Submission for Workshop on the Potential of
Cognitive Semantics for Ontologies

Cognitive Semantics, Complexity and Scale-free Networks

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Introduction

Werner Kuhn's paper claims that "...cognitive linguistics is both more relevant and more useful to information science than traditional (i.e. Chomskian) linguistics when it comes to dealing with semantics." An understanding of the ways in which cognitive linguistics is more relevant and useful to information systems, I consider three information system viewpoints:

1. Conceptual spaces
2. Complexity Theory
3. Scale-free networks

These ideas are not well-formed, but my intuition tells me there is perhaps some gain to be made by the different viewpoints – if only by stimulating other related ideas within the workshop.

Conceptual Spaces

Gardenfors has eloquently described conceptual spaces in his book of the same name. Consider a conceptual space, say, for the concept of a chair. As I move around the space, I encounter a rich variety of properties of the chairs – some have high backs, some low, some have upholstery, some are made entirely of wood. Although these attribute vary in "value," they exhibit a similarity across the conceptual space. At the periphery of the conceptual space, I may encounter something like a park bench. As I pass over the boundary of the space I may encounter a chair-like bed (e.g., a futon), that I no longer consider to be a chair. A chair manufacturer may have a rich relational database with tables filled with woods, glues, fabrics, designs, colors, weights, etc.

If information systems across a network want to interoperate for some purpose using the concept of a chair, it may be that only some attributes of the chair are important to that interaction (e.g., the weight attribute for shipping purposes). It may also be that we categorize a property in some way (e.g., the weight to within 10 pounds.) From a conceptual space viewpoint, we are considering only the projection of the conceptual space onto the designated attribute axis and chunking the conceptual space into regions that have the categorized properties. From a geometric viewpoint, we are examining the attribute of the chair at a course grain (10 pound intervals) and ignoring all the other attributes. From an information theoretic viewpoint, the network interaction now requires considerably less information, and therefore interoperating information system would require a considerably smaller data model than is available at the chair manufacturer's plant.

Thus inherent in a conceptual space is the idea of whether we are utilizing the concept at a fine grain or a course grain. Geometrically that corresponds to observing the conceptual space from up close or far away. In the limit when we move our observation point very far away from the conceptual space, it collapses into a point, i.e., it simply becomes a "chair." The sharing of that information over a network requires a simple data model.

Complexity and Scale

In a complex system, it is the relationship between parts that gives rise to the collective behavior of the whole. A small set of simple interactions gives rise to emergent behavior. Complexity theory indicates there is a trade between the scale at which we describe something and the complexity of that something. If individual systems have uncoordinated and complex data models from which they interact with the network, then at a small scale (individual user level) the behavior is complex, but at a network level the data interchanges appear meaningless and random – no emergent behavior results at the network level. On the other hand, simple data models at the individual level can combine at the network level to be complex and exhibit emergent behavior.

The Semantic web is a massive network of computers interoperating in a machine-to-machine manner. It both shares knowledge and reasons about things. Interoperability is the desired emergent behavior on the Semantic Web. It refers to the relationship between the (details of) individual users and the (larger view of) network-centered operation. Focusing on the details of the rich semantic models of an individual user will not yield interoperability across the network. Likewise, building common data models across a large network of users has proven futile – at least it does not scale. (The amount of information a hierarchical authority must possess grows exponentially with the number of users.) So in achieving wide network interoperability as an emergent behavior of a Semantic Web, what's needed is the interplay of simple data models on a network scale.

Thus if somehow conceptual data models at the individual system level could be dynamically projected and chunked to create simple data models that are shared across the network, the resulting complex system could exhibit interoperability as an emergent behavior.

Scale-free Networks

The next viewpoint to consider is that of scale-free network theory. For each rich semantic model being used in the network, there is a community of interest (COI) sharing that model. However, between the COI's there are simple data models being used to share information at a coarse level. These are loose couplers in the scale-free network world. Here the network is considered dynamic. There is preferential attachment by new users to the COI with the most attractive (to that user) rich semantic model, and interaction follows a power law distribution

Assume the loose couplers are using simple data models that correspond to projections and chunking of the conceptual models.   So even if the details of the conceptual models are different at a fine grain, the projections and chunkings may be identical across the network at a coarse grain. (A chair is a chair is a chair no matter how individual chair manufacturers may construct their detailed databases.) Assume further that these simple models give rise to many simple interactions across the network that in turn give rise to the desired emergent behavior of interoperability.

A Simple What-Where-When Example

Consider a taxonomy of objects (“what”) designated {1, 2, ..., N}. There may be rich semantic models describing the details of each object, but we will chunk them into simple concepts (e.g., chair, table, desk, etc.). Designate the location (“where”) of one such object on the earth by its “latitude,” “longitude” and “altitude above mean sea level” (i.e., a conceptual model of a point on the face of the earth, which might be chunked from the richer model of a space-based sensor). Also designate a time (“when”) at which the object is there by “t” (i.e. a conceptual model of a real line from minus to plus infinity.)

Now if the concept of something being at a certain location at a certain time is of network-wide interest, we could develop a simple (XML) schema which all users could share to communicate about their own “what’s, where’s. and when’s.”   Each COI using a different data model at the fine grain level could now begin to exchange information at the coarse grain level and reason about the going’s on of the “what-where-when’s.”

This is a static example. What is needed is a mechanism to dynamically chunk the conceptual models, form the loose couplers, and create the emergent behavior.

Summary

Along with viewing interoperability in information systems as a problem of cognitive semantics and linguistics, we view it as an emergent property of a complex system of heterogeneous users without any centralized control. The rich data models of each individual user contain some properties that are important to the wide-scale interoperability behavior. If we use conceptual models of the objects of network interest, then on the network scale, a limited subset of the properties of those objects become important. Moreover, the dynamic interaction of users adopting simple standards upon which to interact becomes the dominant mechanism for interoperability.