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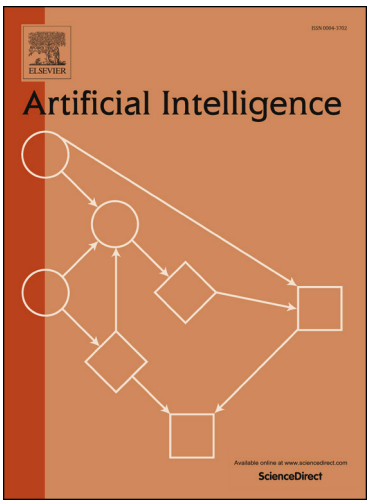

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Hierarchical Conceptual Spaces for Concept Combination

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Abstract

We introduce a hierarchical framework for conjunctive concept combination based on conceptual spaces and random set theory. The model has the flexibility to account for composition of concepts at various levels of complexity. We show that the conjunctive model includes linear combination as a special case, and that the more general model can account for non-compositional behaviours such as overextension, non-commutativity, preservation of necessity and impossibility of attributes and to some extent, attribute loss or emergence. We investigate two further aspects of human concept use, the conjunction fallacy and the 'guppy effect'.

1. Introduction

Humans undoubtedly have the ability to form new concepts by combining existing ones. The development of effective representational models of this phenomenon could potentially shed light on human cognition. Human-like reasoning has been argued to be important to artificial intelligence for its flexibility and robustness [6, 29, 44]. Further, a good representation of human concept use will aid us in considering problems of categorization and typicality, as argued by Freund [18]. Applications of AI that must interact with humans via natural language arguably need to be able to understand and to form for themselves novel combinations of concepts. Examples of theories proposed to account for such concept combination include prototype theory together with fuzzy set theory [51], conceptual spaces [19], and quantum probability [3, 9] approaches. Well-known counterexamples have been identified which suggest that fuzzy sets may not provide an appropriate formalisation in this context [25, 27, 40]. It is argued in [25] that the failure of fuzzy set theory to adequately model human concept combination results from its failure to consider the intension of concepts, i.e., the attributes that the concept possesses. In contrast, the conceptual spaces and the quantum approaches take intension into account, either by considering concepts as being comprised of a combination of properties[1], which are themselves embedded in a space of quality dimensions, or by incorporating context into the model. Our proposed approach utilises a random set interpretation of membership so as to quantify an agent's subjective uncertainty about the extent of application of a concept. We refer to this uncertainty

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[1] In the current paper, we use the terms 'attribute' and 'property' interchangeably