Air Force Institute of Technology

Integrity - Service - Excellence

AFIT SE Research

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Dr. William J. Reckmeyer, Plenary Address, 1st Annual SoS Engineering Conference, 13 June 2005
System Characteristics

Each system/subsystems and component is more complex, intelligent, software-controlled, Internetworked with quickening release
AFIT Research Thrusts

- Early application of SE
  - SoS architecture analysis and evaluation
  - DoDAF support for decision making
  - Interoperability measurement

- Human System Integration
  - Allocation of human functions in conceptual design
  - Human centered design
  - Trust in automation

- Applied design for mission effectiveness
  - Multi-UAS concepts
  - Theater ISR
  - Integrated Health Monitoring
AFIT Students …
…mature, motivated, and experienced!

- AFIT students are typically DoD employees
  - Most are commissioned officers
  - Almost all hold SECRET level clearance or above
- AFIT students have experience in acquiring, testing, sustaining or operating DoD systems
  - Almost all of our students have at least 1-2 military assignments under their belt
  - They often have direct knowledge of sponsoring organization
- AFIT students understand the importance of their research
  - Their lives (or their friend’s lives) depend on DoD weapon systems
Sample of Methods/ Tools

- Operational Research
  - Discrete event or Agent based simulations
  - Monte Carlo analysis, sensitivity analysis
  - Optimization methods

- Graph Theory
  - PetriNets/ Coloured PetriNets (bipartite directed multigraphs)
    - Many extensions: Stochastic, Hierarchical, Timed, etc
    - Used in Manufacturing, Communications, Protocol development
    - CPNTools, MATLAB PetriNet toolbox

- Complexity Theory
  - Biologically inspired Models
  - Local collaboration dynamics, Clustering, Self-Organization
Problem Statement
How can the AEA SoS architecture be used to evaluate the military worth of an Electronic Warfare Battle Management (EWBM)?
Problem/ Opportunity
A general method of measuring collaborative and confrontational interoperability does not exist.

There is no analytical means of relating the interoperability of a heterogeneous set of systems implementing an operational process to a measure of effectiveness for the process.

DEFINITION (System Instantiation)
Given a specific \( s \in S \) and a set \( x \subseteq X \) of system characters descriptive of \( s \), then \( \sigma = x(s) \) is a sequence of system character states, called the instantiation of \( s \), which models \( s \).

Interoperability measurement becomes a similarity measure… using systems characters

\[
Sim(\sigma', \sigma") = w_f(\sigma' \cap \sigma") - \alpha f(\sigma' - \sigma") - \beta f(\sigma" - \sigma')
\]

\[
I = Sim_{Bin}(\sigma', \sigma") = \left( \frac{1}{n} \sum_{i=1}^{n} (\sigma'(i) \cap \sigma"(i)) \right)
\]

\[
I = Sim_{Real}(\sigma', \sigma") = \left[ 1 - \left( \frac{1}{\sqrt{n}} \right) \left( \sum_{i=1}^{n} \frac{\sigma'(i) - \sigma"(i)}{c_{max}} \right)^{1/2} \right]^{1/2}
\]

INTEROPERABILITY: The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to the use the services so exchanged to enable them to operate effectively together.
Long Range Strike 2035: An Analysis of Functional Autonomy

Sponsored by AFRL/RBAA

LCDR Scott Rivera  Captain Anil Hariharan  Captain Alan Louie

Results

• The 2035 LRS system can be Automated
• Concept can be linked to enabling Technologies
Problem/ Opportunity:
Many projects and systems still fall short of effectively integrating humans in the systems engineering processes. Improve quantitative methodology to integrate human considerations into early system design.

Method Summary
• Improves display layout design and evaluation by transforming the problem into graph-theoretic models and performing subsequent analysis.

Time to move through a submenu
\[ d_w(v_0, v_k) = \sum_{i=1}^{k} \left( t_i + \left( 0.212 + (0.152) \log_2 (d^+(v_{i-1}) + 1) \right) \right) \]

Avg control time, HCI Index
\[ D_{w,p}(G) = \sum_{(v_a,v_b) \in E(G)} d_w(v_a,v_b) \cdot \rho_{a,b} \]

Compared to F-15 and A-7 test data from AFRL cockpit design research, Reising and Curry, 1987
Problem/Opportunity:

Many projects and systems still fall short of effectively integrating humans in the systems engineering processes. Improve quantitative methodology to integrate human considerations into early system design.

Method Summary

- Study mishaps in legacy systems where human error was identified as a causal factor
- Quantify the effect of human-machine interaction
- Use that empirical data to predict, and justify, requirements for new system design
OVERALL OBJECTIVES
• Develop a CONOPs and conceptual architecture for cooperative UAV control
• Create a test bed for cooperative control research
• Evaluate concurrently developed UAV algorithms

Adaptable Sensor Coverage
Reduced Revisit Time
Increased Sensor Coverage
Persistent Surveillance

OVERALL RESULTS
• Created conceptual architecture
• Flew 4 UAVs simultaneously
• Identified UAV cooperative control risks & challenges
• Demonstrated UAV algorithms
The Problem

Significant Cost Savings Over Current Inspection Methods with Increased Visibility of Structural Deficiencies and Safety of Flight

Methodology:
- Used Strategic Guidance
- Functional Area Analysis
- Functional Needs Analysis
- Functional Solution Analysis

Necessary Capabilities:
- Reduce Sustainment
- Maintain Situational Awareness
- Facilitate Informative Decision Making
- Assess Performance and Implementation Improvements

Analysis of Solutions:
- Developed CONOPS
- Identified Capability Needs
- Identified Current Capabilities
- Conducted Analysis of Alternative Solutions

Provides Near Real-Time Monitoring of Crack Initiation and Propagation
AFIT SE research program is growing
- Good balance of basic and applied research
- DoD sponsored work supporting acquisition, sustainment and operational communities

AFIT faculty and students provide perspective unmatched in civilian universities
- Students know DoD challenges because they live them
- Military/civilian faculty mix provides balance between new initiatives and sustained research in depth

AFIT research strengths
- Architecture, early application of SE
- Human System Integration
- Applied design for mission effectiveness