Enabling Systems Engineering with an Integrated Approach to Knowledge Discovery and Architecture Framework

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Architecting and Engineering
Different Sides of the Same Coin

• Engineering employs **analysis of function** to iteratively decompose and separate a primarily functional representation of a whole into representations of economically producible components that can be assembled to construct the functional whole.

  - Big implication here! Engineering requires an “initial point” - a representation of the whole — to be successful!

  **Engineering does not work without an initial point!!**

• We refer to this “initial point” as:

  **Engineerible Requirements**
  
  The set of *engineering requirements* necessary and sufficient to initiate the successful engineering and production of a system

  *Brad Mercer, MITRE, Chief Architect Maritime IT and Engineering*
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• Architecting employs synthesis of form to iteratively compose separate elements to form a coherent whole, or a representation of a coherent whole, that can serve as an “initial point” for system development.

• Architecting synthesizes this “initial point” from the collective vision, goals, constraints, and other needs of the stakeholders in the to-be-developed system — converting conflicting stakeholder demands into a conceptualized whole that maximizes the satisfaction of each stakeholder.

• From the point of view of architecting, we refer to this “engineering initial point” as an:

  Architecture Specification
  An architecture description to which all system implementations must adhere; and a set of principles, practices, and constraints guiding implementation, operation, and evolution of the developed system

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Architecting
Synthesis of Form
architecture specification
engineerible requirements

Analysis of Function
Engineering
representations of economically producible components that can be assembled to construct the functional whole

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collective vision, goals, constraints, and other needs of the stakeholders

iteratively decompose and separate a primarily functional representation of a whole

iteratively compose separate elements to form a coherent whole
Root Process Problem

• Complexity of data elements is overwhelming
• Difficult to support the book-keeping management of all of the data elements and their relationships across all the echelons of the Enterprise
  ◆ ‘Structuring’ complexity
  ◆ ‘Echelon integration and enterprise description’– everything is a part of a larger system
  ◆ Persistent, iterative, and evolutionary incorporation in a knowledge and reuse environment
• **Every object, relationship and aggregation of objects in the knowledge metamodel** is in documents, the universe of textual models

• **Discovery** is about finding the objects, relationships, aggregations and descriptions of each of these in the authoritative and original data sources

• **Integration** is about using Discovery to build and describe the Architecture using an architecture meta-model
• A concept, or theme, is the encapsulation of a pattern that is identified as a gestalt: a persistent and unique ‘signature’
• Documents are textual patterns
• Models are labeled, structured patterns
• Labels are knowledge anchors to concepts and themes
• Knowledge is pattern recognition, association and application in integrated textual and model gestalts
DISCOVERING CONCEPTS / THEMES

- ‘Information' can be treated as quantifiable symbols in communications
- Natural language has a high degree of unessential content, the less frequently a unit of communication occurs, the more information it conveys.
- Information objects extracted from Natural Language text form a index unique to that concept
- The architecture metamodel is the syntactic of the knowledge pattern and is semantically rigorous
- Information objects cluster based upon an inference relationship measuring semantic completeness
Mapping and Demonstrating Impactful Relationships

Cluster the indexes of the information objects using Statistical Inference!

Define the information objects and index them

THE UNIVERSE OF DOCUMENTS CONTAINS THE INFORMATION OBJECTS THAT DESCRIBE THE IMPLEMENTATION BASELINE
Cluster and integrate using the architecture meta model
Visualization can take many forms presenting many perspectives.
Tracing of the models back to the authoritative and original data sources.
DISCOVERY PROCESS

1.0 DISCOVER

1.1 INDEX

Information Theory

Indexed Information Objects

Statistical Inference

1.2 CLUSTER

Architecture Conceptual Data Model - Metamodel

Information Clusters

1.3 ANALYZE

Semantic Completeness

Encapsulated Concepts

1.4 DESCRIBE

Information Rich Concepts, Indexes and Clusters

Discovery works best when it has a pre-existent form upon which it can operate.
ARCHITECTURE & DISCOVERY

- Architecture is the *description* of the *intrinsic* relationships, characteristics and behaviors of the system under study
  - All systems have an architecture — intentionally architected or not — and that architecture is a primary determinant of the system’s behavior. Brad Mercer, MITRE Principal Architect
  - *Architecture is* the model in Modeling and Simulation and a rigorous and well-constructed model can be executed

- Discovery: the process for identifying the conceptual syntactic of architecture and the rich semantics

- Present architecture efforts are neither semantically complete nor rich: they contain a series of model artifacts (products) built and limited to “labeled” components and relationships; it has no processes, only product templates
Taxonomies of Primitives

- Indexing and clustering builds initial identification and organization of labeled themes and concepts
- Clusters are labeled taxonomical elements
- Rich taxonomies can be developed from clusters
  - Structured and organized categorization of information
  - Syntactic and semantic descriptions
  - Parent – child relationships
- Labeled themes and concepts are the architecture primitives
Topologies in Domains
(information, behavioral, functional)

- Topology in architectures relates to the connectedness of child – child with order of precedence and importance
- Information object references contain topological reference information useful in describing and identifying the syntactic and semantic elements
- The taxonomical and topological elements provide the structure and precedence of concepts and their references provide the content for specification
Persistence (Primitives) and Re-use (Encapsulations)

To be Persistent, the model must decompose to its fundamental components, its primitives.

IDEF0 MODELS mix component information and concerns and are a visualization standard, not a data standard.

To be Re-useable, the model must encapsulate its fundamental components, or primitives into re-useable Objects.
1. Decomposition is Echelon by Echelon: as two separate ‘synchronous’ taxonomies
2. Functional Decomposition is done with IDEF0, and the Operational Node Decomposition is done synchronously to this
3. Inputs-Output of the IDEF 0 Model and their mapping to the Node Model are the Information Flow Model. These Inputs-Outputs are the Information Elements that provide topological reference, precedence of function and critical exchange information for interoperability concerns
4. This process PROVIDES THE RIGOR for the architecture primitives.
View Relationships: Simplified Calculus

- An Activity done at a Node produces an Output
- A KSA done at a Billet produces an Output
- A System Function done at a System produces an Output

Nodes:
- Activity
- NODE
- System Function
- System
- KSA
- BILLET

Relationships:
- DOCTRINE
- PERSONNEL / ORGANIZATION
- MATERIEL / FACILITY
- TRAINING
DISCOVERY ENABLED ARCHITECTURE SPECIFICATION

• Document information objects describe the taxonomy and topology of architecture primitives and relationships
• Integration is accomplished using the principles and practices of a tightly coupled discovery-based architecting process
  ♦ Indexing and Clustering provide navigation to the authoritative and original sources for descriptions of the information objects
  ♦ Clustering, using these descriptions, iteratively refines and extracts more relevant information objects

  This enables the Synthesis of Form

• Discovery described Architectures enables the development of Rigorous, Semantically complete Architecture Specifications, i.e., engineerible requirements

  This enables the Analysis of Function
QUESTIONS

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