A Non Monotonic Reasoning framework for Human-like Knowledge Invention

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Abstract

Inventing novel knowledge to solve problems is a crucial, creative, mechanism employed by humans, to extend their range of action. In this paper, we present TCL (typicality-based compositional logic): a probabilistic, non monotonic extension of standard Description Logics of typicality, and will show how this framework is able to endow artificial systems of a human-like, commonsense based, concept composition procedure that allows its employment in a number of applications (ranging from computational creativity to goal-based reasoning to recommender systems and affective computing).

The framework relies on 3 main ingredients:
- a non monotonic extension of standard Description Logics (allowing to reason on exceptions to inheritance in standard knowledge bases)
- a probabilistic extension coming from the field of logic programming (the DISPONTE semantics)
- a cognitive heuristics known ad HEAD-Modifier determining preference rules for the inheritance mechanisms of the novel concepts to be generated via commonsense rules.

We report the obtained results and the lessons learned of this research path in the context of model-based AI applications.

Extended Abstract

In this paper we present a logical framework for the dynamic and automatic generation of novel knowledge obtained through a process of commonsense reasoning based on typicality-based concept combination. Addressing this problem is important because represents a classical issue in cognitive semantics and in Artificial Intelligence (AI) concerning how integrate the notion of compositionally in commonsense (i.e. typicality-base) conceptual representation.
Dealing with this problem requires, indeed, the harmonization of two conflicting requirements that are hardly accommodated in standard symbolic systems: the need of a syntactic and semantic compositionality (on the one hand) and that one concerning the exhibition of typicality effects. According to a well-known argument, in fact, prototypes are not compositional. The argument runs as follows: consider a concept like pet fish. It results from the composition of the concept pet and of the concept fish. However, the prototype of pet fish cannot result from the composition of the prototypes of a pet and a fish: e.g. a typical pet is furry and warm, a typical fish is grayish, but a typical pet fish is neither furry and warm nor grayish (typically, it is red), (Osherson and Smith, 1981).
In [Lieto & Pozzato, 2020] we have provided a reasoning framework able to account for this type of human-like concept combination (i.e. the PET-FISH problem) by introducing a probabilistic

extension of a Description Logic of typicality called TCL (typicality-based compositional logic). The nonmonotonic Description Logic TCL combines the semantics based on the rational closure of ALC +TR with the probabilistic DISPONTE semantics [Riguzzi et al, 2015]. This probabilistic extension allows one to endow typical assertion in a knowledge based with propabilities of the form $0.7 :: T(C) \sqsubseteq D$ (meaning “there is a probability of 0.7 that typical Cs are also Ds”). On the top of this extension, we also employed a cognitive heuristic for the identification of a dominance effect between the concepts to be combined, distinguishing between HEAD and MODIFIER (Hampton, 2011).

This cognitively inspired framework (Lieto, 2021) has been employed for goal reasoning and problem-solving. Intuitively, in the context of our application, the overall pipeline of our system works as follows: given a goal expressed as a set of properties, if the knowledge base does not contain a concept able to fulfill all these properties, then our system looks for two concepts to recombine in order to extend the original knowledge based satisfy the goal. Our system has been tested in the task of object composition of compound tools and its results are compared with both human and artificial responses (Lieto et al 2019). In particular, by following (Olteleanu and Falomir, 2016) we asked our system to combine objects in order to obtain the following goals:

G1={Object,Cutting,Graspable}
G2={Object,Graspable,LaunchingObjectsAtDistance}
G3={Object,Support,LiftingFromTheGround}

For what concerns the first goal, i.e. where the purpose of our intelligent system consisted is looking for a graspable object able to cut,the system was not able to find a unique object satisfying all the properties and, therefore, proposed the combination Stone AND Branch a solution, thus suggesting a combined concept having the characteristics resembling a rudimentary Knife with a handle. For what concerns the second goal, where the system was asked to look for a graspable object able to launch objects at distance, the systems combined the concepts Branch AND RubberBand, being those with the highest rank with respect to G2. For what concerns the third goal, the system provides a solution by combining Shelf AND Stump. The last two obtained compounds correspond, roughly to the object of a Rubber Band and Table. We also proposed to 36 human users to solve the same goals (with the same objects of our system Knowledge base) and the obtained results show how the top proposed combination are the same proposed by our system. On the other hand, human users show a much more creative attitude by proposing also alternative combinations. The system has been integrated with the SOAR cognitive architecture, by showing how it is possibile to extend the knowledge processing capabilities of such general systems (Lieto, Lebiere & Oltramari, 2018). The proposed approach has been additionally applied within the context of serendipity-based recommendation systems (Chiodino et al., 2020) and affective computing (Lieto et al. 2021 and 2023).
I will present the obtained results, the lessons learned and the road ahead of this research path.

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