Systems Engineering Education
Systems Engineering and Integration Lab

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UNIVERSITY OF MARYLAND

ISR @25

Transforming Engineering Education – Incorporate Systems ‘Thinking’

- Develop systematic ways to engineer component-based architectures for synthesis of complex systems from heterogeneous components
- Address directly the need for the two fundamental shifts in engineering design
  - **moving forward from the ‘design to assemble’ to ‘integration’ of heterogeneous components. Thus we do not need to insist anymore on ‘orthogonality of concerns’ for the components. They can overlap or be ‘quasi-orthogonal’.**
  - **the ubiquitous embedded IT components allow better integration and most importantly via programmability allow for new functionalities to be created and for easier insertion of new technologies in a system during its life-cycle.**
- What is happening in automotive industry is a good example.
- These trends are become pervasive in all engineered systems.

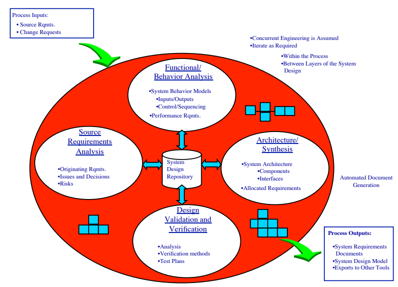
Challenges Addressed by SE

- Synthesis from modular components
  – **not only in aerospace, defense and large government projects**
  – **in all commercial designs and operations**
  – **integration is key**
- Teams of experts working together on complex problems
  – **multiple disciplines**
  – **communication and interpretation problems**
- Characteristics of scientific, technical, business data
  – **large volumes, not all relevant**
  – **numerically intensive, parallel applications**
  – **multidimensional, heterogeneous, distributed**
  – **specialized search engines, multiple views**

Our Strategy and Approach in SE Education

- Promote “information technology-centric” design, operation and management of systems/products
- Do everything using computers and information abstractions: from conception, to design, to parts selection, to manufacturing, to operations
- Hardware/software implementations and specific technology selections near the very end; once and it must work flawlessly
  – Paradigm: “Boeing’s seventh wonder” IEEE Spectrum, 1995 (c.f. 777)
- Abstract multiple disciplines to properly annotated information representations
  – allows communication between disciplines: multiple contextual views
  – much better management of the overall process
- Develop sophisticated algorithmic, mathematical and quantitative methods implementable in modern software environments
- Work simultaneously on top-down (methodological) and bottom-up (specific applications) research and advances
- Promote Behavior-Structure Co-Design and “Orthogonalization” of Design Concerns

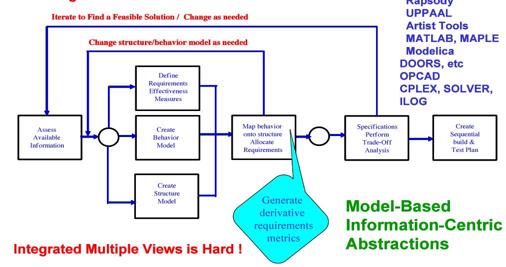
Advanced Methods and Environments for Systems Engineering



SYSTEMS ENGINEERING: TECHNICAL CORE TOPICS
- Object Oriented modeling and beyond
- Automata, languages, design rules
- Trade-off analysis and multi-objective optimization
- Testing, validation, behaviors
- Logic programming and optimization
- Performance over time, hybrid systems
- Simulation and performance analysis

Component-Based System Design and Synthesis Process

Integrated System Synthesis Tools - Environments missing …



Model-based
Beyond UML
Rapsody
UPPAAL
Artist Tools
MATLAB, MAPLE
Modelica
DOORS, etc
OPCAD
CPLEX, SOLVER, ILOG

Integrated Multiple Views is Hard !

Model-Based Information-Centric Abstractions

The ISR Educational Programs in Brief

MSSE

DEGREE REQUIREMENTS

The following courses are required:

Systems Engineering Core
ENSE 621 Systems Engineering Principles
ENSE 622 System Modeling and Analysis
ENSE 623 Systems Engineering Design Project
ENSE 624 Human Factors in Systems Engineering

Management Core
ENSE 626 Systems Life Cycle Cost Estimation
ENSE 627 Quality Management in Systems

Those choosing the thesis option also take ENSE 799 Master’s Thesis (for six credits) as well as an additional four electives. Those choosing the non-thesis option take an additional six electives.

ENPM-SE

DEGREE REQUIREMENTS

The ENPM Systems Option requires four courses from the systems engineering core, three courses from the management core, and four electives. The courses are identical to the MSSE curriculum.

Systems Engineering Core
ENPM 641 Systems Engineering Principles
ENPM 642 System Modeling and Analysis
ENPM 643 Systems Engineering Design Project
ENPM 644 Human Factors in Systems Engineering

Management Core
ENPM 646 Systems Life Cycle Cost Estimation
ENPM 647 Quality Management in Systems

Both Supplemented by Technical Electives form many Technical Areas

Selected Topics from Project Management Component

Project Management

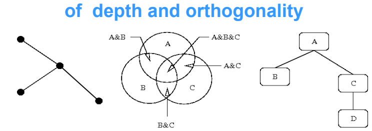
ENCE 620 Risk Analysis in Engineering
ENCE 423 Project Planning, Scheduling and Control
ENCE 662 Introduction to Project Management
ENCE 665 Management of Project Teams
ENCE 667 Project Performance Measurement
ENCE 624 Managing Projects in a Dynamic Environment
ENCE 627 Decision and Risk Analysis for Project Management

Undergraduate Engineering Education

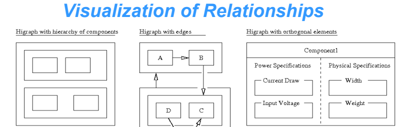
- Educational Challenge: undergraduate courses with system level thinking
- Our three favorite topics:
  - System Models for Synthesis (calculus, logic, physics)
  - Signals and Measurements Representation and Processing
  - Optimization, Trade-off analysis, Feedback
- To be taught in all Engineering Departments, supported by appropriate hands-on applications (a la Medical School)
- Will help create communication between disciplines via the appropriate IT abstractions

From one of our MSSE students MS Thesis: Kevin Fogarty

Higraph: a graph plus notions of depth and orthogonality



Visualization of Relationships



System Modeling and Traceability Applications