SMU Software Intensive Systems Research Overview

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Computer Science & Engineering Department
Lyle School of Engineering
Southern Methodist University

DoD SERC Annual Research Review
Oct. 15-16, 2009
Departments in SMU School of Engineering

- *Engineering Management, Information and Systems (EMIS)*
  - **Systems Engineering Program (SEP)**
- **Computer Science and Engineering (CSE)**
- Mechanical Engineering (ME)
- Electrical Engineering (EE)
- Environmental and Civil Engineering (ENCE)
SEP ACADEMIC PROGRAM

Courses
- Developed in Response to Industry & Government Needs
- Developed by SEP DT
- Core-5
- Electives-
  - Current: 16
  - In-Development: 9

Programs
- Non-Degree Studies in SE
- SE Certificate Series
- MS SE
- PhD SE

Faculty
- Experienced in Defense Systems Development
- Resident
- Adjunct
  - Lockheed Martin
  - Bell Helicopter
  - Raytheon
  - L3 Com
  - MITRE Corp
  - Siemens
  - Abbott Laboratories
  - Freescale Semiconductor

Students
- Employed full-time by A&D Sector
  - U.S. Citizen
  - DoD Security Clearance
- Admissions – 1000+
- Graduates MS SE – 555

Delivery
- On-Campus
- Internet
- Off-Campus Exec. Format

Customer Driven

SEP

SMU_SEP_Highlights_10.05.09
SEP RESEARCH PROGRAM

Research Projects

Defense Systems

• Modeling and Analysis of Defense Systems Development
• Technology Linkage, Selection and Transition to US Warfighter
• Systems Requirements Engineering and Integrated Verification & Validation
• Defense Systems Design and Development

Research Focus

Defense Systems

Funded Research

– US Navy SPAWAR
– DoD DAU
– Lockheed Martin

Research Areas

Selected

• Complex System Design “Management Flight Simulator” Development
• Methodology for Optimizing Verification, Test and Evaluation Complex System Development
• Methodology for Measuring SoS Development Performance
• Methodology for Analysis of Technology Alternatives

PhD SE Students

• 30 Students
  – 2 Full-Time
  – 28 Part-Time
  • Lockheed Martin
  • U.S. Navy SPAWAR
  • Boeing
  • Raytheon

PhD SE and AS

• 20 Applicants in Queue
SMU SEP ORIGIN AND DEVELOPMENT

Admit Students & Approve Degree Plans
Deliver SE Courses

Direct and Administer SEP
Deliver SE Courses
Advise PhD students

Idea
SEP Concept Development
SEP Proposal
SMU SEP ORIGIN AND DEVELOPMENT

SMU School of Engineering

SEP Development Team

Identify & Select Adjunct Faculty
Promote SEP
Develop SE Courses

Industry and Government Volunteers

Promote SEP
Identify & Capture Needs
Develop SE Courses
Develop Proposals
Identify & Select Adjunct Faculty
SEP DEVELOPMENT

SEP Development Team Membership

Current DT

<table>
<thead>
<tr>
<th>Organization</th>
<th>Location</th>
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<tr>
<td>Abbott Laboratories</td>
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<tr>
<td>Vought Aircraft Industries</td>
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SEP Development Process

Development Model
Industry-Government-Student Partnership

Customer-Driven

- PhD SE Start Up
- MS SE Rev4
- New SE Courses
- Defense Systems Developer Needs-Driven Curriculum Review w/INCOSE North Texas Chapter
- Systems Design and Integration Track
FRAMEWORK FOR RESPONSE TO DEFENSE CONTRACTORS AND DOD OPERATIONS PROBLEMS

Concept

A&D Systems Developers
- Problems

Systems Engineering Program

DoD Operations
- Problems

Projects

K-12 Students

Caruth Institute for Engineering Education
- Lockheed Martin Skunk Works Lab

Lyle School of Engineering

Subject Matter Experts

Systems Engineering Program Industry & Government Team

Faculty
- Graduate Students
- Undergraduate Students

Solutions
SEP SUMMARY

The SMU Systems Engineering Program was conceived (1991) and has been developed and administered in response to Dallas/Ft Worth region aerospace and defense systems developers, with focus on:

