DeepStochLog: Neural Stochastic Logic Programming

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Neural Definite Clause Grammars

= grammar + logic + probabillites + neural probabilities

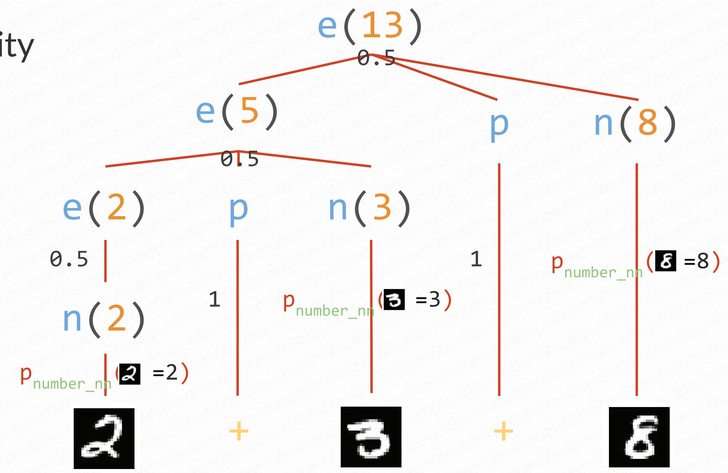
using `nn(model_name,[inputs],[outputs],[domains])` as rule probability

Example: *find sum of handwritten digit additions*

```
0.5 :: e(N) --> n(N).
0.5 :: e(N) --> e(N1), p, n(N2),
                    {N is N1 + N2}.
1.0 :: p    --> ["+"].

nn(number_nn,[X],[Y],[digit]) :: n(Y) --> [X].

digit(Y) :- member(Y,[0,1,2,3,4,5,6,7,8,9]).
```



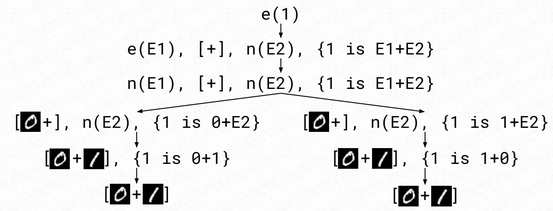
parse symbolic + subsymbolic sequence +

Probability of this parse =

$0.5 * 0.5 * 0.5 * p_{number\_nn}(=2) * 1 * p_{number\_nn}(=3) * 1 * p_{number\_nn}(=8)$

Inference

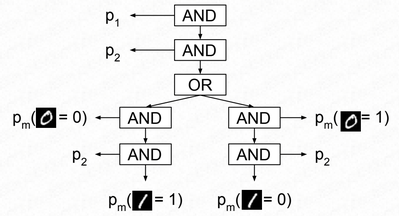
Proof derivations d(e(1),[+]) using Prolog.



Convert to and/or tree + semiring

(+, x) for P_G(derives(e(1),[+])

(max, x) for d_{max}(e(1), [+])



More details

https://arxiv.org/abs/2106.12574

Experiments & Results

Experiment types: math expression outcomes, context-free & sensitive language parsing, citation network tagging, word algebra problem.

Findings: Equivalent accuracy to similar frameworks *(e.g. DeepProbLog)*, but inference time scales linearly instead of exponentially.
Can handle larger inputs, where others time out.

Table 7: Inference times in milliseconds for DeepStochLog, DeepProbLog and NeurASP on task **T1** for variable number lengths.

Numbers Length	1	2	3	4
DeepStochLog	1.3 ± 0.9	2.3 ± 0.4	4.0 ± 0.4	5.7 ± 1.8
DeepProbLog	13.5 ± 3.0	36.0 ± 0.5	199.7 ± 14.0	timeout
NeurASP	9.2 ± 1.4	85.7 ± 22.6	158.2 ± 47.7	timeout

Table 1: The test accuracy (%) on the MNIST addition (**T1**).

	Number of digits per number (N)			
Methods	1	2	3	4
NeurASP	97.3 ± 0.3	93.9 ± 0.7	timeout	timeout
DeepProbLog	97.2 ± 0.5	95.2 ± 1.7	timeout	timeout
DeepStochLog	97.9 ± 0.1	96.4 ± 0.1	94.5 ± 1.1	92.7 ± 0.6

Table 2: The accuracy (%) on the HWF dataset (**T2**).

	Expression length			
Method	1	3	5	7
NGS	90.2 ± 1.6	85.7 ± 1.0	91.7 ± 1.3	20.4 ± 37.2
DeepProbLog	90.8 ± 1.3	85.6 ± 1.1	timeout	timeout
DeepStochLog	90.8 ± 1.0	86.3 ± 1.9	92.1 ± 1.4	94.8 ± 0.9

Conclusion

DeepStochLog is a new **neuro-symbolic logic framework** based on stochastic logic, which **scales better** than alternative frameworks, while still keeping it's **generality**.

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