Bibliography

Abadi, M., Agarwal, A., Barham, P., Brevdo, E., Chen, Z., Citro, C., Corrado, G. S., Davis, A., Dean, J., Devin, M., Ghemawat, S., Goodfellow, I., Harp, A., Irving, G., Isard, M., Jia, Y., Jozefowicz, R., Kaiser, L., Kudlur, M., Levenberg, J., Mané, D., Monga, R., Moore, S., Murray, D., Olah, C., Schuster, M., Shlens, J., Steiner, B., Sutskever, I., Talwar, K., Tucker, P., Vanhoucke, V., Vasudevan, V., Viégas, F., Vinyals, O., Warden, P., Wattenberg, M., Wicke, M., Yu, Y., and Zheng, X. (2015). TensorFlow: Large-scale machine learning on heterogeneous systems. Software available from tensorflow.org. 185, 387

Ackley, D. H., Hinton, G. E., and Sejnowski, T. J. (1985). A learning algorithm for Boltzmann machines. *Cognitive Science*, **9**, 147–169. 576

Alain, G. and Bengio, Y. (2012). What regularized auto-encoders learn from the data generating distribution. Technical Report Arxiv report 1211.4246, Université de Montréal. 449

Alain, G. and Bengio, Y. (2013). What regularized auto-encoders learn from the data generating distribution. In *ICLR'2013*. also arXiv report 1211.4246. 432, 449, 451

Alain, G., Bengio, Y., Yao, L., Éric Thibodeau-Laufer, Yosinski, J., and Vincent, P. (2015). GSNs: Generative stochastic networks. arXiv:1503.05571. 435, 627

Anderson, E. (1935). The Irises of the Gaspe Peninsula. *Bulletin of the American Iris Society*, **59**, 2–5. 19

Ba, J., Mnih, V., and Kavukcuoglu, K. (2014). Multiple object recognition with visual attention. *arXiv:1412.7755*. 191

Bachman, P. and Precup, D. (2015). Variational generative stochastic networks with collaborative shaping. In *Proceedings of the 32nd International Conference on Machine Learning, ICML 2015, Lille, France, 6-11 July 2015*, pages 1964–1972. 630

Bagnell, J. A. and Bradley, D. M. (2009). Differentiable sparse coding. In *NIPS'08*, pages 113–120. 443

Bahdanau, D., Cho, K., and Bengio, Y. (2014). Neural machine translation by jointly learning to align and translate. Technical report, arXiv:1409.0473. 22, 93, 347, 362, 404, 413, 414

Bahl, L. R., Brown, P., de Souza, P. V., and Mercer, R. L. (1987). Speech recognition with continuous-parameter hidden Markov models. *Computer, Speech and Language*, **2**, 219–234. 398

Baldi, P. and Hornik, K. (1989). Neural networks and principal component analysis: Learning from examples without local minima. *Neural Networks*, **2**, 53–58. 249

Baldi, P., Brunak, S., Frasconi, P., Soda, G., and Pollastri, G. (1999). Exploiting the past and the future in protein secondary structure prediction. *Bioinformatics*, **15**(11), 937–946. 344

Baldi, P., Sadowski, P., and Whiteson, D. (2014). Searching for exotic particles in high-energy physics with deep learning. *Nature communications*, **5**. 23

Barron, A. E. (1993). Universal approximation bounds for superpositions of a sigmoidal function. *IEEE Trans. on Information Theory*, **39**, 930–945. 192

Bartholomew, D. J. (1987). *Latent variable models and factor analysis*. Oxford University Press. 436

Basilevsky, A. (1994). *Statistical Factor Analysis and Related Methods: Theory and Applications*. Wiley. 436

Bastien, F., Lamblin, P., Pascanu, R., Bergstra, J., Goodfellow, I. J., Bergeron, A., Bouchard, N., and Bengio, Y. (2012). Theano: new features and speed improvements. Deep Learning and Unsupervised Feature Learning NIPS 2012 Workshop. 76, 185, 387

Basu, S. and Christensen, J. (2013). Teaching classification boundaries to humans. In *AAAI'2013*. 292

Baxter, J. (1995). Learning internal representations. In *Proceedings of the 8th International Conference on Computational Learning Theory (COLT'95)*, pages 311–320, Santa Cruz, California. ACM Press. 236

Baydin, A. G., Pearlmutter, B. A., Radul, A. A., and Siskind, J. M. (2015). Automatic differentiation in machine learning: a survey. *arXiv preprint arXiv:1502.05767*. 183

Bayer, J. and Osendorfer, C. (2014). Learning stochastic recurrent networks. *arXiv preprint arXiv:1411.7610*. 235

Becker, S. and Hinton, G. (1992). A self-organizing neural network that discovers surfaces in random-dot stereograms. *Nature*, **355**, 161–163. 477

Behnke, S. (2001). Learning iterative image reconstruction in the neural abstraction pyramid. *Int. J. Computational Intelligence and Applications*, **1**(4), 427–438. 446

Beiu, V., Quintana, J. M., and Avedillo, M. J. (2003). Vlsi implementations of threshold logic-a comprehensive survey. *Neural Networks, IEEE Transactions on*, **14**(5), 1217–1243. 391

Belkin, M. and Niyogi, P. (2002). Laplacian eigenmaps and spectral techniques for embedding and clustering. In *NIPS'01*, Cambridge, MA. MIT Press. 465

Belkin, M. and Niyogi, P. (2003). Laplacian eigenmaps for dimensionality reduction and data representation. *Neural Computation*, **15**(6), 1373–1396. 152, 483

Bengio, S. and Bengio, Y. (2000a). Taking on the curse of dimensionality in joint distributions using neural networks. *IEEE Transactions on Neural Networks, special issue on Data Mining and Knowledge Discovery*, **11**(3), 550–557. 621

