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A system simulating representation change phenomena while problem solving

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Abstract

This paper deals with a computer programme offering a valid simulation of cognitive human processes related to representation changes while problem solving. An introductory and brief recollection of preceding contributions by psychologists, cognitive scientists and AI researchers provides the necessary background and motivation for our work. A relevant trend of the present research concerns the formal mathematical study of representation phenomena, including precisions about isomorphic and homomorphic representation changes. In order to simplify problem resolution processes, the implemented system performs certain representation changes, by making use of specific procedures which assign and modify a certain relevance value to every attribute involved in the problem representation, on behalf of their respective importance so as to actually solve the problem. The paper includes a full account of mathematical definitions and propositions involved in this system.

Keywords: Automatic representation changes; Cognitive science; Problem solvers

1. Introduction

A relevant AI research trend is committed to develop computer programmes simulating certain features of human intelligent behaviour, in such way that the performance of those programmes, when tested by an external observer, would be regarded as intelligent, just in the same way human behaviour sometimes is [17]. Simon [16,18] regarded such programmes as actual psychological theories of the corresponding human intelligence traits they aim to simulate. So as to grow into valid psychological theories, such programmes should always keep a close correspondence with the empirical data about human intelligence they refer to. Thus interaction between cognitive and computing science provides the desired background for the fulfilment of AI programmes as psychological theories.

In this paper we deal with an AI simulation of representation changes connected to problem solving, on an empirical basis of psychological evidence about human problem solving. Chief contributions on human problem solving by both cognitive and AI researchers have stressed the importance of getting a suitable representation of the elements involved, so as to actually solve the problem. The impression that a same problem may alternatively result easy or difficult to solve on behalf of an accurate or misleading formulation is in a way a familiar sensation to almost everyone

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involved in problem solving tasks. The informal notion of an underlying problem representation supporting the human solver's performance was already present in the earliest experimental work on human problem solving, by the Gestalt psychologists [4,20]. To restate or reformulate a given problem proves, time and time again, to be, by far, the most consistently useful solving tool [14]: this is due to the fact that alterations in the problem description affect the problem difficulty and may be essential to the whole solving process [6,16]. Dealing with human problem solving, Newell and Simon [13] observed that successive problem representations held in the subject's mind (which they called "problem spaces") usually lead the solving process, through a number of changes, from an initial one to the problem solution. Alternative problem representations may differ not only in the problem enunciation, but also in the related mental constructions the human subject assembles to conceive and (if possible) solve the problem [15].

From a computational approach, Craik [3] is first responsible for conceiving representation schemes, which he called "models", as potentially independent from human thought. Prior to the main developments of computing science, this idea of models as symbolic representations of knowledge proved surprisingly prescient of further work leading to representation held by computer systems. In the context of AI studies, much research has resulted in interesting hints toward a valid formal definition of representation, and about the importance of representation changes in problem solving (a concise review, including brief reports on former research by [1,9,10], among others, may be found in [5]). Such computational approaches to problem representation phenomena coincide in pointing out a few elementary conclusions on the matter:

(1) No standard or "universal" representation of a problem can be always obtained.
(2) Alternative representations of a same problem usually consist in different arrays of implicit and explicit information about the problem features.
(3) The inclusion of important features about the problem among the explicit information proves to facilitate the solving process.
(4) Inversely, the selection of irrelevant problem features among the explicit information often results in an awkward performance.

AI researchers have so far developed different abstraction and individual learning algorithms dealing with improvement of problem formulations, but in most of them the user is actually responsible for selecting the suitable representation and algorithm for each problem, as is the case with SOAR [11,12,19]. Fink's SHAPER [5] uses PRODIGY search algorithms designed to provide wholly automatic changes in problem descriptions, in order to improve the efficiency of problem solving processes. More specifically, Fink's system obtains a suitable problem representation, prior to choosing an appropriate algorithm to solve the problem: that is to say, once an appropriate algorithm has been selected to solve the problem, no further representation changes will possibly occur within the system. Other approaches, involving reformulation techniques in the context of reasoning about physical systems [2], do not imply any representation change occurring during the problem solving process. However, there is sufficient psychological evidence that, in human intelligent behaviour, representation changes can actually take place while subjects solve the problem [13].

Having this particular psychological requirement in mind, our own work on the matter [7,8] has been undertaken on the assumption that representation changes should possibly happen while actual problem solving is performed, and has resulted in the design and implementation of a programme architecture dealing so far with representation changes related to the solving of insight problems. In the present paper, we resume prior results and obtain fully automatic representation changes *while* problem solving, that is, not only representation changes somehow intervening in the problem solving process, but actual representation changes occurring *while* the problem solving process takes place. Moreover, this paper's aim will concentrate on "natural" representation changes, being those usually intervening in every human subject's performance when involved in problem solving tasks. As a result, our algorithm will prove to be efficient in connection to such "natural" representation changes, while not specifically designed to convey or perform representation changes occurring in insight problems.

The system we have implemented performs representation changes in two ways: by dropping attributes from the representation and by performing isomorphic representation changes. The system performs this representation changes by making use of specific procedures which assign and modify a certain relevance level to every attribute involved in the problem representation. We have contemplated further kinds of representation changes by associating relevance levels to other elements in the representation, but in this paper we will only discuss on the prior ones, for reasons of briefness.