• U.S. AT&L/defense contractor workforce improvement by offering SE courses developed, delivered by defense industry subject matter experts

• Research conducted by SMU faculty, PhD students and SEP DT volunteers in response to defense systems developers priority needs in selected areas

Utilize SMU faculty* (resident and adjunct), DT members* and PhD SE students* with extensive experience (multiple company) on diverse U.S. defense development programs

**Aircraft Programs**
- F-35
- F-22 + ATF
- F/A-18
- F-16
- A-12 +ATA
- B-2
- C-17
- S-3
- F-8
- A-10
- B-1
- C-130
- V-22
- A/FX
- A-7
- B-52

**Advanced Classified Programs – Sensor Programs – Missile Programs**

* Most hold active DoD security clearance
Phase 1 – Develop Top-Tier Guide for Engineering Requirements for Defense Systems and Integrated Validation & Verification of Requirements

**Background**
Defense Systems development program success begin with “right” requirements – LC-balanced, compatible, consistent, prioritized – depends on development cycle integrated V&V

**Objectives**
- **Purpose/Objectives**
  - To provide a unified guide for defense systems developers
  - Reduce costs by integrated Modeling, Analysis and Simulation to more effectively utilize data and reduce testing
  - Improve AT&L Workforce through capture of experience and practice from retiring component of workforce
- **Benefits**
  - To reduce testing for systems requirements V&V
  - To reduce costs

**Approach**
- Utilize D/FW region defense contractor working groups using the SMU SEP DT to document current practice and capture prioritized needs
- Conduct literature and DoD/Industry survey of relevant guidance and methodologies

**Sponsors and Collaborators**
- **Sponsors**
  - Dallas/Ft Worth region defense contractors
- **Funding**
  - $ TBD for 2 years – Phase 1
- **Collaborators**
  - SMU : Jerrell Stracener
  - Texas A&M University : Abhijit Deshmukh
  - Texas Tech University : David A. Wyrick

Note: Currently an unfunded SMU SEP Research Project
Departments in SMU School of Engineering

- **Engineering Management, Information and Systems (EMIS)**
  - Systems Engineering Program
- **Computer Science and Engineering (CSE)**
- Mechanical Engineering (ME)
- Electrical Engineering (EE)
- Environmental and Civil Engineering (ENCE)
Research in Software Intensive Systems

Dr. Jeff Tian, Dr. LiGuo Huang, Dr. Delores Etter

- Software Verification & Validation, Risk Management and Dependability Improvement
  - Risk identification and management through systematic defect classification and analysis
  - Usage-based statistical testing to focus on high-usage/high-leverage operations and components
  - Integrated data analysis and reliability modeling
  - Evolvable risk reduction experience bases

- Applications: Commercial, telecommunications, aerospace, web-based, e/web-service, and embedded systems

- Focus: Systematic, risk-based dependability improvement
Complete Life-cycle Cost/Schedule/Quality Engineering

- Integrated process and product measurements
- Predictive cost/schedule/quality modeling and economic analysis
- Value-based software quality engineering through stakeholder collaboration
- Stakeholder-oriented hybrid process modeling & simulation
- Automatic requirement traceability modeling for ease of developing, measuring and testing system-level non-functional requirement attributes.

Quality Aspects/Attributes: availability, reliability, safety, security, performance, usability, scalability, maintainability, etc.

