, March 31, 2014, by 5 p.m.

TITLE:	Background Invariant Laser-Spot Detection and Tracking for Embedded Systems		
PI:	Lalit Gupta	**EMAIL:** lgupta@siu.edu	**TEL:** (618)453-7032
DEPT:	ECE	**SCHOOL:** SIUC	

ABSTRACT: (250 OR FEWER WORDS)

The aim of this project is to develop a strategy to accurately detect a laser-spot in low-resolution images and to track the laser-spot in varying background and illumination conditions. Detection will be based on feature extraction and classification. The tracking techniques will be based on motion-related segmentation as well as the Kalman and particle filters. The initial focus will be on detecting the laser-spot in static and simple backgrounds. Subsequent efforts will focus on dynamic, complex, and noisy backgrounds. The final goal will be to improve the computational efficiency by embedding the detection and tracking strategy into a multi-core processing architecture.

PROBLEM:

This project will focus on developing a strategy to detect and track laser-points in varying background and illumination conditions.

RATIONALE:

Lasers are used extensively in the development of smart munitions for targeting and for guiding munitions. It is equally important to be able to detect and track lasers in related counter-measure applications. A successful completion of this project will have a major impact on improving upon these applications and also help identify new real-time applications

APPROACH:

In order to achieve the goal of this project, an ensemble of algorithms will be developed to detect various laser spots and to track the detected spots. Specifically, the algorithms that will be developed include:

1. Laser-spot detection: Develop algorithms to segment [1,2] and detect spots with varying shapes and sizes by extracting characteristic features [3] that are invariant to background and illumination conditions. The detection problem will be formulated as classification problem [4],[5] that will work in conjunction with the selected feature set. Additionally, noise reduction filtering and contrast enhancement algorithms will be developed to facilitate the detection of the spots.
2. Laser-spot tracking: Develop algorithms to track the detected spot based on template matching [6], Kalman filtering [7], and partical filtering [8].

The approach that will be followed will first design and test the detection and tracking algorithms in highly constrained environments consisting of simple backgrounds and illumination conditions. The complexity of the problem will be progressively increased by decreasing the number of constraints systematically.

NOVELTY:

The topic of this project was proposed by Rockwell Collins because they anticipate numerous applications that will benefit from the accurate detection and tracking of laser-spots. The approach proposed in this project is quite unique and novel in its formulation.

POTENTIAL BENEFITS TO INDUSTRY MEMBERS:

Rockwell Collins has indicated that they envision several novel applications resulting from the development of the proposed laser-spot detection and tracking algorithms.

DELIVERABLES:

Rockwell Collins will periodically define the steps of the project problems and SIUC will provide them with the technical background and algorithms to solve the problems.

TIMELINE/MILESTONES: (PER QUARTER)

1st Quarter: Acquire laser-spot videos in simple environments and begin developing detection and tracking algorithms.

2nd Quarter: Test and evaluate the detection and tracking algorithms.

3rd Quarter: Acquire laser-spot videos in complex and noisy environments and test the detection and tracking algorithms.

4th Quarter: Improve the detection and tracking algorithms, perform objective evaluations as functions of background complexity, illumination, and noise.

TECHNOLOGY TRANSFER:

Upon completion of the project, the potential for technology transfer will be quite high because new and robust techniques for laser spot detection and tracking will be developed.

BUDGET:

Direct cost: $25,000/year

BIBLIOGRAPHY: (ATTACH IN IEEE CONFERENCE OR JOURNAL FORMAT)

1. L. Gupta and T. Sortrakul, "A gaussian mixture based image segmentation algorithm," *Pattern Recognition*, vol. 31. No. 3, 315-325, l998.
2. R.C. Gonzales and R.E. Woods. Digital Image Processing. Prentice Hall, 2008
3. Q. Zhou & J.K. Aggarwal, "Object tracking in an outdoor environment using fusion of features and cameras," *Image and Vision Computing*, 24, 1244-1255, 2006.
4. L. Gupta, B. Chung, M.D. Srinath, D.L. Molfese, & H. Kook "Multi-channel fusion models for the parametric classification of differential brain activity," *IEEE Transactions on Biomedical Engineering*, Vol. 52, No. 11, 1869-1881, 2005.
5. R.O. Duda, P.E. Hart, & D.G. Stork, Pattern Classification, John Wiley & Sons, 2001.
6. I. Matthews, T. Ishikawa, & S. Baker, "The Template Update Problem," *IEEE Trans. on Pattern Analysis and Machine Intelligence*, Vol. 26, No. 6. (2004) 810-815.
7. S. Weng, C. Kuo, & S. Tu, "Video object tracking using adaptive Kalman filtering," *Journal of Visual Communication and Image Representation*, vol. 17, Issue 6, 2006.
8. Branko Ristic, Beyond the Kalman Filter: Particle Filters for Tracking Applications , Artech House Radar Library, 2004.

