Conceptual Modeling for Critical Infrastructure

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Roadmap to the presentation

- Introduction
  - Conceptual Models, Potential Models, Actual Models are introduced
- Modeling and the Method
  - Modeling Process, deriving Potential Models, deriving Actual Models
- The Method Applied
  - Method recap, motivation for consideration, the case study application

Introduction

Conceptual Modeling and Conceptual Models

- Conceptual Modeling has many definitions in many communities
- In essence, it means to simplify, or abstract, a representation of a system
- By removing some amount of detail (reducing the number of defining factors), a Conceptual Model eases the grasping of what a system is "all about"

- "First phase in the conceptual-logical-physical design process – a simple description of the entities and relations making up a data model"
  - From the community of Data Engineering
- "A model that describes what the resulting simulation (or enterprise simulation) will represent"
  - From the HLA/FEDEP Federation Design Process
- "A statement of the content and internal representations which are the user's and developer's combined concept of the model"
  - US DoD M&S Glossary

These all have to do with representing a simplified view of a system, by abstracting away some of the details

Conceptual Models – both Potential and Actual

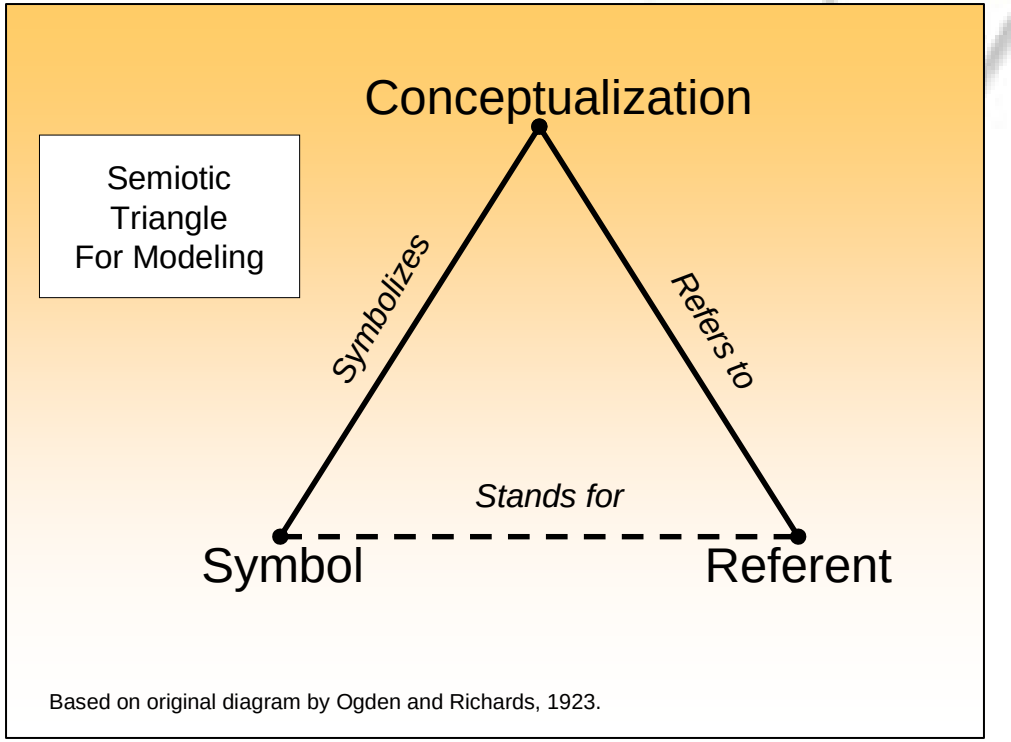
- In the application that led to the development of the technique presented here, the researchers were faced with developing a large class of different models, for simulation
- After some initial work, it was discovered that many of these different models shared some very similar conceptual ideas – if the differences were abstracted away
- If the results of the initial analysis (in the process of modeling) is abstracted a second time – a layer of **potential conceptual models** – those that had the potential to become any of a number of actual conceptual models – can be discovered
- By limiting these potential conceptual models, and limiting the number of features that they contain (and by actually giving attribution to some of the features), then each can become a series of **actual conceptual models** – those that can lead to implementation
- This discovery suggested that a similar technique might be useful in similar instances – where a number of different conceptual models have to be developed and considered – and some grouping of them is possible

