Chapter 13
Knowledge Representation as a Tool for Intelligence Augmentation

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ABSTRACT
The goal of Intelligence Augmentation (IA) is the development of tools that improve the efficiency of human intelligence. To this end, the authors of this chapter introduce a model of human conceptualization on the basis of a cognitive theory of information processing and a Peircean theory of signs. An account of two experiments is provided. The first concerns conceptualization by individuals, and the second describes how problem elicitation was approached by a team of participants. A preliminary analysis of the results shows that the proposed model is congruent with multi channel and multi purpose human information processing. This implies that the cognitive model can be used as a model for knowledge representation in various fields of human-computer interfacing such as computer aided problem solving and problem elicitation.

INTRODUCTION
Intelligence Augmentation (IA) research aims at the development of tools that improve the efficiency of human intelligence. This form of enhancement contrasts with Artificial Intelligence (AI), whereby intelligence would be produced in an entirely artificial form. According to D.C. Engelbart (1962, p.1),
“by ‘augmenting human intellect’ we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems”.

Due to the importance of man in problem solving, computer systems augmenting intelligence demand a ‘human-compatible’ formal model of knowledge representation (KR). Important characteristic properties of human KR are flexibility (for adjustments) and portability (knowledge in one domain can be directly used in another domain). Experience with static, fact-based KR in past decades has shown that it is inflexible and non-portable. We believe that process-based, dynamical KR offers better perspectives. An illustration of the differences between static and dynamic KR may be found in natural language (NL) processing. Traditional (static) language modeling, characterized by large formal grammars and relatively small lexicons is not robust against modifications. By separating static and dynamic aspects of language symbols, respectively, in a lexicon (which is apt for modification) and a relational process (which can be invariantly used), dynamic modeling enables a more robust alternative (Sarbo, Farkas & van Breemen, 2007).

A philosophically informed dynamic view of KR has been introduced in (Breemen & Sarbo, 2009). The most important conclusion of this work is that the processes of perception and cognition can be modeled in the same way. We grounded our model in the theory of the American philosopher, C.S. Peirce (1839-1914) for two reasons. On the first hand, Peirce’s sign theory (cf. semiotics) provides a unique classification of signs and sign aspects. On the other, his category theory enables categorical classification to be applied recursively hence it enables the development of ontological specification in a systematic fashion.

Here we start with a recapitulation and definition of our cognitively based, semiotically inspired model of KR that complies with those philosophical considerations. This model of knowledge representation models conceptualization as a process. A characteristic property of all processes, including conceptualization, is their teleological, goal-driven character. Such a goal is the generation of an appropriate response to the input problem. In practice this comes down to the generation of a response that is appropriate from a certain point of view as, for instance, when the response is mathematically well-formed (in the case of a mathematical problem).

Since in conceptualization it is only the final interpretation that really is of interest, intermediate representations can be considered as expressions of the input from the perspective of their contribution to the (desired) result. Such intermediate interpretations can be associated with Peircean sign aspects (Peirce, 1931-58). On the basis of the dependency and subservience relations between different sign aspects that are identified by Peirce, we suggest that intermediate representations can be ordered in a dependency structure.

The focus of this chapter is on an application of our theory of IA in human conceptualization. We will consider two fields: problem solving (Bruner, 1966) and problem elicitation (Krogstie, Sindre & Jorgensen, 2006). Utterances generated during problem solving and problem elicitation can be associated with sign aspects and ordered accordingly. Following this line of thinking, the quality of a conceptualization process can be characterized by the relation between the structure induced by the generated sign aspects, and the dependency structure defined by Peirce. In our first experiment, the quality of conceptualization is determined statistically. As an analysis of conceptualization by teams of participants can be more complex, in the second experiment we restricted our focus to a qualitative analysis of contiguous segments of a single process. Ontology specification is beyond the scope of this paper. An illustration of such a definition of syntactic symbols may be found in (Sarbo, Farkas & van Breemen, 2007).
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