Bengio, S., Vinyals, O., Jaitly, N., and Shazeer, N. (2015). Scheduled sampling for sequence prediction with recurrent neural networks. Technical report, arXiv:1506.03099. 333

Bengio, Y. (1991). *Artificial Neural Networks and their Application to Sequence Recognition*. Ph.D. thesis, McGill University, (Computer Science), Montreal, Canada. 354

Bengio, Y. (2000). Gradient-based optimization of hyperparameters. *Neural Computation*, **12**(8), 1889–1900. 378

Bengio, Y. (2002). New distributed probabilistic language models. Technical Report 1215, Dept. IRO, Université de Montréal. 406

Bengio, Y. (2009). *Learning deep architectures for AI*. Now Publishers. 147, 193

Bengio, Y. (2013). Deep learning of representations: looking forward. In *Statistical Language and Speech Processing*, volume 7978 of *Lecture Notes in Computer Science*, pages 1–37. Springer, also in arXiv at http://arxiv.org/abs/1305.0445. 389

Bengio, Y. and Bengio, S. (2000b). Modeling high-dimensional discrete data with multi-layer neural networks. In *NIPS'99*, pages 400–406. MIT Press. 620, 621, 623, 624, 625

Bengio, Y. and Delalleau, O. (2009). Justifying and generalizing contrastive divergence. *Neural Computation*, **21**(6), 1601–1621. 449, 535, 585

Bengio, Y. and Grandvalet, Y. (2004). No unbiased estimator of the variance of k-fold cross-validation. In *NIPS'03*, Cambridge, MA. MIT Press, Cambridge. 112

Bengio, Y. and LeCun, Y. (2007a). Scaling learning algorithms towards AI. In L. Bottou, O. Chapelle, D. DeCoste, and J. Weston, editors, *Large Scale Kernel Machines*. MIT Press. 17, 196

Bengio, Y. and LeCun, Y. (2007b). Scaling learning algorithms towards AI. In *Large Scale Kernel Machines*. 147

Bengio, Y. and Monperrus, M. (2005). Non-local manifold tangent learning. In *NIPS'04*, pages 129–136. MIT Press. 148, 483

Bengio, Y. and Sénécal, J.-S. (2003). Quick training of probabilistic neural nets by importance sampling. In *Proceedings of AISTATS 2003*. 409

Bengio, Y. and Sénécal, J.-S. (2008). Adaptive importance sampling to accelerate training of a neural probabilistic language model. *IEEE Trans. Neural Networks*, **19**(4), 713–722. 409

Bengio, Y., De Mori, R., Flammia, G., and Kompe, R. (1991). Phonetically motivated acoustic parameters for continuous speech recognition using artificial neural networks. In *Proceedings of EuroSpeech'91*. 24, 398

Bengio, Y., De Mori, R., Flammia, G., and Kompe, R. (1992). Neural network - gaussian mixture hybrid for speech recognition or density estimation. In *NIPS 4*, pages 175–182. Morgan Kaufmann. 398

Bengio, Y., Frasconi, P., and Simard, P. (1993). The problem of learning long-term dependencies in recurrent networks. In *IEEE International Conference on Neural Networks*, pages 1183–1195, San Francisco. IEEE Press. (invited paper). 254, 363

Bengio, Y., Simard, P., and Frasconi, P. (1994). Learning long-term dependencies with gradient descent is difficult. *IEEE Tr. Neural Nets*. 254, 255, 256, 351, 359, 363

Bengio, Y., Latendresse, S., and Dugas, C. (1999). Gradient-based learning of hyper-parameters. Learning Conference, Snowbird. 378

Bengio, Y., Ducharme, R., and Vincent, P. (2001a). A neural probabilistic language model. In *NIPS'00*, pages 932–938. MIT Press. 16, 388, 405

Bengio, Y., Ducharme, R., and Vincent, P. (2001b). A neural probabilistic language model. In *NIPS'2000*, pages 932–938. 400, 411, 422

Bengio, Y., Ducharme, R., and Vincent, P. (2001c). A neural probabilistic language model. In T. K. Leen, T. G. Dietterich, and V. Tresp, editors, *NIPS'2000*, pages 932–938. MIT Press. 484

Bengio, Y., Ducharme, R., Vincent, P., and Jauvin, C. (2003a). A neural probabilistic language model. *JMLR*, **3**, 1137–1155. 401, 405, 411

Bengio, Y., Ducharme, R., Vincent, P., and Jauvin, C. (2003b). A neural probabilistic language model. *Journal of Machine Learning Research*, **3**, 1137–1155. 484

Bengio, Y., Le Roux, N., Vincent, P., Delalleau, O., and Marcotte, P. (2006a). Convex neural networks. In *NIPS'2005*, pages 123–130. 232

Bengio, Y., Delalleau, O., and Le Roux, N. (2006b). The curse of highly variable functions for local kernel machines. In *NIPS'2005*. 147

Bengio, Y., Larochelle, H., and Vincent, P. (2006c). Non-local manifold Parzen windows. In *NIPS'2005*. MIT Press. 148, 482

Bengio, Y., Lamblin, P., Popovici, D., and Larochelle, H. (2007a). Greedy layer-wise training of deep networks. In *NIPS'2006*. 12, 16, 456, 458

Bengio, Y., Lamblin, P., Popovici, D., and Larochelle, H. (2007b). Greedy layer-wise training of deep networks. In *NIPS 19*, pages 153–160. MIT Press. 193, 287, 288

Bengio, Y., Louradour, J., Collobert, R., and Weston, J. (2009). Curriculum learning. In *ICML'09*. 292

Bengio, Y., Mesnil, G., Dauphin, Y., and Rifai, S. (2013a). Better mixing via deep representations. In *ICML'2013*. 529

Bengio, Y., Léonard, N., and Courville, A. (2013b). Estimating or propagating gradients through stochastic neurons for conditional computation. arXiv:1308.3432. 188, 191, 389

