Upgrading Terminological Reasoners to Account for Current Theories of Categorization

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1 Statement of Interest

The KL-ONE family of knowledge representation languages can be credited with raising the consciousness level of frame-based and object-oriented systems. Previously such systems had few services to offer beyond inheritance (And the value of even that much is questionable). Terminological logics should at least provide the service of determining the similarity of structured concepts. They should do so in a formal way, and preferably the expressability and limitations of a language and associated operations should be well established. It may be necessary to limit the size and functionality of these languages to achieve these objectives, but at least what they can do they do well.

A major role of terminological logics is to automatically group objects into classes. In my view, this automatic categorization is a fundamental service to be provided. This is the function provided by the KL-ONE classifier. Nevertheless, I shall argue that existing classifiers are promoting an inaccurate view of categorization. In particular, their reliance on necessary and sufficient
conditions, that an object is a member of a class if it can meet the necessary and sufficient conditions specified by the structure of the class object, has been shown to be inadequate as a theory of categorization [Neisser,1987; Lakoff,1987; Rosch and Mervis,1975]. This has its worst consequence in the primitive classes. Other important phenomenon such as prototype effects, family resemblance, default reasoning, reasoning by analogy, and dealing with incomplete information, are generally ignored.

Some may argue that an accurate representation of categorization is beyond the limited intentions and capabilities of formal terminological logics. I do not believe that this is the case. In fact, it is possible to account for these other phenomena by augmenting the terminological reasoners with additional inferencing operations. In particular, a much greater emphasis on reasoning about instances is needed. I hope to show that this can be done without sacrificing the ideals advanced by the KL-ONE family.

2 Underlying Theory of Terminology Meaning

The following is an outline of a theory of meaning which has emerged from current theories of categorization. I am proposing that terminological logics be expanded to accommodate this theory:

2.1 Family Resemblance

Category membership cannot be defined by simple necessary and sufficient conditions. There is very little that all members of a category have in common, rather they are related only via a vague, often indescribable family resemblance [Wittgenstein,1953]. Categories consist of a very complex clustering of concepts. In addition, effects such as prototypes and basic levels, similarity, boundary effects, and exceptions are phenomena to be explained.

2.2 Reasoning about Instances

The process of recognition, of deciding how to put a particular object into a category, is not dictated by a fixed law or theory of category membership. Rather, the emphasis is on the particulars of the instance being considered.
Case-based reasoning [Kolodner,1988] is needed to generate complex categories from the properties of particular instances.

2.3 Cognitive Models and Theories

Empirical reasoning about instance similarity alone is not sufficient. Our theories and beliefs about the world do play a role in categorization. Constant conflicts between empirical evidence and theories result in continuing shifts in perception, a process not unlike that of scientific revolution.

2.4 An A Priori Concept Network

Such a network is necessary as a substrate for initial theory building, and to provide contexts in which to build instance descriptions.

2.5 The Language Game

The social aspects of categorization play a central role in evolution of word meaning, a concept originally illustrated in Wittgenstein’s language games. The consequence is that automatic classification techniques must always be guided by human interaction.

3 New Functions for a Terminological Reasoner

It is proposed to add two new functions to the inventory of inferencing techniques provided by the terminological reasoner. These deal with reasoning about instances:

"Intersect" takes two instance descriptions and determines their structural similarity. Any structure in common is extracted and used to form a new class description. For example, the intersection of:

\[(\text{John (all male ) (children (Fred Tom))})\]
with:

(Mary (all female ) (children (Bill)))

is the class description:

((all parent ) (children (atleast 1 male)
  (all male)))

and of course the new class description has John and Mary as instances. The process is then extended such that any two instances in the knowledge base can form a class based on their intersection, leading to rich, complex clusters of class descriptions over the set of instances.

"Evolve" is a function which changes existing classes in response to the addition of a new class produced by "Intersect". The notion is borrowed from database management (Schema Evolution) in which class objects must be modified to account for exceptions or new instances which do not fit existing patterns. One effect resulting from Evolve is that class objects have less and less structure as they gain more instances. In other words, this results in the family resemblance effect. For example, the concept of a parent as having only male children may not have been known previously by the system, and may require modification to existing classes to be accepted.

Notice that an Intersect function can be built using the same approach as has been used to build Subsume functions. It is likely that the representational language will need to be limited to maintain tractability, or not all connections between two instances could be discovered. Nevertheless, this new function adds many capabilities to the system. In particular, it would now be possible to determine if a new instance belongs to a class by its similarity to other instances in the class instead of having to meet one definition which applies to all instances of the class.

4 Applications

The categorization process described here is being applied to lexicon design and automated vocabulary acquisition for a natural language processor.
[Beck, 1989]. Rather than a simple dictionary definition, each lexical item is associated with a complex cluster of classes which cover many instances in which the word is used. The approach offers hope that the system can recognize new or novel usage by comparing the new instance with the vast number of existing instances in the knowledge base.

The process hopefully will also lead to improvements over existing approaches to querying databases using terminological reasoning [Beck et al., 1989].

References


