



**Trust, Decision, & Control**  
For Networked Teams on Communication Graphs

PM- Dr Fariba Fahroo. PI: F.L. Lewis. AFOSR FA9550-09-1-0278



**Objective 1:**

*New Distributed Feedback Control Algorithms for Emergent Team Behavior on Graph Topologies*

**Accomplishments:**

- ❑ **New definition of Nash Equilibrium** for Games on Communication Graphs
- ❑ Optimal Control and Game Decisions made *in real time* for Networked Teams depending on *varying mission objectives*
- ❑ Online Optimal Adaptive Control to *solve coupled Game HJB* equations in real-time without knowing dynamics:

$$H_i(\delta_i, \frac{\partial V_i}{\partial \delta_i}, u_i, u_{-i}) \equiv \frac{\partial V_i}{\partial \delta_i} \left( A\delta_i + (d_i + g_i)B_i u_i - \sum_{j \in \mathcal{N}_i} e_{ij} B_j u_j \right) + \frac{1}{2} \delta_i^T Q_i \delta_i + \frac{1}{2} u_i^T R_i u_i + \frac{1}{2} \sum_{j \in \mathcal{N}_i} u_j^T R_j u_j = 0$$

**Papers listed online as top-cited in their journals:**

- ❑ **Automatica**, Vamvoudakis & Lewis- online Optimal Adaptive Control.
- ❑ **IEEE Trans. Systems, Man, and Cybernetics, Part B**, Al-Tamimi, AbuKhalaf, Lewis- adaptive critic for Optimal Adaptive Control
- ❑ **Automatica**, Liu, Xie, Lewis- cooperative control by delay information



**US Army Transitions & ARO Leveraging funding-**

Dr Greg Hudas, RDECOM/JCR  
*Distributed Games for Military Teams on Communication Graphs*

Coadvising RDECOM PhD student D. Mikulski

**Best Paper Awards:**

- ❑ Vamvoudakis, Hudas, Mikulski, Lewis- **Army Science Conf. Autonomous Systems Award**, 2010
- ❑ Vrabie & Lewis- ADP Reinforcement Learning Conf. 2010

**Recent PhD students:**

Draguna Vrabie- United Technologies Research Ctr.  
Abhijit Das- Caterpillar, Inc.

K. Vamvoudakis- Research Fellow, UC Santa Barbara

**Army Science Conf. Best Paper Award:**

**Award-Winning Research Keeps Soldiers Safe, Effective**



Dr. Marilyn Freeman, Deputy Assistant Secretary of the Army, K.G. Vamvoudakis of University of Texas-Arlington, TARDEC Engineer D. Mikulski, TARDEC Engineer Dr. Greg Hudas and U.S. Army Chief Scientist Dr. Scott Fish. Not pictured: Frank Lewis, University of Texas-Arlington



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Automation & Robotics Research Institute  
THE UNIVERSITY OF TEXAS AT ARLINGTON



**Objective 2:**

*Overcome graph communication limitations using Optimal Design for multi-agent control*

**Problem:** The communication links restrict what is possible using feedback control for multiple-agent teams

**Accomplishments:**

- Proved that local optimal control design yields **synchronization on arbitrary connected graphs**
- **Decoupled** cooperative control design from graph topology constraints

- Condition for Group synchronization:

$$\mu(A) \equiv \prod_u |\lambda^u(A)| < \frac{1 + \Lambda_{\min} / \Lambda_{\max}}{1 - \Lambda_{\min} / \Lambda_{\max}}$$

Min. bandwidth needed to stabilize system

Communication connectivity properties of graph

**Air Force Transition Partner David Doman**

WPAFB Control Science Center- Microair Vehicle Control  
USAF Summer Scholars: C. McMurrough, 2009, Drew Morgan, 2010, Isaac Weintraub 2011.

USA students recruited to Graduate program at UTA.

**Multicore Design Award, NI 2009- McMurrough & Doman**

**Dual-Use Leveraging Funding:**

DARPA SBIR I- Control of UAV  
NSF- Cooperative Games: Applications to Microgrid

**Dual-Use Tech Transfer to Industry:**

**Singapore Manufacturing Inst.**

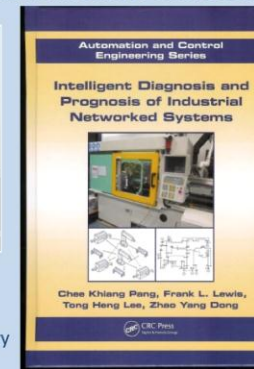
*Dynamic Resource Assignment for Energy-Aware Manufacturing*

**Best Paper Award:**

Pang & Lewis, *Best Application*, Asian Control Conf. 2011.



**High speed milling machine**



New Book- Industry Fault Diagnosis

**PI Awards-** UTA Dean 's Excellence in Doctoral Mentoring Award.

**IEEE Region 5 Outstanding Engineering Educator Award.**

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