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5b. GRANT NUMBER  
5c. PROGRAM ELEMENT NUMBER  611102
5d. PROJECT NUMBER  
5e. TASK NUMBER  
5f. WORK UNIT NUMBER  
6. AUTHORS  Frank L. Lewis
7. PERFORMING ORGANIZATION NAMES AND ADDRESSES  University of Texas at Arlington
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Arlington, TX  76019 - 0145
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14. ABSTRACT  This grant focuses on the design of advanced control systems for high performance Army vehicles and Autonomous Unmanned Vehicles (UAV/UGV). We focus on the inherent complexity and design challenges of achieving significant performance in short time intervals. Structured Nonlinear Network controllers are designed to significantly improve performance precision and speed of Army systems that have uncertain dynamics, disturbances, and control actuator limitations. On-line adaptive controllers are designed that converge to Optimal Control solutions with guaranteed performance.
15. SUBJECT TERMS  nonlinear adaptive control, neural network control, high performance intelligent control, maneuvering system control, distributed decision and control, autonomous systems control
16. SECURITY CLASSIFICATION OF:  
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18. NUMBER OF PAGES  
19a. NAME OF RESPONSIBLE PERSON  Frank Lewis
19b. TELEPHONE NUMBER  817-272-5972

Standard Form 298 (Rev 8/98)
Prescribed by ANSI Std. Z39.18
Final Report for Discrete Event Supervisory Control and Nonlinear Motion Control for DoD and Industrial Systems

ABSTRACT

This grant focuses on the design of advanced control systems for high performance Army vehicles and Autonomous Unmanned Vehicles (UAV/UGV). We focus on the inherent complexity and design challenges of achieving significant performance in short time intervals. Structured Nonlinear Network controllers are designed to significantly improve performance precision and speed of Army systems that have uncertain dynamics, disturbances, and control actuator limitations. On-line adaptive controllers are designed that converge to Optimal Control solutions with guaranteed performance.

Based on support by National Automotive Center and RDECOM, we also have an initiative in Distributed Control of Networked Heterogeneous Teams. Methods for cooperative control of teams are being developed including discrete event decision & control, trust consensus, and collaborative control.

Significant leveraging funds have been received from NSF, AFOSR, DARPA, and the DoD SBIR Program. This grant has goals: Goal 1 - Neural Network High Performance Nearly Optimal Control. Goal 2 - Neural Network H-Infinity Structured Output Feedback Control. Goal 3 - Decision and control for distributed heterogeneous teams of autonomous rotorcraft, ground vehicles, and humans.
Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

<table>
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<th>Received</th>
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<td>07/25/2011 11.00</td>
<td>Frank. L. Lewis. please see attachment file for list of papers, various journals see attachment please, (01 2010): 0. doi:</td>
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<td>08/02/2006 1.00</td>
<td>Murad Abu-Khalaf, Frank L. Lewis. Nearly optimal control laws for nonlinear systems with saturating actuators using a neural network HJB approach, Automatica, ( ): . doi:</td>
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<td>08/06/2006 4.00</td>
<td>Tao Cheng, Frank L. Lewis, and Murad Abu-Khalaf. A Neural Network Solution for Fixed-Final Time Optimal Control of Nonlinear Systems, , ( ): . doi:</td>
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TOTAL: 10
(b) Papers published in non-peer-reviewed journals (N/A for none)

(Number of Papers published in peer-reviewed journals:

(Number of Papers published in non peer-reviewed journals:

(c) Presentations

(2) Plenary Speaker, IFAC Workshop on Adaptation and Learning in Control, Antalya, Turkey, August 2010.
(3) Nanyang Technological University, Singapore, distributed control, January 2011.

Number of Presentations: 8.00

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

TOTAL:
Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received  Paper

08/06/2006  6.00  Murad Abu-Khalaf, Frank L. Lewis, and Jie Huang. Policy Iterations on the Hamilton-Jacobi-Isaacs Equation for H? State Feedback Control with Input Saturation, IEEE ( )

TOTAL:  1

Number of Manuscripts:

Books

Received  Paper

TOTAL:

Patents Submitted

Patents Awarded


Awards

(2) IEEE Region 5 Outstanding Engineering Educator Award, 2010.
(3) UTA Graduate Dean's Excellence in Doctoral Mentoring Award, 2010.
### Graduate Students

<table>
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<th>NAME</th>
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<td>Drew Morgan</td>
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<td>Matt Middleton</td>
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<td>Draguna Vrabie</td>
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### Names of Post Doctorates

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### Names of Faculty Supported

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### Names of Under Graduate students supported

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### Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period.

The number of undergraduates funded by this agreement who graduated during this period: ...... 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields: ...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields: ...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale): ...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering: ...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense ...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: ...... 0.00
Names of Personnel receiving masters degrees

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<th>NAME</th>
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<tr>
<td>Matt Middleton</td>
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<tr>
<td>Chris McMurrough</td>
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<td>Drew Morgan</td>
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Total Number: 3

Names of personnel receiving PHDs

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<tr>
<td>Kyriakos Vamvoudakis</td>
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<td>Draguna Vrabie</td>
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Total Number: 2

Names of other research staff

<table>
<thead>
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Total Number: 

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

(1) With Dr. Greg Hudas, Army RDECOM/TARDEC, Joint research and publications on trust-based control and supervisory decision for networked military teams. Numberous publications have resulted so far, please see list in attached file. We are organizing two special issues of J. Defense Modeling & Simulation together. We won the Best Paper Award for Autonomous Systems at 2010 Army Science Conference.

(2) With Dr. Grant Gerhart, Organizing special sessions for him and giving invited talks at his conferences. We have organized sessions on Intelligent Behaviors at SPIE Defense Symposium, Orlando, for the past 3 years. These sessions bring together internationally known scientists in Intelligent Control and Autonomous Systems. Participants were: Sylvia Ferrari, Lauta Barnes, Greg Hudas, Richard Garcia, Kevin Moore, Kimon Valavanis, Jagannathan Sarangapani, F.L. Lewis. The papers will be published in 2 special issues of JDMS.

(3) With Dariusz Mikulski, NAC, I am on his PhD committee as co-supervisor with Dr. Edward Gu at Oakland Univ. We are working on distributed decision and trust consensus for networked teams.

Other Collaborations:

(1) My USA MS student Chris McMurrough was selected as an Air Force Summer Scholar last year 2008 and this year 2009 to work with Dr. David Doman at Dr. Siva Banda's USAF Controls Center of Excellence at Wright Patterson AFB. My USA MS student Drew Morgan was selected in 2010 and Isaac Weintraub in 2011.

(2) Worked with DARPA throughan SBIR I from SignalPro, Inc., CEO Chiman Kwan, on reinforcement learning for control of UAV.

Tech Transfer to Industry:
We worked with Singapore Manufacturing Technology Institute to use the results of our ARO research for fault diagnosis in Industrial machines. We won the Best Application Paper Award at 2011 Asian Control Conference.

Technology Transfer
Publications for ARO report between 1 August 2010 – 31 July 2011

Journal Papers


Invited Plenary Talks- Presentations with no publications

2. Plenary Speaker, IFAC Workshop on Adaptation and Learning in Control, Antalya, Turkey, August 2010.
7. Plenary Speaker, ISA, “Approximate dynamic programming and cooperative control,” Wuhan, China, May 2011

Refereed and Published Conference Papers


*Won the Best Paper Award for Autonomous/Unmanned Vehicles, Army Science Conf. 2010.*


*Won the Best Application Paper Award at Asian Control Conference, Taiwan, May 2011.*


Books


Book Chapters


Journal Special Issues
