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Recall and Reasoning—an information theoretical model of cognitive processes

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Abstract

Cognitive Psychology studies humans' capabilities to memorize and recall knowledge and images, among others. Connectionistic, propositional and conceptual models are a means to survey these phenomenons. This paper proposes an information theoretical network for simulating stimulus and response in categorical structures. A stimulus triggers an information flow throughout the whole network and generates for all ideas representing vertices an impact in the information theoretical unit [bit], thus measuring the recall intensity and producing a response. The method is shown to yield results of high performance even for complex taxonomies and connectionistic models. Reasoning is the logical counterpart of recall. Once an idea is associated with a stimulus, logical dependencies between both must be established, if required. Information theoretical networks allow to switch between a recall mode and a reasoning mode, also permitting logical reasoning within the same framework. Both capabilities are demonstrated by suitable examples.

Keywords: Artificial intelligence; Association; Logical reasoning; Stimulus/response; Information Network; Connectionistic model; Semantic Network; Conditional logic; Inference; Recall

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1. Introduction

Perception and attention, acquisition, representation, memory and recall of knowledge and images as well as problem solving mechanisms are topics of Cognitive Psychology, among others (cf. [1,28]). Since the 1950s intensive research in the field of Artificial Intelligence tried to link Cognitive Psychology, (nonmonotonic) Logics and Computer Science. The objective was and is a better understanding of human knowledge processing, the creation of adequate logics and the simulation of such logical reasoning on a computer (see [11,18,21] (especially Chapters 8–10); [26]).

In the present paper we treat two aspects of knowledge processing:

- *Recall*. Find a high performance model to memorize relations between ideas and to recall ideas by a stimulus. Make this model disposable at a computer and test it for adequate examples.
- *Reasoning*. The same model should be able to conclude propositions about ideas from other propositions.

What comes into our mind when we learn that something is a `RECTANGLE`: `SQUARE`, `RHOMBUS`, `PARALLELOGRAM` or `TRAPEZIUM`? This Recall is quite different from the question whether a `RECTANGLE` is a `PARALLELOGRAM`, a `TRAPEZIUM`, a `RHOMBUS` or a `SQUARE`. The last problem preoccupied the German nation after a TV quiz show (due to a weak education standard in mathematics and geometry); the first problem is just the question of association among geometrical figures rather than of strict mathematical reasoning. We think that the reader associates first a `SQUARE` with a `RECTANGLE`. And hopefully she or he knows, that a `RECTANGLE` is a `PARALLELOGRAM` and a `TRAPEZIUM`, but neither a `RHOMBUS` nor a `SQUARE`, in general. Which properties do we associate with the category `BIRD`, which category comes into our mind, if we learn that something flies. And if we highly associate fly with a `BIRD`, does this also imply that all `BIRDS fly`? Propositional and Semantic Networks help to model such semantic dependencies and logical relations (cf. [8,9,13]). They are studied likewise in Cognitive Psychology and in Artificial Intelligence. In Propositional Networks linguistic sentences are decomposed into smallest unities—propositions—and they for their part are related by relations or predicates. Graphical devices visualize the dependencies [2,7]. Semantic Networks permit a meaningful representation of categories and their respective properties [8,16]. In Cognitive Psychology they serve as a means to identify an association's strength and recall-time. Schemas (frames) store knowledge about objects, their attributes and respective connections [4,17].

Generalizing such concepts, in the present paper we shall develop Information Networks (I-Nets), thus combining the advantage of Propositional Networks and an information theory based knowledge processing. Initializing a stimulus