Focus: stakeholder Win-Win cost/schedule/quality engineering throughout the entire life-cycle
Coverage

- End-to-end security
- Devices, networks, and systems security
- Physical security (Access control)
- Policies and logistics
- Financial implications

Focus

- Systems vs. Ad hoc Perspective
- Process vs. Product Perspective
- Business vs. Deployment Perspective
NSA Center of Excellence

CSE and SMU have been designated as a National Center of Academic Excellence in Information Assurance Education by NSA and the Department of Homeland Security. March 2006

HIGH ASSURANCE COMPUTING AND NETWORKING LAB

Create an Authoritative Forum for the convergence of the needs and solutions of Government, Industry, and Researchers dedicated to addressing security issues
SMU/Skunk Works Partnership

Dr. Delores Etter

**Partnership** – first time that Lockheed Martin Skunk Works® has partnered with an engineering program

**Goal** – Integrate the Skunk Works design philosophy into the engineering program to make our students more creative/innovative

**Characteristics of Skunk Works projects include:**
- rapid design/development,
- maximum use of commercial systems,
- small focused team
SMU Participation in Net-centric Software Engineering Consortium and NSF I/UCRC

➢ Net-centric Software Engineering Consortium
  - Working with industrial/university partners since 2005
  - Focusing on system reliability, security, and safety of Net-centric software and systems
  - Emphasizing risk identification and management in system development life cycle

➢ NSF I/UCRC of Net-Centric Software and Systems
  - Established in March 2009 (SMU/UTD/UNT)
  - An academia-industry collaborative approach of research and development in net-centric systems
  - Industrial members: Lockheed-Martin Aero, Raytheon, Boeing, Cisco, EDS/HP, Texas Instruments, T-Systems, Fujitsu, Codekko, GlobeRanger, Hall Financial Group
Software Data Quality and Estimation Research In Support of Future Defense Cost Analysis (1)

- **Agency:** DoD SERC
- **SMU Researcher:** LiGuo Huang
- **Collaborator:** USC Center for Systems and Software Engineering
- **Objective:** Research and develop next generation of data definitions and estimation methods for complex software-intensive systems
Software Data Quality and Estimation Research In Support of Future Defense Cost Analysis (2)

Coverage:

- Improve current cost estimation metrics, models and methods for software-intensive systems (SISs) to reflect emerging changes in DOD SIS cost and process drivers.
- Collect and analyze data to test hypothesis about SIS cost estimation metrics, models and methods (i.e., software sizing, reuse and productivity).
- Explore alternative SIS cost estimation methods via data mining of SIS size, effort, and process data.
- Develop chapters on DoD SIS software sizing, reuse and productivity for a Software Cost Estimation Metrics Manual.
- Support the establishment of policy, related guidance, and recommended implementation approaches for data collection and analysis across all DoD acquisition programs which leverage existing and emerging data standards.
- Develop and evolve an integrated SIS data repository and related tools which enable program assessment, cost analysis, SIS development risk assessment, and progress measurement.
SMU Focus:

- Perform data mining of DoD project and cost data repositories to determine relationships between shortfalls in SIS architecture & risk resolution and SIS rework effort.
- Develop DoD-oriented case-based or analogy-based cost estimation models.
- Expand data mining of DoD project and cost data repositories to determine commonalities and variabilities within and across different categories of DoD software projects.
- Perform data mining of the new attributes of DoD project and cost data to determine commonalities and variabilities within and across different categories of DoD software projects.
Objective: Research and develop an automatic approach to constructing risk reduction knowledge base for complex software intensive systems

Collaborators: NASA JPL V&V

Motivation Example: The mishap of Mars Climate Orbiter (MCO) launched in late December, 1998.

What happened?

The MCO entered the Martian atmosphere at approximately 57km, not at its estimated 110km.

Unit mismatch among interoperating software subsystems/components. Ground navigation software used English units, not the required Metric units. All other calculations were in metric.

The discrepancy sent the spacecraft closer to the planet than its calculated trajectory indicated. Increased atmospheric stress destroyed the spacecraft.
Root Cause/Underlying Issues:

- **Verification & Validation:**
  - Development and V&V did not rely on the Software Interface Specification (SIS) to ensure the software was compatible.
  - The mishap investigation board found no evidence of complete, end-to-end testing for the trajectory tracking software.