Modeling and the Method

Modeling – a quick “how to”

- The process of modeling something – for whatever reason – is actually preparing a less detailed, more abstract “symbol” or representation of the original referent

- This is done in three steps
  - Consider the thing to be modeled – the “referent”
  - Form a conceptualization of the referent that captures its key features
  - Formulate that conceptualization into a “symbol” or “model” of the referent

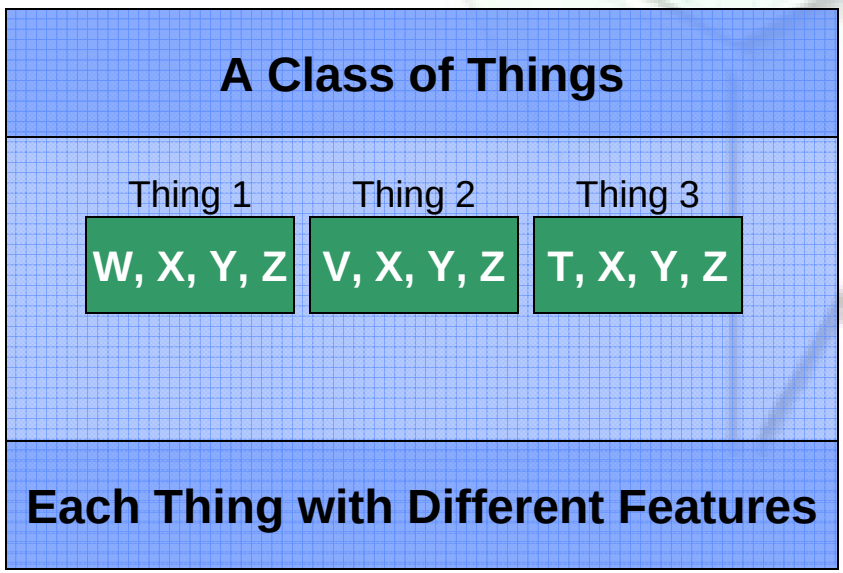


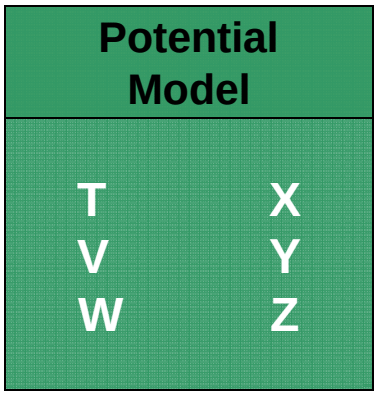
Modeling a class of things

- If a model is desired of a class of related things, then the alignment of the perceived attributes must be done in the process of modeling
- In consideration of the referent, assuming that this alignment is possible, then a conceptualization of the entire class of things is possible
- Preparing a model from the conceptualization that represents the entire class of things making up the referent means, however, that the worst case must be considered – one where even the differences of the things must be captured

Deriving a Potential Model from a Class of Things

- A **Potential Model** for a class of things is similar to what we just described
- Meaning that the “worst case”, or all the distinctions of the individual members of the class must be part of the **Potential Model**
- The **Potential Model** contains ALL the features of all the things in the class, not just the common features

