Learning Sum-Product Networks

Master's Dissertation

Student: Renato Lui Geh
Advisor: Prof. Dr. Denis Deratani Mauá

University of São Paulo (USP)

Institute of Mathematics and Statistics - USP

SPSAS 2019

Supported by CNPq Grant 133787/2019-2

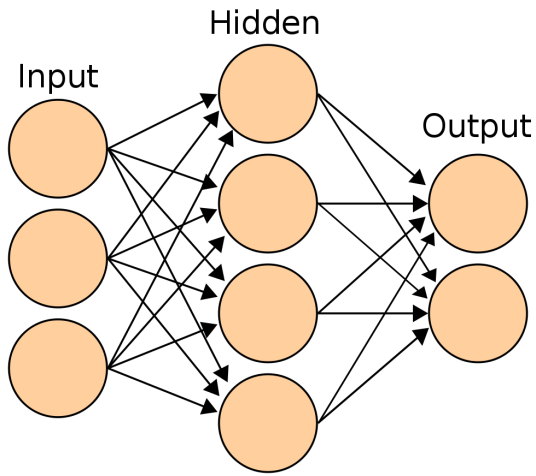
Motivation

What if you could have...

Contact: Renato Geh (renatolg@ime.usp.br)

Motivation

What if you could have...

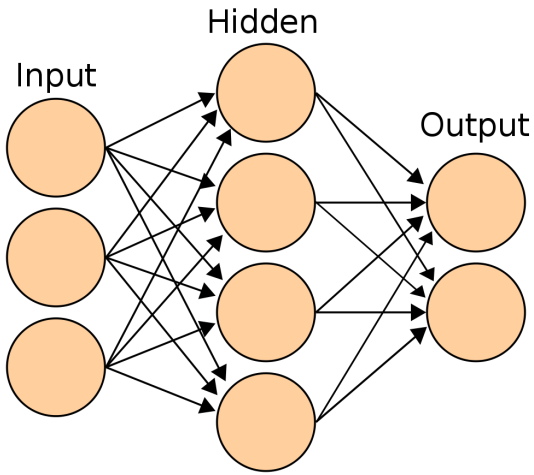


The expressivity and toolset of neural networks...

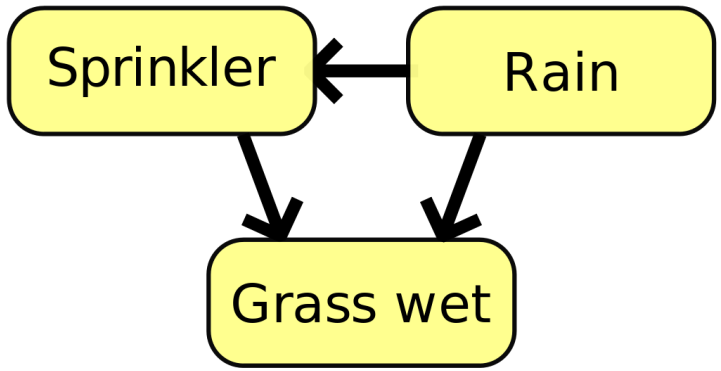
Contact: Renato Geh (renatolg@ime.usp.br)

Motivation

What if you could have...



The expressivity and toolset of neural networks...

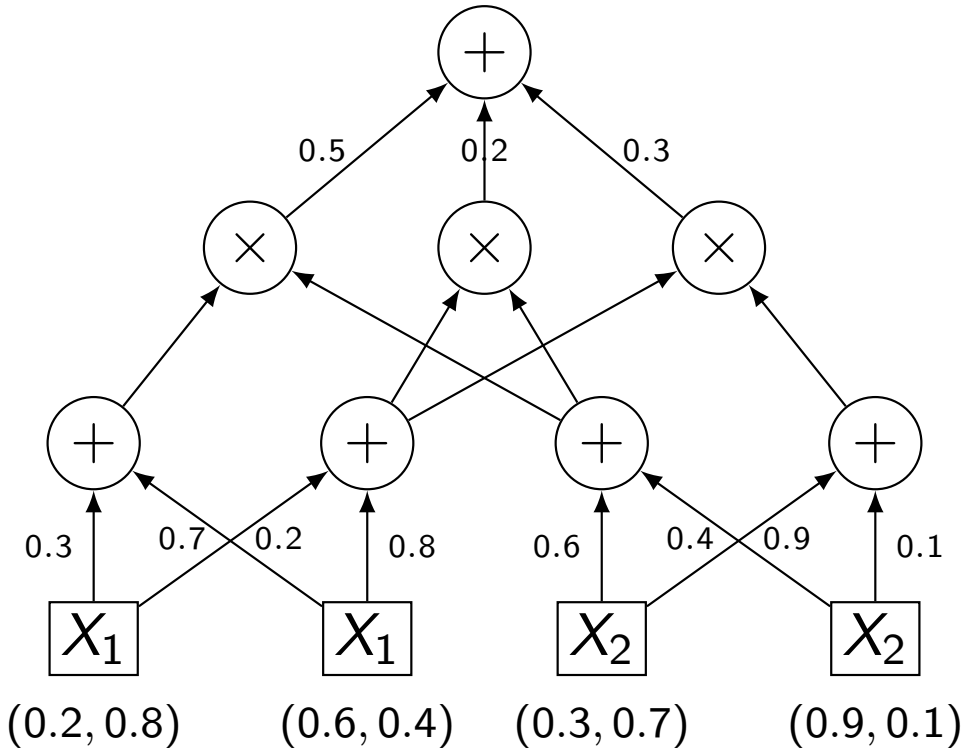


... and the interpretability and probabilistic semantics of PGMs.

