If MEml is the Answer, What is the Question?

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The goal of "capturing, representing, and modeling mechanical engineering (ME) design knowledge" is a very challenging one. If we can know exactly what the knowledge is *for* then the task is easier, as what knowledge to be included can be limited, and appropriate representations can be chosen to support the proposed use. However, the workshop 'charge' specifies education, research and applications: i.e., no limits. While limiting and shaping knowledge for a particular task makes it more powerful for that task, it makes its use for other tasks harder or impossible. But with no limits imposed then there are many factors that make general knowledge hard to use in specific situations: of necessity more processing will be required to find, integrate and use that knowledge for a specific design task.

We need to look at all the factors that contribute to making the task of Capturing, Representing, and Modeling (CRM) ME general utility design knowledge so difficult. In addition, we need to add Using to that list (CRMU), as for at least the near future people will still be in the loop for most design tasks. In addition, computers will also be users of the knowledge: there are challenges concerning acquisition, translation, searching, completeness, and semantic consistency there too.

I will divide the challenges/factors that serve as, and influence, the Requirements for the CRMU task into categories: Volume, Complexity, Distribution, Diversity, Compatibility, Context, and Task. Very little of what is included below is original. Citations are not included. If a Mechanical Engineering Modeling Language (MEml) is the answer, then these factors must be explicitly addressed or properly dismissed.

Volume

There's a *huge* amount of design knowledge about things and processes. Such an amount prohibits having a single collection of knowledge. Large amounts and multiple collections make capturing, finding and using what you need very hard. Knowledge acquisition from experts and users is motivated by potential personal gain: i.e., one can't rely on altruism. The expression of knowledge to/from any system or knowledge-base must be easy (i.e., not too formal). However, there is a growing potential role for Machine Learning, and extraction from Natural Language. New technologies and products make Knowledge Acquisition a continuous process. Inference techniques should allow incomplete knowledge to be expanded and uncertain knowledge to be used.

Complexity

Most real-world designs are complex; hence the knowledge about and used in those designs is too. Inclusion of different domains (e.g., electrical & mechanical) also adds complexity. Multiple domain-specific (as well domain-independent) representations are hard to integrate: the connections between them must be obvious, and one should fluidly lead to another. Lack of integration produces fragmentation of knowledge, leading to processing complexity. Just the existence of multiple representations (both formal and informal) leads to complexity.

Distribution

Geographical distribution of design knowledge is the norm. Distribution makes finding and using what you need harder. Similarities and differences between knowledge are not normally recorded, even at one location, but they will be required with distributed knowledge. Comprehensive indexing is essential.

Diversity

There are many types of representations (i.e., form), such as structured knowledge representations, databases, solid models, etcetera, and different versions of each of those. There are many ways to use representations (i.e., content), including: descriptions of components; relationships between parts; first principle about physics, chemistry, materials, geometry and time; codes and standards; cases and heuristics; numerical and symbolic models for analysis and prediction; world knowledge; design plans and goals; history and rationale. There are many goals for representations (e.g., ease of inference; ease of display), and there are many types of reasoning supported by representations (e.g., classification; layout; spatial intersection). Design teams add new things to capture and represent: e.g., email, gesture, conversation, sketches and other forms of interaction.

Compatibility

Compatibility problems are due to representation diversity: diversity is hard to control due to personal, cultural and commercial pressures (e.g., a particular software tool preferred by a company requires a certain form of input). Compatibility problems are also due to different ontologies, formats, and standards, as well as representation errors and inter-representation translation errors.

Context

The context for the stored representation is mostly hidden, and cannot be totally reverse engineered. Context includes design intent, requirements, geographically varying cultural aspects and standards, the design rationale and history, the nature of the design tasks/methods used, and the assumptions made. In addition, knowledge is rarely context free, even though it is often used that way.

Task

There is no such thing as *the* design process. Design tasks vary depending on the knowledge and experience of the individual or team, as well as the context. For example, different levels of routineness of a design problem would need different amounts and types of knowledge being used or captured. Having a goal of creativity might increase the need for cross-domain associative knowledge, such as for biomimetic design by analogy. Collecting and representing knowledge for Design Education is probably quite different than for Design Practice.