Concept Maps: Front End or Replacement for SysML/MBSE?

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Concept Maps

• A diagrammatic knowledge representation technique

• Distinguishing features
  • Propositions (Concept – Link – Concept)
    • Concept = perceived regularity in events and objects
    • Links = expressed relationships
    • Propositional coherence = all propositions can be read independent of the concept map
  • Contextual meaning = all propositions are understood in the context of the concept map
  • Shape (Semi-hierarchy)
    • Allows for cross-links
    • Proposition & shape interaction
The user of any system, of any artifact, necessarily develops a mental model of how that system works and of how he or she should interact with it to carry out some task.

The designer/developer(s) of an artifact has some mental model of how the system/product would work and that that mental model, the designer/developer model, is de facto instantiated as the system/product itself.

Norman (2014)
Concept Mapping in Software Development

• Conceptual Mapping as a First Step in Data Modeling
  - Hector Gómez-Gauchía and Ron McFadyen
  - (Chapter 14 of Applied Concept Mapping)

• Using Concept Maps in Product Development: Preparing to Redesign java.sun.com
  - Hugh Dubberly
    1. Set Goals
    2. Identify Terms
    3. Prioritize Terms
    4. Define Terms
    5. Organize Terms
    6. Test “Armature” (primary sentence or two)
    7. Add Terms
    8. Review and Revise
    9. Subdivide Large Maps
   10. Refine the Typography
   11. Check Again
Concept Mapping in Software Development

- **Concept Mapping Usability Evaluation**
  - Bias, Moon and Hoffman

- **UML for Developing Knowledge Management Systems**
  - Anthony Rhem
## Sample Linking Phrases and Categories

<table>
<thead>
<tr>
<th>Causal</th>
<th>Classificational</th>
<th>Nominal</th>
<th>Property</th>
<th>Explanatory</th>
<th>Procedure or Method</th>
<th>Event</th>
<th>Uncertainty or Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>can lead to</td>
<td>involves</td>
<td>which are/is</td>
<td>consists of</td>
<td>explains</td>
<td>is followed by</td>
<td>becomes</td>
<td>always</td>
</tr>
<tr>
<td>causes</td>
<td>is a type of</td>
<td>is a, is</td>
<td>has</td>
<td>reasons for</td>
<td>produces</td>
<td>evolves to</td>
<td>may or may not</td>
</tr>
<tr>
<td>requires</td>
<td>types of which</td>
<td>i.e.</td>
<td>has</td>
<td>requires</td>
<td>done by</td>
<td></td>
<td>sometimes is</td>
</tr>
<tr>
<td></td>
<td>are</td>
<td></td>
<td>feature</td>
<td></td>
<td></td>
<td></td>
<td>is more likely</td>
</tr>
<tr>
<td>because</td>
<td>includes</td>
<td>for example, e.g.</td>
<td>has defining feature</td>
<td>is a way to do</td>
<td></td>
<td></td>
<td>is more likely</td>
</tr>
<tr>
<td></td>
<td>categories</td>
<td>referred to as</td>
<td>has property</td>
<td>results in</td>
<td></td>
<td></td>
<td>can be</td>
</tr>
<tr>
<td></td>
<td>examples</td>
<td>such as</td>
<td>have</td>
<td>demands</td>
<td></td>
<td></td>
<td>often is</td>
</tr>
<tr>
<td></td>
<td>is a kind of</td>
<td></td>
<td></td>
<td>prompts</td>
<td></td>
<td></td>
<td>usually is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>rarely is</td>
</tr>
</tbody>
</table>
The categories of linking phrases in Concept Mapping overlap nicely with the various SysML diagram types:

- Causal → State Diagram
- Classificational → Use Case Diagram
- Nominal → Package Diagram
- Property → Block Definition Diagram
- Explanatory → Requirements Diagram
- Procedure/Method → Sequence Diagram
- Event → Activity Diagram (State Diagram)
- Uncertainty → Parametric Diagram
Compare to Aristotle’s Universals

1. Substance
2. Quantity
3. Quality
4. Relation
5. Place
6. Time
7. Position
8. State
9. Action
10. Affection
Use Case Diagram
"involves; is a type of; types of which are; includes; categories; examples; is a kind of"

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
Sequence Diagram

"is followed by; produces; done by; is a way to do; results in; demands; prompts"

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
State Machine Diagram

"becomes; evolves to"

Figure C.8 - Finite State Machine Associated with “Drive the Vehicle” (State Machine Diagram)

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
Activity Diagram

"becomes; evolves to"

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
Requirements Diagram

"explains;reasons for;requires"

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
Block Definition Diagram
"consists of; has; has feature; has defining feature; has property; have"

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
Parametric Diagram

"always; may or may not; sometimes is; is more likely; can be; often is; usually is; rarely is"

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
Package Diagram

"which are/is;is a;is;i.e.;for example;e.g.;referred to as; such as"

Figure C.3 - Establishing Structure of the User Model using Packages and Views (Package Diagram)

Source: OMG Systems Modeling Language (OMG SysML™) - Version 1.3
When to Apply Concept Mapping during the Systems Lifecycle

• NEW SYSTEMS AT KICKOFF: Consider starting project using Concept Mapping (e.g. Stakeholder Elicitation of Requirements)

• COMPLETE LIFECYCLE: Low Budget and have time to manual convert Concept Maps database to requirements documents.

• SYSTEM MODIFICATIONS: For modifications to existing systems, consider Concept Mapping to capture expertise on current system, then modify

• SPECIAL CASES: Consider strongly when migration to SysML is really required:
  • Special automatic code generation tools being used
  • High Complexity requiring symbolic properties difficult to express in words
Words of Potential

- Extremely flexible
- No special vocabulary, symbology required
- Quick uptake
Words of Caution

• May not integrate readily with other tools
• No inherent symbology
• Limited drawing capabilities
• Big difference between making maps and making ‘good’ maps
Concept Mapping Skills Development

• Concept Map features (propositional thinking)
• Concept Mapping software capabilities (merging, exporting, auto-arranging)
• Quickly drawing while interviewing stakeholders
• Reorganizing maps
• Interviewing skills
CmapTools

• Free!
• Florida Institute of Human and Machine Cognition
• cmap.ihmc.us
• Client – desktop, laptop; platform independent
  • Create, edit
• Server
  • Share, publish
• iPad
Thank you!

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