Bengio, Y., Yao, L., Alain, G., and Vincent, P. (2013c). Generalized denoising auto-encoders as generative models. In *NIPS'2013*. 451, 625, 628

Bengio, Y., Courville, A., and Vincent, P. (2013d). Representation learning: A review and new perspectives. *IEEE Trans. Pattern Analysis and Machine Intelligence (PAMI)*, **35**(8), 1798–1828. 475, 476, 614

Bengio, Y., Thibodeau-Laufer, E., Alain, G., and Yosinski, J. (2014). Deep generative stochastic networks trainable by backprop. In *ICML'2014*. 626, 627, 628, 629

Bennett, C. (1976). Efficient estimation of free energy differences from Monte Carlo data. *Journal of Computational Physics*, **22**(2), 245–268. 552

Bennett, J. and Lanning, S. (2007). The Netflix prize. 419

Berger, A. L., Della Pietra, V. J., and Della Pietra, S. A. (1996). A maximum entropy approach to natural language processing. *Computational Linguistics*, **22**, 39–71. 412

Berglund, M. and Raiko, T. (2013). Stochastic gradient estimate variance in contrastive divergence and persistent contrastive divergence. *CoRR*, **abs/1312.6002**. 539

Bergstra, J. (2011). *Incorporating Complex Cells into Neural Networks for Pattern Classification*. Ph.D. thesis, Université de Montréal. 230

Bergstra, J. and Bengio, Y. (2009). Slow, decorrelated features for pretraining complex cell-like networks. In *NIPS'2009*. 439

Bergstra, J. and Bengio, Y. (2012). Random search for hyper-parameter optimization. *J. Machine Learning Res.*, **13**, 281–305. 377, 378

Bergstra, J., Breuleux, O., Bastien, F., Lamblin, P., Pascanu, R., Desjardins, G., Turian, J., Warde-Farley, D., and Bengio, Y. (2010a). Theano: a CPU and GPU math expression compiler. In *Proceedings of the Python for Scientific Computing Conference (SciPy)*. Oral Presentation. 76, 387

Bergstra, J., Breuleux, O., Bastien, F., Lamblin, P., Pascanu, R., Desjardins, G., Turian, J., Warde-Farley, D., and Bengio, Y. (2010b). Theano: a CPU and GPU math expression compiler. In *Proc. SciPy*. 185, 186

Bergstra, J., Bardenet, R., Bengio, Y., and Kégl, B. (2011). Algorithms for hyper-parameter optimization. In *NIPS'2011*. 379

Berkes, P. and Wiskott, L. (2005). Slow feature analysis yields a rich repertoire of complex cell properties. *Journal of Vision*, **5**(6), 579–602. 440

Bertsekas, D. P. (2004). *Nonlinear programming*. Athena Scientific, 2 edition. 258

Bertsekas, D. P. and Tsitsiklis, J. (1996). *Neuro-Dynamic Programming*. Athena Scientific. 98

Besag, J. (1975). Statistical analysis of non-lattice data. *The Statistician*, **24**(3), 179–195. 540

Bishop, C. M. (1994). Mixture density networks. 170

Bishop, C. M. (1995a). Regularization and complexity control in feed-forward networks. In *Proceedings International Conference on Artificial Neural Networks ICANN'95*, volume 1, page 141–148. 217, 225

Bishop, C. M. (1995b). Training with noise is equivalent to Tikhonov regularization. *Neural Computation*, **7**(1), 108–116. 217

Bishop, C. M. (2006). *Pattern Recognition and Machine Learning*. Springer. 91, 137

Blum, A. L. and Rivest, R. L. (1992). Training a 3-node neural network is np-complete. 256

Blumer, A., Ehrenfeucht, A., Haussler, D., and Warmuth, M. K. (1989). Learnability and the vapnik–chervonenkis dimension. *Journal of the ACM*, **36**(4), 929—865. 105

Bonnet, G. (1964). Transformations des signaux aléatoires à travers les systèmes non linéaires sans mémoire. *Annales des Télécommunications*, **19**(9–10), 203–220. 188

Bordes, A., Weston, J., Collobert, R., and Bengio, Y. (2011). Learning structured embeddings of knowledge bases. In *AAAI 2011*. 423

Bordes, A., Glorot, X., Weston, J., and Bengio, Y. (2012). Joint learning of words and meaning representations for open-text semantic parsing. *AISTATS'2012*. 351, 423, 424

Bordes, A., Glorot, X., Weston, J., and Bengio, Y. (2013a). A semantic matching energy function for learning with multi-relational data. *Machine Learning: Special Issue on Learning Semantics*. 423

Bordes, A., Usunier, N., Garcia-Duran, A., Weston, J., and Yakhnenko, O. (2013b). Translating embeddings for modeling multi-relational data. In C. Burges, L. Bottou, M. Welling, Z. Ghahramani, and K. Weinberger, editors, *Advances in Neural Information Processing Systems 26*, pages 2787–2795. Curran Associates, Inc. 423

Bornschein, J. and Bengio, Y. (2015). Reweighted wake-sleep. In *ICLR'2015, arXiv:1406.2751*. 611

Bornschein, J., Shabanian, S., Fischer, A., and Bengio, Y. (2015). Training bidirectional Helmholtz machines. Technical report, arXiv:1506.03877. 611

Boser, B. E., Guyon, I. M., and Vapnik, V. N. (1992). A training algorithm for optimal margin classifiers. In *COLT '92: Proceedings of the fifth annual workshop on Computational learning theory*, pages 144–152, New York, NY, USA. ACM. 16, 133, 162

Bottou, L. (1998). Online algorithms and stochastic approximations. In D. Saad, editor, *Online Learning in Neural Networks*. Cambridge University Press, Cambridge, UK. 259

Bottou, L. (2011). From machine learning to machine reasoning. Technical report, arXiv.1102.1808. 349, 351