PI INFORMATION: (ATTACH 2-PAGE CV)

Lalit Gupta
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Education

- Ph.D. Electrical Engineering, Southern Methodist University, Dallas, Texas, l986.
- M.S. Electrical Engineering (Digital Systems), Brunel Univerity, Uxbridge, England, l981.
- B.E. (Hons.) Electrical Engineering, Birla Institute of Technology and Science, Pilani, India, l976.

Academic Experience

- Professor, Department of Electrical and Computer Engineering, Southern Illinois University, Carbondale, Illinois, July 2001 present.
- Associate Professor, Department of Electrical Engineering, Southern Illinois University, Carbondale, Illinois, July l992 June 2001.
- Assistant Professor, Department of Electrical Engineering, Southern Illinois University, Carbondale, Illinois, June l986 June l992.

Professional Associations

- Associate Editor, Pattern Recognition Journal (5-year journal impact factor: 3.402).
- Senior Member, Institute of Electrical and Electronics Engineers.
- Member, Pattern Recognition Society.
- Member, American Society for Engineering Education.

Research Interests

Pattern Recognition, Multi-dimensional Signal Processing, and Neuroinformatics.

Recent External Funding

1. L. Gupta, "Seizure analysis and prediction (Phase I; NIH/SBIR)," Cleveland Medical Devices subcontract, 5/15/03 5/14/04.
2. L. Gupta, "Seizure analysis and prediction (Phase II; NIH/SBIR)," Cleveland Medical Devices subcontract, 4/1/04 3/31/05.
3. L. Gupta, "An ear device for hands free wheelchair control (Phase I, NIH/SBIR)," Think-A-Move Ltd. subcontract, 9/1/03 5/1/04.
4. L. Gupta, "Online database and analysis system for ERP screening (1)," Neuronetrix, 1/1/05 8/15/05.
5. L. Gupta, "Online database and analysis system for ERP screening (2)," Neuronetrix, 6/1/05 12/31/05.
6. L. Gupta, "An ear device for hands free wheelchair control (Phase II, NIH/SBIR)," Think-A-Move Ltd. subcontract, 6/1/05 5/15/06).
7. L. Gupta, "Human-Machine Interface System for Hands-Free Robot Tele-Operation", Naval Postgraduate School, 8/7/06 - 12/30/06.
8. H. Sevim, L. Gupta, J. Mathias, K. A. Pericak-Spector, J. Tezcan, "Engineering and Technology Talent Expansion Program at Southern Illinois University", NSF, 9/15/06 - 8/31/10.
9. L. Gupta, "Color-agnostic dropout of document background," California Testing Bureau/McGraw Hill (funding approved for 5/15/2012 – 5/14/2013).
10. L. Gupta, "Object identification and tracking," NSF Center for Embedded Systems, (5/15/2012 – 5/14/2013).