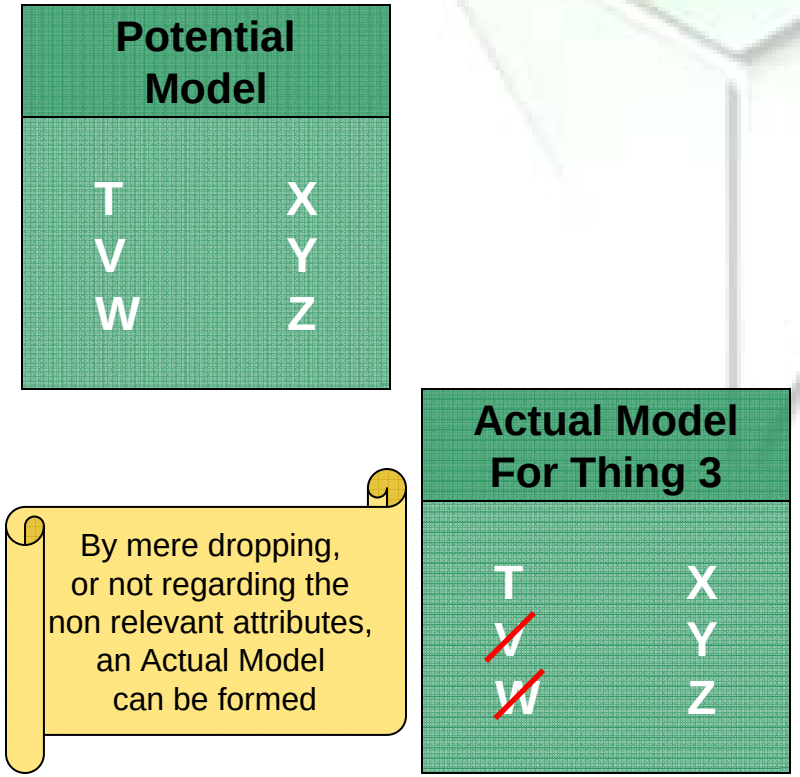




This has the **POTENTIAL** To model each Thing in the class

Deriving an Actual Model from a Potential Model

- Once a Potential Model for a class of things exists, then it is possible to derive an Actual Model from that Potential Model
- This is easily accomplished by disregarding the attribution within the Potential Model that is not germane to the Actual Model that is being derived
- This step is so simple, as to be near trivial, **if the Potential Model is well designed**



The Method Applied

The Method – from Class of Things to Actual Conceptual Model

- Beginning with a class of related things that need to be modeled, the consideration of the attributes of each of those things is performed

- Out of the consideration of attributes, a **Potential Model** is derived that has all of the attributes considered

- Now, finally, for each “thing” from the original class of things that is to be a specific model instance, it is easy to derive an **Actual Model** from the existing **Potential Model**

Motivation – reasons for following this two-step process

- The proviso before even evaluating the worth of this method is, of course, that a “class” of things is to be modeled

- The first motivational factor for following the method is that is makes the job of deriving actual models easier – do the work of creating the **potential model** once, and then any number of actual models for that class of thing may be derived (good when an unknown number of final **actual models** may be required)

- The second motivational factor is much more pragmatic – it is that once the attributes of the **potential model** are known, then implementing software services for the attributes that are “common” will create a toolbox of reusable software services that can be used for a large number of resulting systems from the **actual models** that are derived

The Case Study – Intersecting Layers of Critical Infrastructure

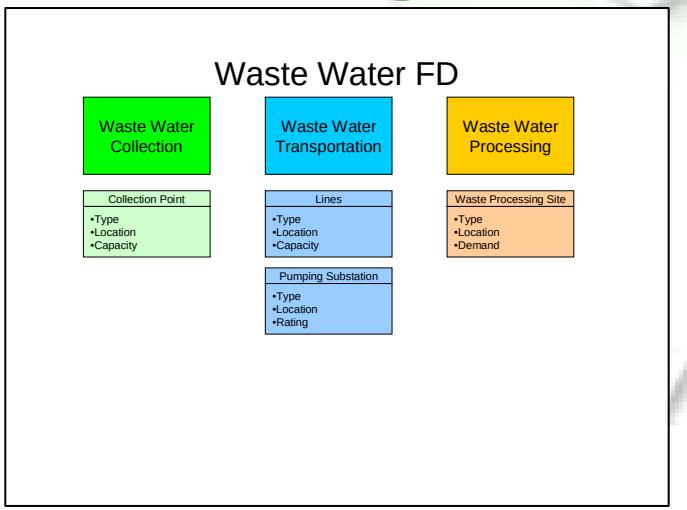
- The project that this method arose out of was concerned with modeling the nodes that exist within the various intersecting layers of Critical Infrastructure for an urban area
  - Power Supply
  - Transportation
  - Communication
  - Waste Removal
  - Fresh Water