Bottou, L. (2015). Multilayer neural networks. Deep Learning Summer School. 383

Bottou, L. and Bousquet, O. (2008). The tradeoffs of large scale learning. In *NIPS'2008*. 246, 258, 260

Boulanger-Lewandowski, N., Bengio, Y., and Vincent, P. (2012). Modeling temporal dependencies in high-dimensional sequences: Application to polyphonic music generation and transcription. In *ICML'12*. 415

Boureau, Y., Ponce, J., and LeCun, Y. (2010). A theoretical analysis of feature pooling in vision algorithms. In *Proc. International Conference on Machine learning (ICML'10)*. 305

Boureau, Y., Le Roux, N., Bach, F., Ponce, J., and LeCun, Y. (2011). Ask the locals: multi-way local pooling for image recognition. In *Proc. International Conference on Computer Vision (ICCV'11)*. IEEE. 305

Bourlard, H. and Kamp, Y. (1988). Auto-association by multilayer perceptrons and singular value decomposition. *Biological Cybernetics*, **59**, 291–294. 429

Bourlard, H. and Wellekens, C. (1989). Speech pattern discrimination and multi-layered perceptrons. *Computer Speech and Language*, **3**, 1–19. 398

Boyd, S. and Vandenberghe, L. (2004). *Convex Optimization*. Cambridge University Press, New York, NY, USA. 86

Brady, M. L., Raghavan, R., and Slawny, J. (1989). Back-propagation fails to separate where perceptrons succeed. *IEEE Transactions on Circuits and Systems*, **36**, 665–674. 248

Brakel, P., Stroobandt, D., and Schrauwen, B. (2013). Training energy-based models for time-series imputation. *Journal of Machine Learning Research*, **14**, 2771–2797. 602, 614

Brand, M. (2003). Charting a manifold. In *NIPS'2002*, pages 961–968. MIT Press. 152, 483

Breiman, L. (1994). Bagging predictors. *Machine Learning*, **24**(2), 123–140. 230

Breiman, L., Friedman, J. H., Olshen, R. A., and Stone, C. J. (1984). *Classification and Regression Trees*. Wadsworth International Group, Belmont, CA. 137

Bridle, J. S. (1990). Alphanets: a recurrent 'neural' network architecture with a hidden Markov model interpretation. *Speech Communication*, **9**(1), 83–92. 165

Briggman, K., Denk, W., Seung, S., Helmstaedter, M. N., and Turaga, S. C. (2009). Maximin affinity learning of image segmentation. In *NIPS'2009*, pages 1865–1873. 314

Brown, P. F., Cocke, J., Pietra, S. A. D., Pietra, V. J. D., Jelinek, F., Lafferty, J. D., Mercer, R. L., and Roossin, P. S. (1990). A statistical approach to machine translation. *Computational linguistics*, **16**(2), 79–85. 19

Brown, P. F., Pietra, V. J. D., DeSouza, P. V., Lai, J. C., and Mercer, R. L. (1992). Class-based n-gram models of natural language. *Computational Linguistics*, **18**, 467–479. 403

Bryson, A. and Ho, Y. (1969). *Applied optimal control: optimization, estimation, and control*. Blaisdell Pub. Co. 199

Bryson, Jr., A. E. and Denham, W. F. (1961). A steepest-ascent method for solving optimum programming problems. Technical Report BR-1303, Raytheon Company, Missle and Space Division. 199

Buchberger, B., Collins, G. E., Loos, R., and Albrecht, R. (1983). *Computer Algebra*. Springer-Verlag. 186

Buciluă, C., Caruana, R., and Niculescu-Mizil, A. (2006). Model compression. In *Proceedings of the 12th ACM SIGKDD international conference on Knowledge discovery and data mining*, pages 535–541. ACM. 388

Cai, M., Shi, Y., and Liu, J. (2013). Deep maxout neural networks for speech recognition. In *Automatic Speech Recognition and Understanding (ASRU), 2013 IEEE Workshop on*, pages 291–296. IEEE. 198

Carreira-Perpiñan, M. A. and Hinton, G. E. (2005). On contrastive divergence learning. In R. G. Cowell and Z. Ghahramani, editors, *AISTATS'2005*, pages 33–40. Society for Artificial Intelligence and Statistics. 535, 585

Caruana, R. (1993). Multitask connectionist learning. In *Proc. 1993 Connectionist Models Summer School*, pages 372–379. 236

Cauchy, A. (1847). Méthode générale pour la résolution de systèmes d'équations simultanées. In *Compte rendu des séances de l'académie des sciences*, pages 536–538. 78, 199

Cayton, L. (2005). Algorithms for manifold learning. Technical Report CS2008-0923, UCSD. 152, 478

Chapelle, O., Weston, J., and Schölkopf, B. (2003). Cluster kernels for semi-supervised learning. In *NIPS'02*, pages 585–592, Cambridge, MA. MIT Press. 465

Chapelle, O., Schölkopf, B., and Zien, A., editors (2006). *Semi-Supervised Learning*. MIT Press, Cambridge, MA. 465

Chellapilla, K., Puri, S., and Simard, P. (2006). High Performance Convolutional Neural Networks for Document Processing. In Guy Lorette, editor, *Tenth International Workshop on Frontiers in Handwriting Recognition*, La Baule (France). Université de Rennes 1, Suvisoft. http://www.suvisoft.com. 21, 24, 386

Chen, S. F. and Goodman, J. T. (1999). An empirical study of smoothing techniques for language modeling. *Computer, Speech and Language*, **13**(4), 359–393. 401, 402, 412

Chen, T., Du, Z., Sun, N., Wang, J., Wu, C., Chen, Y., and Temam, O. (2014a). Diannao: A small-footprint high-throughput accelerator for ubiquitous machine-learning. In *Proceedings of the 19th international conference on Architectural support for programming languages and operating systems*, pages 269–284. ACM. 391

