Inductive Logic Programming (ILP) and Reasoning by Analogy in Context of Embodied Robot Learning

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ABSTRACT

The ability to reason by analogy is essential for many cognitive processes from low-level and high-level perception to categorization. Intuitively, the idea is to use what is already known to explain new observations that appear similar to old knowledge. In a sense, it is opposite of induction, where to explain the observations one comes up with new hypotheses/theories. Therefore, a system capable of both types of reasoning would be superior. In this paper, the authors present an overview of Inductive Logic Programming (ILP) systems that use reasoning by analogy and discuss the results of combining Analogical Prediction with an ILP system, showing that, for some cases, it is possible to improve significantly the learning speed of the ILP system. This paper will examine the problems that arise in the context of a physically embodied robot that tries to learn regularities in its environment.

Keywords: Inductive Logic Programming, Information Technology, Learning in Embodied Systems, Perception, Reasoning by Analogy

INTRODUCTION

Our main goal was to combine reasoning by analogy and Inductive Logic Programming (ILP).

In (Stojanov & Kulakov, 2008) we give an overview of the role of analogical reasoning in everyday life as well as in scientific reasoning.

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Here, we will briefly summarize the main points to give the minimal context for the work done. We have suggested a classification of the computational models of reasoning by analogy with respect to the underlying approach towards the problem of knowledge representation:

a) “Symbolic” models, so called because they are largely part of the “symbolic” paradigm in AI, in which symbols, logic,
planning, search, means-ends analysis, etc. play a predominant role,
b) “Connectionist” models that adopt, broadly speaking, the framework of the connectionist networks, including nodes, weights, spreading activation, etc. and
c) “Hybrid” models that lie somewhere in between connectionist and symbolic models, based on the idea that high-level cognition emerges as a result of the continual interaction of relatively simple, low-level processing units, capable of doing only local computations.

In the remainder of this introduction we give a brief context of the issues arising in the attempts to combine analogical reasoning and ILP.

There is a considerable body of research in analogical reasoning in cognitive sciences (Gentner, 1983; Hofstadter, 1995; Kokinov, 1994; Indurkhya, 1992) and Artificial Intelligence (Evans, 1968; Becker, 1973; McDermott, 1994). Thus, from perception to problem solving, recollection, explanation and case based reasoning, as well as many other cognitive abilities, rely (in one way or another) on analogical reasoning. Analogical reasoning is also an important research area in AI as a technique to reason from incomplete knowledge.

On the other hand, to our knowledge, there are very few attempts to combine reasoning by analogy and ILP. ILP, as defined in (Muggleton & De Raedt, 1994), is the intersection of inductive learning and logic programming (LP) which infers new knowledge by inducing hypotheses given some background knowledge and a set of positive and negative examples. The reason for scarcity of research that combines analogy and ILP may be in the fact that ILP techniques have rather well elaborated and formalized theoretical background, whereas this is not the case for analogy based systems.

One of the most difficult problems with any analogy based system is how to justify or evaluate how good is certain analogy. Given that in our context we use analogy in combination with ILP, the problem is aggravated because analogy is not a logically sound inference method and therefore the new hypotheses and knowledge may not be consistent with the existing knowledge. Moreover, as the new hypothesis ideally describes a new concept and in order to evaluate it in some way, within the adopted ILP framework, we have to have positive and possibly negative examples of it. In our proposal these examples will be generated by design of the experiments module. Once we have the positive examples the hypothesis generated by analogy is submitted to the HYPER (Bratko, 1986) cover predicate in order to verify how much of the positive examples of the new concept are covered. This will give an estimate of how good is the analogy, and add it to the knowledge base or discard it. We believe that this approach is quite an original solution to the problem of integrating analogy based (or any other logically unsound method) reasoning with ILP.

The remaining part of the paper consists of three main parts: a) a review of what we believe to be the most representative research combining reasoning by analogy and ILP, b) our own approach to the integration problem, and c) software implementation, illustrative experimental results, and overall discussion and conclusion on the achievements, open issues, and potential future research.

We present two different ways to the integration of ILP and analogy: a) using the hypothesis produced by the AP method as a seed hypothesis for HYPER (the ILP system that we use), biasing thus the search process and b) using HYPER to evaluate the plausibility of some analogy generated by a module external to it, and on the basis of the available positive and negative examples.

In the conclusions we summarize our findings and discuss the applicability and generality of the work presented in this deliverable in the robot discovery task.
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