Recent Journal Publications

1. J. Phegley, K. Perkins, L. Gupta, & L. Hughes, "Multi-category prediction of multifactorial diseases through risk factor fusion and rank sum selection," *IEEE Transactions on Systems, Man, & Cybernetics A*, Vol. 35, No. 5, 718-726, September 2005.
2. L. Gupta, H. Kook, D.L. Molfese, & K.C. Fadem, "Multi-stimuli multi-channel data and decision fusion strategies for dyslexia prediction using neonatal ERPs," *Pattern Recognition*, Vol. 28, No. 11, 2174-2184, 2005.
3. L. Gupta, B. Chung, M.D. Srinath, D.L. Molfese, & H. Kook "Multi-channel fusion models for the parametric classification of differential brain activity," *IEEE Transactions on Biomedical Engineering*, Vol. 52, No. 11, 1869-1881, 2005.
4. R. Vaidyanathan, B. Chung, L. Gupta, H. Kook, S. Kota, & J. West, "A tongue-movement communication and control strategy for hands-free human-machine interfaces," *IEEE Transactions on Systems, Man, & Cybernetics A*, 533-546, July 2007.
5. R.Vaidyanathan, M.Fargues, R.S. Kurkan, L. Gupta, S. Kotta, R.D. Quinn, & D. Lin, "A Dual-Mode Human-Machine Interface for Robotic Control based on Acoustic Sensitivity of the Aural Cavity," *International Journal of Robotics Research*, Special Issue, November 2007.
6. H. Kook, L. Gupta, S. Kota, D. Molfese, & H. Lyytinen, "An Offline/Real-Time Artifact Rejection Strategy to Improve the Classification of Multi-channel Evoked Potential," *Pattern Recognition*, vol. 41, no. 6, pp. 1985-1996, 2008.
7. R. Vaidyanathan, T. S. Prince, M. Modarreszadeh, L. Gupta, & F. J. Lisy, "Computationally Efficient Predictive Adaptive Control for Robotic Operation in Dynamic Environments and Task Domains," *Proceedings of the Institution of Mechanical Engineers*, Part B, Journal of Engineering Manufacture, 222, 12, 1695-1713, 2008.
8. S. Kota, L. Gupta, D. Molfese & R. Vaidyanathan, "A dynamic channel selection strategy for dense array ERP classification," *IEEE Transactions on Biomedical Engineering*, vol. 56, no. 4, 1040-1051, 2009.
9. U.B. Karangula, M.A. Kassem, L Gupta, H. El-Shemy, & D.A. Lightfoot, "Locus Interactions Underlies Seed Yield In Soybeans Resistant to *Hetrodera glycines*," *Current Issues in Molecular Biology*, 11 (Suppl. 1) i73-84, 2009.
10. M. Mace, R. Vaidyanathan, S.Wang, & L. Gupta, "Tongue in Cheek: A Novel Concept in Assistive Human Machine Interface", Journal of Assistive Technologies, vol. 3, pp. 14-26, 2009.
11. L. Gupta, S. Kota, S. Murali, D. L. Molfese, and R. Vaidyanathan, "Feature Ranking Strategy to Facilitate Multivariate Signal Classification," *IEEE Transactions on Systems, Man, and Cybernatics C*, vol. 40, no. 1, PP. 98-108, 2010.
12. L. Gupta, S. Kota, P. Yarlagadda and D. L. Molfese, "Central-Tendency Estimation and Nearest-Estimate Classification of Event Related Potentials," *Pattern Recognition*, Vol. 44-7, 1418-1425, 2011.
13. K. A. Mamun, M. Mace, L. Gupta, C. A. Verschuur, M. E. Lutman, M. Stokes, R. Vaidyanathan, S. Wang, "Robust Real-time Identification of Tongue Movement Commands from Interferences," *Neurocomputing*, 80, pp 83-92, 2012.
14. Y. Nanyam, R. Choudhary, L. Gupta L, J. Paliwal, "A Decision-Fusion Strategy for Hyperspectral Fruit Inspection," *Biosystems Engineering*, Vol. 111, 118-125, 2012.
15. M. Mace, K. Abdullah-al-Mamun, A.A. Naeem, L. Gupta, L, S. Wang, R. Vaidyanathan, "A heterogeneous framework for real-time decoding of bioacoustic signals: Applications to assistive interfaces and prosthesis control", *Expert Systems with Applications* 40, 13, pp 5049-5060, 2013.
16. S. Kota, L. Gupta, D. Molfese, R. Vaidyanathan, "Diversity-Based Selection of Polychotomous Components for Multi-Sensor Fusion Classifiers", *Journal of Engineering in Medicine*, 227, 6, 655-662, 2013.

Ph.D. Dissertation Supervision

Ravi Tammana, June 1994; Thotsapon Sortrakul, September l995; Mark McAvoy, September 1998; J. Phegley, Summer 2001; Beom S. Chung, Summer 2004; Hyunseok Kook, December 2006; S. Kota, December, 2010; M. Kelsey, May 2011, Ahmed Fadhil, May 2014.

I/UCRC Executive Summary - Project Synopsis		Date: 3/31/2014
Project Title:	**Background Invariant Laser-Spot Detection and Tracking for Embedded Systems**	
Center/Site: SIUC		
Principle Investigator: Lalit Gupta		**Type: (New or Continuing)** New
Tracking No.: (CES office to input)	**Phone :618-529-3552**	**E-mail : lgupta@siu.edu**
		Proposed Budget: $25,000

Abstract: The aim of this project is to develop a strategy to accurately detect a laser-spot in low-resolution images and to track the laser-spot in varying background and illumination conditions. Detection will be based on feature extraction and classification. The tracking techniques will be based on motion-related segmentation as well as the Kalman and particle filters. The initial focus will be on detecting the laser-spot in static and simple backgrounds. Subsequent efforts will focus on dynamic, complex, and noisy backgrounds. The final goal will be to improve the computational efficiency by embedding the detection and tracking strategy into a multi-core processing architecture.

Problem: This project will focus on developing a strategy to detect and track laser-points in varying background and illumination conditions.

Rationale / Approach: Lasers are used extensively in the development of smart munitions for targeting and for guiding munitions. It is equally important to be able to detect and track lasers in counter-measure applications. The approach is to formulate the detection problem in terms of classification and develop tracking algorithms based the Kalman and particle analysis filters.

Novelty: The topic of this project was proposed by Rockwell Collins. They anticipate numerous applications that will benefit from the successful development of novel algorithms to detect and track laser-spots.

Potential Member Company Benefits: Rockwell Collins has indicated that they envision several novel applications resulting from the development of the proposed laser-spot detection and tracking algorithms.

Deliverables for the proposed year: Detection and tracking algorithms.

Milestones for the proposed year: Develop algorithms to:

(a) Detect laser-spots in a sequence of images in varying illumination and backgrounds.
(b) Track laser-spots in a sequence of images in varying illumination and backgrounds.
(c) Evaluate the detection and fusion algorithms on a wide range of images.

Progress to Date: **THIS SECTION TO BE UPDATED IN JANUARY**

Estimated Start Date: August 2014	**Estimated Knowledge Transfer Date**: August 2015