Chen, Y., Luo, T., Liu, S., Zhang, S., He, L., Wang, J., Li, L., Chen, T., Xu, Z., Sun, N., *et al.* (2014b). Dadiannao: A machine-learning supercomputer. In *Microarchitecture (MICRO), 2014 47th Annual IEEE/ACM International Symposium on*, pages 609–622. IEEE. 391

Chilimbi, T., Suzue, Y., Apacible, J., and Kalyanaraman, K. (2014). Project adam: Building an efficient and scalable deep learning training system. In *11th USENIX Symposium on Operating Systems Design and Implementation (OSDI'14)*. 388

Cho, K., van Merrienboer, B., Gulcehre, C., Bougares, F., Schwenk, H., and Bengio, Y. (2014a). Learning phrase representations using RNN encoder-decoder for statistical machine translation. In *Proceedings of the Empiricial Methods in Natural Language Processing (EMNLP 2014)*. 339, 345, 359, 413, 414

Cho, K., Van Merriënboer, B., Bahdanau, D., and Bengio, Y. (2014b). On the properties of neural machine translation: Encoder-decoder approaches. *ArXiv e-prints*, **abs/1409.1259**. 359

Choromanska, A., Henaff, M., Mathieu, M., Arous, G. B., and LeCun, Y. (2014). The loss surface of multilayer networks. 248, 250

Chorowski, J., Bahdanau, D., Cho, K., and Bengio, Y. (2014). End-to-end continuous speech recognition using attention-based recurrent nn: First results. arXiv:1412.1602. 399

Christianson, B. (1992). Automatic hessians by reverse accumulation. *IMA Journal of Numerical Analysis*, **12**(2), 135–150. 186

Chrupala, G., Kadar, A., and Alishahi, A. (2015). Learning language through pictures. arXiv 1506.03694. 359

Chung, J., Gulcehre, C., Cho, K., and Bengio, Y. (2014). Empirical evaluation of gated recurrent neural networks on sequence modeling. NIPS'2014 Deep Learning workshop, arXiv 1412.3555. 359, 399

Chung, J., Gülçehre, Ç., Cho, K., and Bengio, Y. (2015). Gated feedback recurrent neural networks. In *ICML'15*. 359

Ciresan, D., Meier, U., Masci, J., and Schmidhuber, J. (2012). Multi-column deep neural network for traffic sign classification. *Neural Networks*, **32**, 333–338. 22, 193

Ciresan, D. C., Meier, U., Gambardella, L. M., and Schmidhuber, J. (2010). Deep big simple neural nets for handwritten digit recognition. *Neural Computation*, **22**, 1–14. 21, 24, 386

Coates, A. and Ng, A. Y. (2011). The importance of encoding versus training with sparse coding and vector quantization. In *ICML'2011*. 24, 443

Coates, A., Lee, H., and Ng, A. Y. (2011). An analysis of single-layer networks in unsupervised feature learning. In *Proceedings of the Thirteenth International Conference on Artificial Intelligence and Statistics (AISTATS 2011)*. 395

Coates, A., Huval, B., Wang, T., Wu, D., Catanzaro, B., and Andrew, N. (2013). Deep learning with cots hpc systems. In S. Dasgupta and D. McAllester, editors, *Proceedings of the 30th International Conference on Machine Learning (ICML-13)*, volume 28 (3), pages 1337–1345. JMLR Workshop and Conference Proceedings. 21, 24, 318, 388

Collobert, R. (2004). *Large Scale Machine Learning*. Ph.D. thesis, Université de Paris VI, LIP6. 162

Collobert, R. (2011). Deep learning for efficient discriminative parsing. In *AISTATS'2011*. 94

Collobert, R. and Weston, J. (2008). A unified architecture for natural language processing: Deep neural networks with multitask learning. In *ICML'2008*. 410

Collobert, R., Bengio, S., and Bengio, Y. (2001). A parallel mixture of SVMs for very large scale problems. Technical Report IDIAP-RR-01-12, IDIAP. 390

Collobert, R., Bengio, S., and Bengio, Y. (2002). Parallel mixture of SVMs for very large scale problems. *Neural Computation*, **14**(5), 1105–1114. 390

Collobert, R., Weston, J., Bottou, L., Karlen, M., Kavukcuoglu, K., and Kuksa, P. (2011a). Natural language processing (almost) from scratch. *Journal of Machine Learning Research*, **12**, 2493–2537. 292

Collobert, R., Kavukcuoglu, K., and Farabet, C. (2011b). Torch7: A matlab-like environment for machine learning. In *BigLearn, NIPS Workshop*. 184, 387

Comon, P. (1994). Independent component analysis - a new concept? *Signal Processing*, **36**, 287–314. 437

Cortes, C. and Vapnik, V. (1995). Support vector networks. *Machine Learning*, **20**, 273–297. 16, 133

Couprie, C., Farabet, C., Najman, L., and LeCun, Y. (2013). Indoor semantic segmentation using depth information. In *International Conference on Learning Representations (ICLR2013)*. 22, 193

Courbariaux, M., Bengio, Y., and David, J.-P. (2015). Low precision arithmetic for deep learning. In *Arxiv:1412.7024, ICLR'2015 Workshop*. 392

Courville, A., Bergstra, J., and Bengio, Y. (2011). Unsupervised models of images by spike-and-slab RBMs. In *ICML'11*. 496, 606

Courville, A., Desjardins, G., Bergstra, J., and Bengio, Y. (2014). The spike-and-slab RBM and extensions to discrete and sparse data distributions. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, **36**(9), 1874–1887. 607

Cover, T. M. and Thomas, J. A. (2006). *Elements of Information Theory, 2nd Edition*. Wiley-Interscience. 65

