Integration of logical knowledge into the machine learning paradigm

Keywords: Neurosymbolic AI, Logical knowledge, Machine learning, Shallow and Deep networks.

The objective of this proposal is to study how to integrate logical knowledge into the machine learning paradigm, and more particularly in shallow and deep neural networks. We will be more particularly interested into alternatives to first order logic (existential second order ESO, existential first order EFO), and more generally to the integration of other abstract and domain dependent knowledge.

This PhD subject is proposed as part of the development of a Neurosymbolic working group within the LIMOS.

After a formal analysis of the state of the art, a taxonomy of existing approaches will allow to position the work and design an original framework for integrating logical knowledge into machine learning algorithms.

If several approaches have already been proposed (eg design of predictive layers, transformation of logical constraint into a differentiable loss function,transfer of the structured information of logic rules into the weights of neural networks,. . .), they indeed suffer from intrinsic or extrinsic limits that have to be identified and solved.

The original developments that will be proposed in this work will be conducted with several objectives:

- Expressiveness of the solution, eg the ability to solve NP complete problems on consistent data sets.
- Efficiency and precision of the solution, eg logical constraints being satisfied, or partially accounted for (forall quantifiers are hard to approximate)
- If both are not possible, find an effective trade off between the two.

All the steps of the solution will not only be theoretically proved but also implemented in a dedicated environment, allowing to deploy it into several practical problems, as for example:

- Image processing (semantic interpretation of scenes, spatial reasoning,..)
- OR problems, NP problems (vertex cover, others. . .)
- Data query over incomplete / inconsistent data sets.
- Graph analysis
- Document understanding
- Reinforcement Learning

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