Horn-Clause Neural Networks

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A simple FOL-based neural network model - an example program:

1: brightTetrahedron(A,B,C,D) :- brightTriangle(A,B,C), brightTriangle(A,B,D),
   brightTriangle(B,C,D), brightTriangle(A,C,D).
0.1: brightTriangle(X,Y,Z) :- bright(W), bright(X), bright(Y), bright(Z),
   edge(X,W), edge(W,Y), edge(Y,Z), edge(Z,X). /* A rectangle is almost a triangle too :) */
0.1: bright(white).
1: bright(yellow).
2: bright(green).
0.1: bright(blue).

Procedure constructNetworkForGroundAtom(A = p(C1,..,Ck)) node := a neuron with no inputs and bias w₀
best := NULL
For each grounding 0 of C
   If node := a neuron with no inputs and bias w₀
      best := node
      best := TRUE
   EndFor
EndFor
Return best

Procedure constructNetworkForClause(C = h :- b₁,...,bₖ)
node := a neuron with no inputs and bias w₀
If node := a neuron with no inputs and bias w₀
   best := node
   best := TRUE
Else
   Connect subnetwork to node (weight 1)
EndIf
EndFor
Return node

Parameter learning:

Parameter learning is done by repeating the following steps:
1. Construct neural networks for every program H+e, where H is a hypothesis e is a learning example.
2. Check if the stopping criterion is met and if so, finish.
3. Perform online backpropagation for a given number of steps for each of the networks (updating the shared weights - note that the networks for different examples in the dataset can be different but they share some weights).

Some preliminary experiments:

Experiments were performed on chemical data. The structure was selected so that the program would have to induce soft clusterings of atom and bond types relevant for the respective datasets.

wᵣᵢᵣ: toxic :- bond(A₁,A₂,B₁), bond(A₂,A₃,B₂),
   atg₁(A₁), atg₂(A₂), atg₃(A₃), bg₁(B₁), bg₂(B₂).

Future work:

1. Experiments with datasets where the ability to construct useful soft concepts (clusters) is expected to be useful.
2. Structure learning
3. Make it deep

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References: