

Analogy and Constructive Memory

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Abstract

This paper presents the integrated AMBR model of analogy and memory based on the cognitive architecture DUAL. This model was also able to predict new phenomena such as context effects on problem solving and memory distortions as result of double analogies, which effects were then tested and confirmed in psychological experiments.

Introduction

Typically human thinking and human memory are modeled separately by use of independent models. This does not allow integrating them into a united cognitive architecture, neither to explore the interaction effects between the two. The current work is based on the achievements in the field of analogy-making (Gentner's SMT, Holyoak & Thagard's ACME, Hummel & Holyoak's LISA), however, the existing models assume perfect memory for old episodes. The proposed model is also based on the attempts to build models of constructive memory (CHARM and Trace Synthesis Model), however, these models completely ignore the structure of the episodes and explain the memory distortions by overlap of the feature vectors. The model presented in this paper is based on a general cognitive architecture (DUAL). Its general spirit is similar to Hofstadter's group COPYCAT and TABLETOP architectures.

The DUAL Cognitive Architecture

The DUAL cognitive architecture (Kokinov, 1994b, 1994c, Petrov & Kokinov, 1999) is a hybrid (symbolic/connectionist) architecture based on decentralized representation over vast amount of micro-agents and emergent computation.

At the micro-level a DUAL-based system consists of micro-agents each of them being a hybrid processing unit. Its symbolic part represents a small piece of knowledge (e.g. a simple statement or a piece of procedural knowledge). Its connectionist part represents the relevance of that piece of knowledge to the current context.

Each concept or episode is represented in DUAL in a decentralized way as a coalition of micro-agents. This makes partial access possible, i.e. only some features of the concept are available in a certain context, and only some aspects of an episode are being recalled under certain circumstances. Moreover, it is possible to activate and

blend aspects of two different episodes and thus produce a false memory for a nonexistent event. Coalitions might be strongly tied or loose corresponding to fixed and robust or flexible and vague memories of an episode or concept.

At the macro level the network of all micro-agents forms the Long-Term Memory (LTM) of the system, while the subset of active agents forms the Working Memory (WM). The most active agent is called focus of attention.

The AMBR2 Model

The AMBR2 (Kokinov, 1998, 2003, Kokinov & Petrov, 2001) model is the successor of AMBR1 (Kokinov, 1994a) and is built upon DUAL. It is an integrated model of analogical mapping and memory retrieval. Actually, "retrieval" is not the correct term, since AMBR views memory as a constructive process. Old episodes are not retrieved "pre-packed" and conserved in memory, but are constructed on the spot out of the various pieces we have in memory. This reconstruction is mainly based on the spreading activation mechanism which brings various micro-agents in WM. However, the mapping process runs in parallel to the reconstruction and thus it can also help and guide the reconstruction producing an episode that will best match the target problem. Thus our present forms our past (Kokinov, 2003).

The mapping process is also an emergent process which is based on the local marker passing mechanism as well as on local structure-preserving processes. This process heavily depends on the activation levels of the micro-agents and in that way is influenced by the spreading activation mechanism.

Predicted Context Effects

A number of simulations have been run with the AMBR model demonstrating the context-sensitivity of the model (Kokinov, 1994a, Kokinov & Grinberg, 2001). These simulations predicted that the presence of a supposedly irrelevant object or picture in the visual field of the subject could influence his or her problem solving. A series of experiments has been performed to test this prediction. These experiments confirmed that an irrelevant picture could change the way a problem is being solved (Kokinov, Yoveva, 1996) and that the result could be opposite to the result obtained in a hint condition, namely, the same picture presented as irrelevant element of the environment produced a facilitating effect, while presented as an explicit hint

produced an inhibitory effect (Kokinov, Hadjiilieva, Yoveva, 1997). This was interpreted as a support of the AMBR model which predicts that the irrelevant picture would unconsciously influence the process of problem solving, while the hint will result in an attempt to make an explicit analogy between the problem and the picture.

Predicted Memory Distortions

The AMBR model being a model of constructive memory predicts the possibility for memory insertions, episode blending, and other types of memory distortions (Kokinov & Petrov, 2001). A series of simulations has been run to demonstrate a specific type of memory distortions, namely blending between episodes. It has been shown that not only similar episodes can be blended, but also very different ones (Grinberg & Kokinov, 2003a, 2003b). This was a novel prediction in contrast with the blending between highly similar to each other episodes obtained by other authors. This prediction was tested in a series of psychological experiments and it turned out that dissimilar episodes can be blended as result of their participation in a double analogy with a third one (Kokinov & Zareva, 2001, Zareva & Kokinov, 2003a) and that this distortion is not temporary but it is rather present even a week after the double analogy has been made. It has also been demonstrated that the double analogy could not be replaced by simple co-occurrence and building associative links between the dissimilar episodes (Zareva & Kokinov, 2003b). The experiments were run with various materials, including stories and spatially organized geometric figures. Thus the predictions of the model have been completely confirmed.

Conclusions

The AMBR model integrates analogy-making and memory construction and thus is able to explore the interactions between reasoning and memory and to predict new, previously unreported, phenomena. In addition, it provides an example of a computational model that implements the constructive memory approach and explains why human memory is not reliable. The model has predicted context effects on problem solving and memory reconstruction and serious memory distortions, including blending of dissimilar episodes. All these predictions were confirmed by psychological experiments.

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