Enhancing Similarity Measures

with Imperfect Rule-based Background Knowledge

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Humans are known to classify objects based on its similarity to previously encountered objects. Similarity-assessment is partly a top-down process, that is, what is regarded as similar depends on background knowledge. This thesis proposes techniques how to integrate various types of background knowledge into technical similarity measures. A special focus is how to treat incorrect or incomplete knowledge.

1 Introduction

Many cognitive and computational tasks can be seen as classification problems. Concept learning, decision processes and object recognition can be treated in a classification framework. This thesis integrates rule-based and instance-based approaches to classification which were traditionally assumed to exclude each other. Rule-based approaches process inference rules that express generalized relations between properties ([1, 6]). In contrast, instance-based approaches defer generalization until classification time and store instances without further analysis ([4]). Generalization is achieved by inferring properties from similar instances. Recently the question arose of how these two approaches can be integrated [3]. One motivation for this integration is psychological evidence that humans apply both rules and instances in categorization and learning. Another, more technical motivation is that the approaches may complement each other in overcoming approach-specific weaknesses [2, 3].

In this thesis, the two approaches are integrated by enhancing similarity-measures with chunks of rule-based background knowledge. The thesis applies an explicit cognitive science perspective to an AI technique. On the one hand it draws on findings from cognitive science about human similarity assessment in order to apply them in the technical domain of case-based reasoning (CBR). A particular goal is to increase the accuracy of similarity-based classification. On the other hand it aims to provide cognitive science with an analysis of which kinds of information are contained in rule-based background knowledge and which kinds of rule-based knowledge could play a role in the similarity-assessment process. In its early stages, CBR was inspired by psychological models about human problem solving. New problems are solved by using experience about similar known problems [4]. Accordingly, a CBR system compares a new instance (called query) to a set of known cases and retrieves the most similar known case. The solution of the retrieved case is used and adapted for the query. As the state of the art progressed, CBR became practically a standard approach in computer science, with much of the research focussing on technical details. Nowadays, cognitive science studies provide much more insights about human problem solving and how humans assess the similarity of problem instances [5]. These findings are at odds with typical recent CBR approaches. This work aims at integrating new psychological models into the similarity measures of CBR in order to enhance their flexibility and accuracy.

Since human knowledge and knowledge available for complex technical domains is usually not complete or fully correct, the approach also deals with imperfect background knowledge.

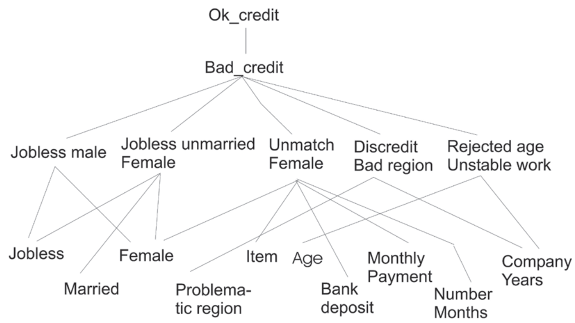

Figure 1: Structure of a domain theory. Leafs correspond to observable features, the root node is the classification goal. In between are intermediate concepts. Arcs denote that the more abstract concept is defined in terms of the less abstract concept.

2 Knowledge and Similarity

There are several top-level influences on similarity judgement. For example, the context, knowledge and the goal of the subject influence which features are selected for the similarity judgement and how important each feature is [5]. Due to the interdisciplinarity of cognitive science the terminology regarding these top-level influences is rather diverse. In some cases even the distinction between objects and domain knowledge is not clear. In this thesis, background knowledge is defined as rules that describe relations between features (e. g. *if fast(X) then expensive(X)*) rather than describe specific instances (e. g. *fast(car1)*).

Using this definition of background knowledge, the thesis identified the following types of knowledge in the cognitive science literature about top-level influences on similarity. For each type, integration methods for similarity measures are introduced.

Deep attributes: Early work on similarity assumed that similarity is only based on easily perceivable features (e. g. color, shape, size). This can be seen as a bottom-up approach. Nowadays, it is acknowledged that there are also top-down effects. Deep attributes cannot be perceived directly, but are inferred from the perceived features using background knowledge [5]. For example, the dangerousness of a beast cannot be perceived directly, but must be inferred

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