Contact: Renato Geh (renatolg@ime.usp.br)

Sum-Product Network (SPN)

Sum-product networks (SPNs) are density estimators with a deep architecture.



Learning SPNs

Structure

- Poon dense architecture
- LearnSPN
- Clustering architecture
- Random-Tensorized SPNs
- ID-SPNs
- SPNs + Chow-Liu Trees

Parameter

- Gradient descent;
- Expectation-Maximization;
- Extended Baum-Welch;
- Collapsed Variational Inference;
- Concave-convex procedure;
- Bayesian Moment Matching.

Contact: Renato Geh (renatolg@ime.usp.br)

Some results

Not quite there yet on the discriminative side...

MNIST classification accuracy results

LearnSPN	ID-SPN	SPN-SVD	DSPN-SVD
81.8%	84.4%	85%	97.6%

SPN-TH	RAT-SPN	Prometheus	DC-SPN
98.34%	98.19%	98.37%	99.19%

...but gradually getting better.

More results

SPNs shine on generative tasks!

Figure: Image reconstruction

Applications

SPNs have reached incredible results in different fields:

- Image segmentation, classification and completion
- Protein folding
- Speech recognition
- Natural language processing
- Semantic mapping and control in robotics
- Activity recognition
- Semantic Web

Contact: Renato Geh (renatolg@ime.usp.br)

Thank you!

Contact: Renato Geh (renatolg@ime.usp.br)

References I


Darwiche, Adnan (May 2003). "A Differential Approach to Inference in Bayesian Networks". In: *J. ACM* 50.3, pp. 280–305. ISSN: 0004-5411. DOI: 10.1145/765568.765570. URL: http://doi.acm.org/10.1145/765568.765570.


Dennis, Aaron and Dan Ventura (2012). "Learning the Architecture of Sum-Product Networks Using Clustering on Variables". In: *Advances in Neural Information Processing Systems* 25.


Gens, Robert and Pedro Domingos (2012). "Discriminative Learning of Sum-Product Networks". In: *Advances in Neural Information Processing Systems 25 (NIPS 2012)*.


– (2013). "Learning the Structure of Sum-Product Networks". In: *International Conference on Machine Learning* 30.

References II


Peharz, R. et al. (2018). "Probabilistic Deep Learning using Random Sum-Product Networks". In: *ArXiv e-prints*.


Poon, Hoifung and Pedro Domingos (2011). "Sum-Product Networks: A New Deep Architecture". In: *Uncertainty in Artificial Intelligence 27*.


Rashwan, Abdullah, Pascal Poupart, and Chen Zhitang (2018). "Discriminative Training of Sum-Product Networks by Extended Baum-Welch". In: *Proceedings of the Ninth International Conference on Probabilistic Graphical Models*. Vol. 72. Proceedings of Machine Learning Research, pp. 356–367.

Contact: Renato Geh (renatolg@ime.usp.br)

References III


Rashwan, Abdullah, Han Zhao, and Pascal Poupart (Sept. 2016). "Online and Distributed Bayesian Moment Matching for Parameter Learning in Sum-Product Networks". In: *Proceedings of the 19th International Conference on Artificial Intelligence and Statistics*. Ed. by Arthur Gretton and Christian C. Robert. Vol. 51. Proceedings of Machine Learning Research. Cadiz, Spain: PMLR, pp. 1469–1477. URL: http://proceedings.mlr.press/v51/rashwan16.html.


Rooshenas, Amirmohammad and Daniel Lowd (2014). "Learning Sum-Product Networks with Direct and Indirect Variable Interactions". In: *International Conference on Machine Learning 31 (ICML 2014)*.

References IV


Vergari, Antonio, Nicola di Mauro, and Floriana Esposito (2015). "Simplifying, Regularizing and Strengthening Sum-Product Network Structure Learning". In: *European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECMLPKDD 2015)*.


Zhao, Han, Tameem Adel, et al. (20–22 Jun 2016). "Collapsed Variational Inference for Sum-Product Networks". In: *Proceedings of The 33rd International Conference on Machine Learning*. Ed. by Maria Florina Balcan and Kilian Q. Weinberger. Vol. 48. Proceedings of Machine Learning Research. New York, New York, USA: PMLR, pp. 1310–1318. URL: http://proceedings.mlr.press/v48/zhaoa16.html.

References V

Zhao, Han, Pascal Poupart, and Geoffrey J Gordon (2016). "A Unified Approach for Learning the Parameters of Sum-Product Networks". In: *Advances in Neural Information Processing Systems 29*. Ed. by D. D. Lee et al. Curran Associates, Inc., pp. 433–441. URL: http://papers.nips.cc/paper/6423-a-unified-approach-for-learning-the-parameters-of-sum-product-networks.pdf.