- Each layer had to be represented in such a way so that its interactions with the other layers was apparent

- This approach was deemed to be very different from the existing models in this area – all of which exist either at a much higher level of detail (for instance, detailed engineering models for each layer), or a much lower level of detail (for instance, the abstraction layers for HLS, which show Power Supply for a region much, much larger than a single Urban area)

The Case Study – the steps followed leading to Conceptual Modeling

- Each of the layers, individually, was considered an analyzed
- First a functional decomposition (FD) was performed, to identify the functions that take part within the layer
- Then an analysis of the FD was completed to identify key features of each function
- It was decided that for every location in the Urban area that one of the functions was being performed, that a Software Agent would simulate that function



Fresh Water Infrastructure Feature Analysis

- Generation (Processing Site)
  - Input
    - Power
    - People
    - Policy
    - Communications
    - Consumables
    - Water
  - Output
    - Water
    - Communications
- Generation (pre-process storage)
  - Input
    - PPPCC
    - Water
  - Output
    - Water
- Generation (Supply)
  - Output
    - Water
- Transportation (Lines)
  - Input/Output
    - Water
- Transportation (Storage Point)
  - Input
    - PPPCC
    - Water
  - Output
    - Water
- Transportation (Substation)
  - Input
    - PPPCC
    - Water
  - Output
    - Water
    - Communications
- Consumption Point (Terminal Node)
  - Input
    - Water

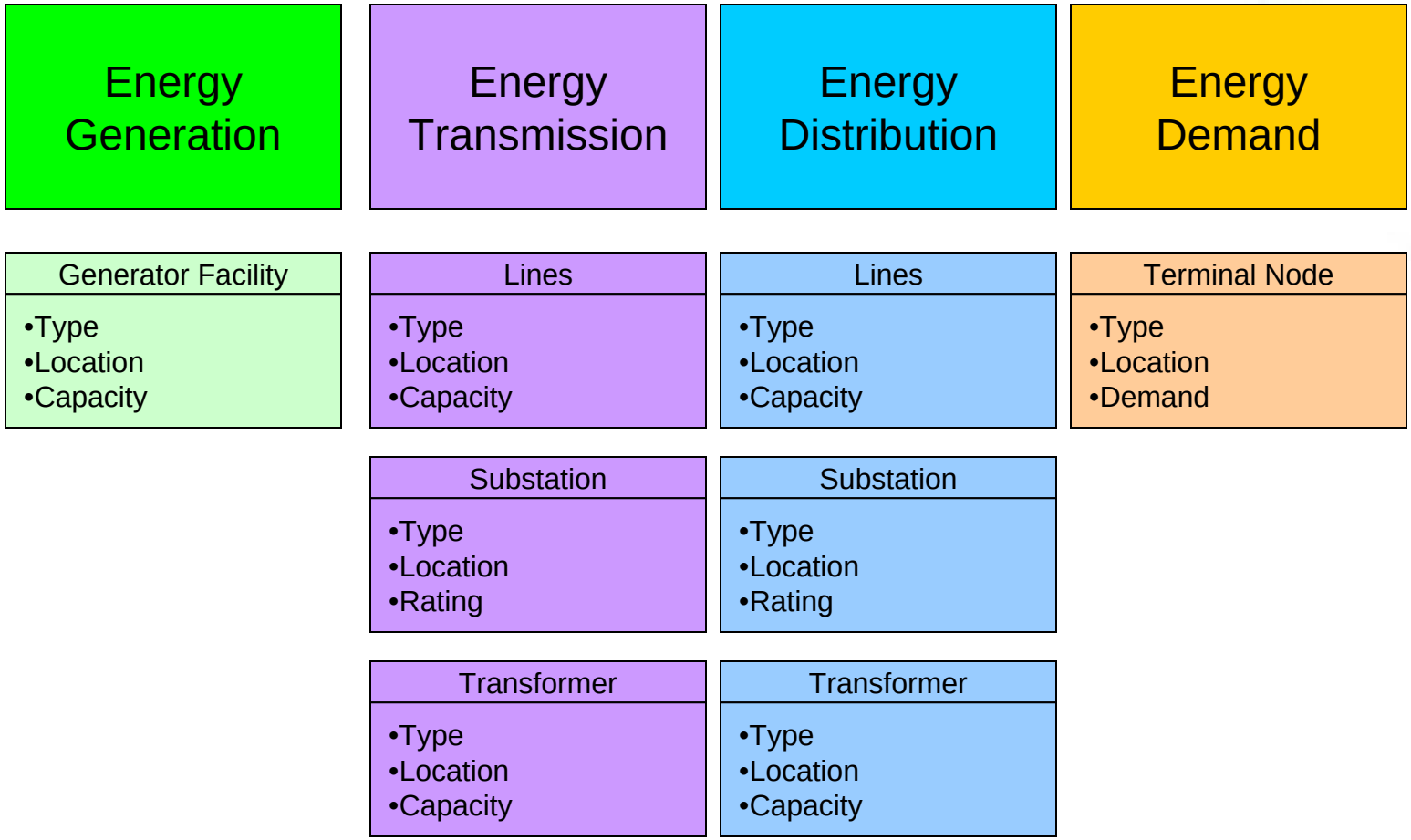
The Case Study – Deriving Potential Models, Preparing for Implementation

