

Galley:

Computational Models of Analogy-Making

on exhaustive search of long-term memory (LTM) and on the assumption that old episodes have context-independent, encapsulated representations. There are, however, exceptions (e.g., AMBR) that rely on context-sensitive reconstruction of old episodes performed in interaction with the mapping process.

Mapping

0098.006 Mapping is the core of analogy-making. All computational models of analogy-making include mapping mechanisms, i.e., means of discovering which elements of the base correspond to which elements of the target. The difficulty is that one situation can be mapped to a second situation in many different ways. We might, for example, make a mapping based on the color of the objects in both the base and target (the red-shirted person in the base domain would be mapped to the red-shirted person in the target domain). This would, in general, be a very superficial mapping (but might, nonetheless, be appropriate on occasion). We could also map the objects in the two domains based on their relational structures. For example, we could decide that it was important to map the giver-receiver relationship in the first domain to the same relationship in the target domain, ignoring the fact that in the base domain the giver had a red shirt and in the target domain the giver was wearing a blue shirt.

0098.007 Experimental work has demonstrated that finding this type of structural isomorphism between base and target domains is crucial for mapping (Centner, 1983). Object similarity also plays a role in mapping, although generally a secondary one. A third factor is the pragmatic importance of various elements in the target: we want to find mappings that involve the most important elements in the target. Searching for the appropriate correspondences between the base and the target is a computationally complex task that can become infeasibly time-consuming if the search is unconstrained.

Transfer

0098.008 New knowledge then has to be inserted into the target domain based on the mapping. For example, suppose a new brand of car appears on the market, and that this car maps well onto another brand of car that is small, fast, and handles well on tight curves. But you also know that this latter brand of car is frequently in need of repair. You then wonder whether the new brand of car will also be in frequent need of repair.

0093.009 Transfer is present in some form in most models of analogy-making, and is typically integrated with mapping. Transfer is considered by some researchers as an extension of the mapping already established, adding new elements to the target.

Evaluation

0098.010 Evaluation is the process of establishing the likelihood that the transferred knowledge will be applicable to the target domain. In the example above, the evaluation process would have to assign the degree of confidence we would have that the new car would also be in frequent need of repair. Evaluation is often implicit in the mechanisms of mapping and transfer.

Learning

0098.011 Only a few models of analogy-making have incorporated learning mechanisms. This is somewhat surprising since analogy-making is clearly a driving force behind much learning. However, some models are capable of generalization from the base and target, or from multiple exemplars, to form an abstract schema, as in LISA (Hummel and Holyoak, 1997) and the SQL model based on SME (Falkenhainer *et al*, 1989).

0098.012 Below we will review a number of important computational models of analogy-making belonging to different classes and following different approaches. First the 'symbolic' models will be presented. These models employ separate local representations of objects, relations, propositions and episodes (e.g., 'John', 'chair', 'run', 'greater than', 'John ate fish', 'my birthday party last year'). Then, 'connectionist' models will be presented. Here the objects, relations, and episodes are represented as overlapping patterns of activation in a neural network. Finally, a third, hybrid class of models will be presented. These models combine symbolic representations with connectionist activations. They are based on the idea that cognition is an emergent property of the collective behavior of many simple agents.

SYMBOLIC MODELS

ANALOGY

0098.013 The earliest computational model of analogy-making, ANALOGY, was developed by Thomas Evans (1964). This program solves multiple-choice geometric analogy problems of the form A is to B