Cox, D. and Pinto, N. (2011). Beyond simple features: A large-scale feature search approach to unconstrained face recognition. In *Automatic Face & Gesture Recognition and Workshops (FG 2011), 2011 IEEE International Conference on*, pages 8–15. IEEE. 317

Cramér, H. (1946). *Mathematical methods of statistics*. Princeton University Press. 125, 260

Crick, F. H. C. and Mitchison, G. (1983). The function of dream sleep. *Nature*, **304**, 111–114. 533

Cybenko, G. (1989). Approximation by superpositions of a sigmoidal function. *Mathematics of Control, Signals, and Systems*, **2**, 303–314. 191, 473

Dahl, G. E., Ranzato, M., Mohamed, A., and Hinton, G. E. (2010). Phone recognition with the mean-covariance restricted Boltzmann machine. In *NIPS'2010*. 22

Dahl, G. E., Yu, D., Deng, L., and Acero, A. (2012). Context-dependent pre-trained deep neural networks for large vocabulary speech recognition. *IEEE Transactions on Audio, Speech, and Language Processing*, **20**(1), 33–42. 398

Dahl, G. E., Jaitly, N., and Salakhutdinov, R. (2014). Multi-task neural networks for QSAR predictions. arXiv:1406.1231. 23

Dauphin, Y. and Bengio, Y. (2013). Stochastic ratio matching of RBMs for sparse high-dimensional inputs. In *NIPS26*. NIPS Foundation. 543

Dauphin, Y., Glorot, X., and Bengio, Y. (2011). Large-scale learning of embeddings with reconstruction sampling. In *ICML'2011*. 410

Dauphin, Y., Pascanu, R., Gulcehre, C., Cho, K., Ganguli, S., and Bengio, Y. (2014). Identifying and attacking the saddle point problem in high-dimensional non-convex optimization. In *NIPS'2014*. 248, 249, 250

Davis, A., Rubinstein, M., Wadhwa, N., Mysore, G., Durand, F., and Freeman, W. T. (2014). The visual microphone: Passive recovery of sound from video. *ACM Transactions on Graphics (Proc. SIGGRAPH)*, **33**(4), 79:1–79:10. 392

Dayan, P. (1990). Reinforcement comparison. In *Connectionist Models: Proceedings of the 1990 Connectionist Summer School*, San Mateo, CA. 191

Dayan, P., Hinton, G. E., Neal, R. M., and Zemel, R. S. (1995). The Helmholtz machine. *Neural computation*, **7**(5), 889–904. 611

Dean, J., Corrado, G., Monga, R., Chen, K., Devin, M., Le, Q., Mao, M., Ranzato, M., Senior, A., Tucker, P., Yang, K., and Ng, A. Y. (2012). Large scale distributed deep networks. In *NIPS'2012*. 388

Delalleau, O. and Bengio, Y. (2011). Shallow vs. deep sum-product networks. In *NIPS*. 17, 193, 474

Deng, J., Dong, W., Socher, R., Li, L.-J., Li, K., and Fei-Fei, L. (2009). ImageNet: A Large-Scale Hierarchical Image Database. In *CVPR09*. 19, 140

Deng, J., Berg, A. C., Li, K., and Fei-Fei, L. (2010a). What does classifying more than 10,000 image categories tell us? In *Proceedings of the 11th European Conference on Computer Vision: Part V*, ECCV'10, pages 71–84, Berlin, Heidelberg. Springer-Verlag. 19

Deng, L. and Yu, D. (2014). Deep learning – methods and applications. *Foundations and Trends in Signal Processing*. 399

Deng, L., Seltzer, M., Yu, D., Acero, A., Mohamed, A., and Hinton, G. (2010b). Binary coding of speech spectrograms using a deep auto-encoder. In *Interspeech 2010*, Makuhari, Chiba, Japan. 22

Denton, E., Chintala, S., Szlam, A., and Fergus, R. (2015). Deep generative image models using a laplacian pyramid of adversarial networks. *NIPS*. 616, 617, 632

Desjardins, G. and Bengio, Y. (2008). Empirical evaluation of convolutional RBMs for vision. Technical Report 1327, Département d'Informatique et de Recherche Opérationnelle, Université de Montréal. 607

Desjardins, G., Courville, A., and Bengio, Y. (2011). On tracking the partition function. In *NIPS'2011*. 552

Devlin, J., Zbib, R., Huang, Z., Lamar, T., Schwartz, R., and Makhoul, J. (2014). Fast and robust neural network joint models for statistical machine translation. In *Proc. ACL'2014*. 412

Devroye, L. (2013). *Non-Uniform Random Variate Generation.* SpringerLink : Bücher. Springer New York. 612

DiCarlo, J. J. (2013). Mechanisms underlying visual object recognition: Humans vs. neurons vs. machines. NIPS Tutorial. 23, 320

Donahue, J., Hendricks, L. A., Guadarrama, S., Rohrbach, M., Venugopalan, S., Saenko, K., and Darrell, T. (2014). Long-term recurrent convolutional networks for visual recognition and description. arXiv:1411.4389. 94

Donoho, D. L. and Grimes, C. (2003). Hessian eigenmaps: new locally linear embedding techniques for high-dimensional data. Technical Report 2003-08, Dept. Statistics, Stanford University. 152, 483

Dosovitskiy, A., Tobias Springenberg, J., and Brox, T. (2015). Learning to generate chairs with convolutional neural networks. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pages 1538–1546. 613, 619

Doya, K. (1993). Bifurcations of recurrent neural networks in gradient descent learning. *IEEE Transactions on Neural Networks*, **1**, 75–80. 256, 351

Dreyfus, S. E. (1962). The numerical solution of variational problems. *Journal of Mathematical Analysis and Applications*, **5(1)**, 30–45. 199

Dreyfus, S. E. (1973). The computational solution of optimal control problems with time lag. *IEEE Transactions on Automatic Control*, **18(4)**, 383–385. 199

Drucker, H. and LeCun, Y. (1992). Improving generalisation performance using double back-propagation. *IEEE Transactions on Neural Networks*, **3**(6), 991–997. 491

Dudik, M., Langford, J., and Li, L. (2011). Doubly robust policy evaluation and learning. In *Proceedings of the 28th International Conference on Machine learning*, ICML '11. 421

Dugas, C., Bengio, Y., Bélisle, F., and Nadeau, C. (2001). Incorporating second-order functional knowledge for better option pricing. In *NIPS'00*, pages 472–478. MIT Press. 61, 162

Dziugaite, G. K., Roy, D. M., and Ghahramani, Z. (2015). Training generative neural networks via maximum mean discrepancy optimization. *arXiv preprint arXiv:1505.03906*. 618

El Hihi, S. and Bengio, Y. (1996). Hierarchical recurrent neural networks for long-term dependencies. In *NIPS 8*. MIT Press. 347, 349, 367

ElHihi, S. and Bengio, Y. (1996). Hierarchical recurrent neural networks for long-term dependencies. In *NIPS'1995*. 355

Elkahky, A. M., Song, Y., and He, X. (2015). A multi-view deep learning approach for cross domain user modeling in recommendation systems. In *Proceedings of the 24th International Conference on World Wide Web*, pages 278–288. 420

Elman, J. L. (1993). Learning and development in neural networks: The importance of starting small. *Cognition*, **48**, 781–799. 292

Erhan, D., Manzagol, P.-A., Bengio, Y., Bengio, S., and Vincent, P. (2009). The difficulty of training deep architectures and the effect of unsupervised pre-training. In *Proceedings of AISTATS'2009*. 193

Erhan, D., Bengio, Y., Courville, A., Manzagol, P., Vincent, P., and Bengio, S. (2010). Why does unsupervised pre-training help deep learning? *J. Machine Learning Res.* 457, 458, 459

Fang, H., Gupta, S., Iandola, F., Srivastava, R., Deng, L., Dollár, P., Gao, J., He, X., Mitchell, M., Platt, J. C., Zitnick, C. L., and Zweig, G. (2015). From captions to visual concepts and back. arXiv:1411.4952. 94

Farabet, C., LeCun, Y., Kavukcuoglu, K., Culurciello, E., Martini, B., Akselrod, P., and Talay, S. (2011). Large-scale FPGA-based convolutional networks. In R. Bekkerman, M. Bilenko, and J. Langford, editors, *Scaling up Machine Learning: Parallel and Distributed Approaches*. Cambridge University Press. 445

Farabet, C., Couprie, C., Najman, L., and LeCun, Y. (2013a). Learning hierarchical features for scene labeling. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 22, 193

Farabet, C., Couprie, C., Najman, L., and LeCun, Y. (2013b). Learning hierarchical features for scene labeling. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **35**(8), 1915–1929. 314

Fei-Fei, L., Fergus, R., and Perona, P. (2006). One-shot learning of object categories. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **28**(4), 594–611. 462

Fischer, A. and Igel, C. (2011). Bounding the bias of contrastive divergence learning. *Neural Computation*, **23**(3), 664–73. 585

Fisher, R. A. (1936). The use of multiple measurements in taxonomic problems. *Annals of Eugenics*, **7**, 179–188. 19, 97

Földiák, P. (1989). Adaptive network for optimal linear feature extraction. In *International Joint Conference on Neural Networks (IJCNN)*, volume 1, pages 401–405, Washington 1989. IEEE, New York. 439

Franzius, M., Sprekeler, H., and Wiskott, L. (????). Slowness and sparseness lead to place, head-direction, and spatial-view cells. 441

Franzius, M., Wilbert, N., and Wiskott, L. (2008). Invariant object recognition with slow feature analysis. In *Artificial Neural Networks-ICANN 2008*, pages 961–970. Springer. 441

Frasconi, P., Gori, M., and Sperduti, A. (1997). On the efficient classification of data structures by neural networks. In *Proc. Int. Joint Conf. on Artificial Intelligence*. 349, 351

Frasconi, P., Gori, M., and Sperduti, A. (1998). A general framework for adaptive processing of data structures. *IEEE Transactions on Neural Networks*, **9**(5), 768–786. 349, 351

Freund, Y. and Schapire, R. E. (1996a). Experiments with a new boosting algorithm. In *Machine Learning: Proceedings of Thirteenth International Conference*, pages 148–156, USA. ACM. 232

Freund, Y. and Schapire, R. E. (1996b). Game theory, on-line prediction and boosting. In *Proceedings of the Ninth Annual Conference on Computational Learning Theory*, pages 325–332. 232

Frey, B. J. (1998). *Graphical models for machine learning and digital communication*. MIT Press. 620, 621

Fukushima, K. (1975). Cognitron: A self-organizing multilayered neural network. *Biological Cybernetics*, **20**, 121–136. 456

Fukushima, K. (1980). Neocognitron: A self-organizing neural network model for a mechanism of pattern recognition unaffected by shift in position. *Biological Cybernetics*, **36**, 193–202. 14, 21, 24, 321

Gal, Y. and Ghahramani, Z. (2015). Bayesian convolutional neural networks with bernoulli approximate variational inference. *arXiv preprint arXiv:1506.02158*. 234

Gallinari, P., LeCun, Y., Thiria, S., and Fogelman-Soulie, F. (1987). Memoires associatives distribuees. In *Proceedings of COGNITIVA 87*, Paris, La Villette. 446

Garcia-Duran, A., Bordes, A., Usunier, N., and Grandvalet, Y. (2015). Combining two and three-way embeddings models for link prediction in knowledge bases. *arXiv preprint arXiv:1506.00999*. 423

Garofolo, J. S., Lamel, L. F., Fisher, W. M., Fiscus, J. G., and Pallett, D. S. (1993). Darpa timit acoustic-phonetic continous speech corpus cd-rom. nist speech disc 1-1.1. *NASA STI/Recon Technical Report N*, **93**, 27403. 398