- Once the Functional Decomposition, and Feature Analysis (concentrating on the input/output requirements for each identified functional area of the layer) was finished, this work could serve as the basis (and did) for **potential models** for each functional area

- The next stage in the project (this is ongoing) is the design of the software agents to represent specific instances of the functional areas. These instances will have specific attribution for the features (as they are represented in the agents), and of course, not all agents will have all of the features (this is a defining quality of the **potential model**)

- In order for the analysists who are doing the modeling to make the job of the implementers (who are crafting the agents) easier, the derivation of specific **actual models** will help immensely

The Case Study – The Energy Supply Critical Infrastructure and Potential Models



The Case Study – The Energy Supply Critical Infrastructure (II)

- Energy Generation
  - Inputs
    - People
    - Policy
    - Power
    - Communications
    - Consumables (fuel, cooling water, etc)
    - Energy
  - Outputs
    - Energy
    - Communications
    - Waste
- Energy Transmission (lines)
  - Inputs/Outputs
    - Energy
- Energy Transmission (transformers)
  - Inputs/Outputs
    - Energy
- Energy Transmission (subsystems)
  - Inputs
    - PPPCC
    - Energy
  - Outputs
    - Energy
    - Communications
- Energy Consumption (terminal)
  - Inputs
    - Energy
- Energy Distribution (lines)
  - Inputs/Outputs
    - Energy
- Energy Distribution (transformers)
  - Inputs/Outputs
    - Energy
- Energy Distribution (subsystems)
  - Inputs
    - PPPCC
    - Energy
  - Outputs
    - Energy
    - Communications

The Case Study – The Energy Supply Critical Infrastructure (III)

Energy Supply								
	Energy Generation Facility	Energy Transmission - Lines	Energy Transmission - Substation	Energy Transmission - Transformer	Energy Distribution - Lines	Energy Distribution - Substation	Energy Distribution - Transformer	Terminal Node (Customer)
People								
Power								
Policy								
Communications								
Consumables								
Water (as a consumable)								
Wastewater								
Energy								
Waste								
Processed Wastewater								

Conclusion

- The project is ongoing, further results will be reported on, and additional aspects of the project that are of interest will be reported on
- The distinction between potential models and actual models in the Conceptual Modeling process for such a project seems to be valuable
- It is the unknown requirement for a number of different final implementations from a class of similar things that makes the method valuable
- Further analysis and formalization of this method should prove useful, if it continues to be followed

Thank You For Your Attention

Questions?

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