Current NASA JPL V&V Problems:

- A lot of risk reduction experience from historical missions
- Unstructured information scattered in historical documents
Automatic Inference of Risk Reduction Knowledge Base(3)

Approach Overview:

Unstructured historical mission/project risk reduction experience !

Organized historical mission/project risk reduction rules !
Objective: Build a Hybrid Requirement Traceability (HRT) model to automatically trace system-level non-functional requirements to software functional requirements, design and code in order to quickly adapt to changes.

Approach:
- Apply text mining and Natural Language Processing techniques to classify and cluster FRs and NFRs from process artifacts (e.g., requirements documents)
  - Verify with original requirements – identify erroneous requirement classification
- Trace the requirement changes to system architecture design and to code through the HRT model
- Reverse engineer the HRT model from the code to verify and validate the requirements.

Collaborator: NASA JPL
Requirement Traceability (3)
– Example Requirement Interdependency Graph for Critical Resource Management System

Automate this!
Backup Charts
**MAIN ACHIEVEMENT:**
- Demonstrated semi-automatic hybrid requirement traceability model
  - improves effectiveness of NFR and FR traceability
  - improves measurability and testability of NFRs
  - improves adaptability to changes
  - reduces intensive manual efforts in NFR tracing

**HOW IT WORKS:**
- Apply text mining and Natural Language Processing techniques to classify and cluster FRs and NFRs from process artifacts
- Automatically build FR and NFR interdependency graphs
- Trace the requirement changes to system architecture design and to code through the HRT model
- Reverse engineer the HRT model from the code to verify and validate the requirements.

**ASSUMPTIONS AND LIMITATIONS:**
- Explicit associations between NFRs and FRs.
- Semi-automatic NFR traceability through text mining and NPL techniques.
- Formatted requirement specifications (no specific templates are required)
- Complete requirement specification documents

**END-OF-PHASE GOAL**
- More effective and efficient NFR and FR management and traceability
- Make it easier to trace, measure and test system level NFRs
- Better adaptability to changes

**QUANTITATIVE IMPACT**
- Task 1: Verify FR/NFR clusters in real world large scale software applications
- Task 2: Explore automatic requirement conflict detection in large scale software applications
- Task 3: Explore the effectiveness of automatic requirement traceability recovery from code

**NEW INSIGHTS**
- Hybrid Requirement Traceability Model can reveal the FR and NFR conflicts
- System-level NFRs can be automatically linked to related FRs

**SYSTEM LEVEL NFRs are difficult to trace, measure or test**
- Traditional manual requirement traceability approaches requires intensive human efforts.
- Current research traces FR or NFR in separate models.

**SYSTEM LEVEL NFRs can be automatically linked to related FRs**
- By automatically clustering FRs and NFRs in process artifacts can improve and semi-automate requirement traceability

**Semi-automatic Hybrid Requirement Traceability (HRT) Model integrates FR/NFR tracing**
- Classical manual traceability approach requires intensive human efforts.
- Current research traces FR or NFR in separate models.

**ASSUMPTIONS AND LIMITATIONS:**
- Formatted requirement specifications (no specific templates are required)
- Complete requirement specification documents

**BUT, automatically clustering FRs and NFRs in process artifacts can improve and semi-automate requirement traceability**
- But, automatically clustering FRs and NFRs in process artifacts can improve and semi-automate requirement traceability

**END-OF-PHASE GOAL**
- More effective and efficient NFR and FR management and traceability
- Make it easier to trace, measure and test system level NFRs
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**Semi-automatic Hybrid Requirement Traceability (HRT) Model integrates FR/NFR tracing**
- Classical manual traceability approach requires intensive human efforts.
- Current research traces FR or NFR in separate models.
Objective: Research and develop stakeholder-oriented approach to hybrid process modeling and simulation for large scale software intensive systems (in distributed development setting)

Collaborators:
- USC Center for Systems and Software Engineering
- Irish Software Engineering Research Centre
Two Dimensions of Process Modeling & Simulation Concerns

- Stakeholder Classes
- Process Phases
Stakeholder-based Hybrid Process Simulations: