Towards Learning a First-order Stochastic Action Language

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Extended Abstract

Challenging applications such as bioinformatics and cognitive robotics contain temporal aspects. In order to meet the demands of handling such data under uncertainty, there is a need to combine temporal representations with probability. One of the aims of our study is to introduce a new approach for handling stochastic and dynamic changing worlds in an ILP setting. In our framework, dynamic changing worlds are captured using a stochastic conditional-causal relations and are represented in a newly designed high-level first-order stochastic action language, called Datalog-SAL. Datalog-SAL is translated into a Stochastic Logic Program (SLP) to fit an ILP setting. Datalog-SAL is a proper subset of SLPs.

Action languages are formal models for describing actions and changes in a simple natural-language-like syntax. They usually operate at a propositional level. Action languages provide solutions for well-known difficulties such as the frame problem, ramification problem, and qualification problem. Datalog-SAL extends Action Language $\mathcal{C}$ [1] by allowing actions to be Markov processes. It also extends the expressivity of Stochastic Action Language $\mathcal{A}$ [2] from propositional to first-order relations. Datalog-SAL is a declarative language for describing stochastic causal relations.

From a learning perspective, different kinds of knowledge can be learned at the Datalog-SAL level and SLPs level. At the Datalog-SAL level, since the semantics of Datalog-SAL is provided in stochastic state transition diagrams which is equivalent with Hidden Markov Models (HMMs), learning Datalog-SAL is realized with well-studied HMM learning algorithms such as the Baum-Welch for parameter learning and model merging for topology learning.

Since HMM learning algorithms do not provide a scheme to learn relational information between atoms in Datalog-SAL, we employ ILP techniques at the SLP level. In Datalog-SAL, state transitions are represented as conditional causal relations with the notion of conditional probability $Pr(\ \mid\ )$ in the form of

$$Pr(\textbf{caused}\ F\ \textbf{if}\ L_1 \wedge \cdots \wedge L_m \mid A \wedge L_{m+1} \wedge \cdots \wedge L_n) = c$$

where F and L_i are fluent atoms, A is an action atom and c is a constant number in the range [0,1]. We read the above expression as "c is the probability of F being caused to become true if $L_1 \wedge \cdots \wedge L_m$ is true after the execution of action A in which $L_{m+1} \wedge \cdots \wedge L_n$ held". The above formula is expressed in SLP in the form of

$$\begin{aligned} c : fluent_F(t_1) \leftarrow & fluent_{L_1}(t_1), ..., fluent_{L_m}(t_1), \\ & fluent_{L_{m+1}}(t_0), ..., fluent_{L_n}(t_0), \\ & action_A(t_0). \end{aligned}$$

with time stamps. A domain description written in Datalog-SAL is translated into SLPs and can be used as background knowledge in ILP systems.

In the presentation, syntax and semantics of Datalog-SAL will be introduced with an example of a metabolic pathway reaction. Next, we show the result of the complexity analysis of parameter learning in Datalog-SAL with Baum-Welch algorithm. We also explain how to translate Datalog-SAL into SLPs with an example of the metabolic pathway reaction. Our study has indicated that action languages are interesting applications for ILP and contain several challenging topics including combining logic and probability in three-valued semantics.

References

[1] Enrico Giunchiglia and Vladimir Lifschitz. An action language based on causal explanation: Preliminary report. In *AAAI-98*, pages 623–630, 1998.

[2] Hiroaki Watanabe and Stephen Muggleton. Stochastic action language $\mathcal{A}$. Technical report, Imperial College, 2002.