Garson, J. (1900). The metric system of identification of criminals, as used in in great britain and ireland. *The Journal of the Anthropological Institute of Great Britain and Ireland*, (2), 177–227. 19

Gers, F. A., Schmidhuber, J., and Cummins, F. (2000). Learning to forget: Continual prediction with LSTM. *Neural computation*, **12**(10), 2451–2471. 360

Giudice, M. D., Manera, V., and Keysers, C. (2009). Programmed to learn? the ontogeny of mirror neurons. *Dev. Sci.*, **12**(2), 350—363. 579

Glorot, X. and Bengio, Y. (2010a). Understanding the difficulty of training deep feedforward neural networks. In *AISTATS'2010*. 161, 383

Glorot, X. and Bengio, Y. (2010b). Understanding the difficulty of training deep feedforward neural networks. In *JMLR W&CP: Proceedings of the Thirteenth International Conference on Artificial Intelligence and Statistics (AISTATS 2010)*, volume 9, pages 249–256. 283

Glorot, X., Bordes, A., and Bengio, Y. (2011a). Deep sparse rectifier neural networks. In *AISTATS'2011*. 14, 162

Glorot, X., Bordes, A., and Bengio, Y. (2011b). Deep sparse rectifier neural networks. In *JMLR W&CP: Proceedings of the Fourteenth International Conference on Artificial Intelligence and Statistics (AISTATS 2011)*. 197, 198

Glorot, X., Bordes, A., and Bengio, Y. (2011c). Domain adaptation for large-scale sentiment classification: A deep learning approach. In *ICML'2011*. 431, 461

Gong, S., McKenna, S., and Psarrou, A. (2000). *Dynamic Vision: From Images to Face Recognition*. Imperial College Press. 481, 483

Goodfellow, I., Le, Q., Saxe, A., and Ng, A. (2009). Measuring invariances in deep networks. In *NIPS'2009*, pages 646–654. 230

Goodfellow, I., Koenig, N., Muja, M., Pantofaru, C., Sorokin, A., and Takayama, L. (2010). Help me help you: Interfaces for personal robots. In *Proc. of Human Robot Interaction (HRI)*, Osaka, Japan. ACM Press, ACM Press. 92

Goodfellow, I., Courville, A., and Bengio, Y. (2012). Large-scale feature learning with spike-and-slab sparse coding. In *ICML'2012*. 443

Goodfellow, I. J. (2010). Technical report: Multidimensional, downsampled convolution for autoencoders. Technical report, Université de Montréal. 312

Goodfellow, I. J. (2014). On distinguishability criteria for estimating generative models. In *International Conference on Learning Representations, Workshops Track*. 546, 615

Goodfellow, I. J., Courville, A., and Bengio, Y. (2011). Spike-and-slab sparse coding for unsupervised feature discovery. In *NIPS Workshop on Challenges in Learning Hierarchical Models*. 193, 462

Goodfellow, I. J., Warde-Farley, D., Mirza, M., Courville, A., and Bengio, Y. (2013a). Maxout networks. In S. Dasgupta and D. McAllester, editors, *ICML'13*, pages 1319–1327. 198, 234, 319, 395

Goodfellow, I. J., Mirza, M., Courville, A., and Bengio, Y. (2013b). Multi-prediction deep Boltzmann machines. In *NIPS26*. NIPS Foundation. 93, 542, 600, 601, 602, 604, 614

Goodfellow, I. J., Courville, A., and Bengio, Y. (2013c). Scaling up spike-and-slab models for unsupervised feature learning. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **35**(8), 1902–1914. 572, 607

Goodfellow, I. J., Mirza, M., Xiao, D., Courville, A., and Bengio, Y. (2014a). An empirical investigation of catastrophic forgeting in gradient-based neural networks. In *ICLR'2014*. 198

Goodfellow, I. J., Shlens, J., and Szegedy, C. (2014b). Explaining and harnessing adversarial examples. *CoRR*, **abs/1412.6572**. 238

Goodfellow, I. J., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A., and Bengio, Y. (2014c). Generative adversarial networks. In *NIPS'2014*. 188, 614, 619

Goodfellow, I. J., Bulatov, Y., Ibarz, J., Arnoud, S., and Shet, V. (2014d). Multi-digit number recognition from Street View imagery using deep convolutional neural networks. In *International Conference on Learning Representations*. 22, 93, 193, 194, 195, 339, 390

Goodfellow, I. J., Vinyals, O., and Saxe, A. M. (2015). Qualitatively characterizing neural network optimization problems. In *International Conference on Learning Representations*. 248, 250

Goodman, J. (2001). Classes for fast maximum entropy training. In *International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, Utah. 406

Gori, M. and Tesi, A. (1992). On the problem of local minima in backpropagation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **PAMI-14**(1), 76–86. 248

Gosset, W. S. (1908). The probable error of a mean. *Biometrika*, **6**(1), 1–25. Originally published under the pseudonym "Student". 19

Gouws, S., Bengio, Y., and Corrado, G. (2014). Bilbowa: Fast bilingual distributed representations without word alignments. Technical report, arXiv:1410.2455. 414, 463

Graf, H. P. and Jackel, L. D. (1989). Analog electronic neural network circuits. *Circuits and Devices Magazine, IEEE*, **5**(4), 44–49. 391

Graves, A. (2011a). Practical variational inference for neural networks. In J. Shawe-Taylor, R. Zemel, P. Bartlett, F. Pereira, and K. Weinberger, editors, *Advances in Neural Information Processing Systems 24*, pages 2348–2356. Curran Associates, Inc. 216, 217

Graves, A. (2011b). Practical variational inference for neural networks. In *NIPS'2011*. 219

Graves, A. (2012). *Supervised Sequence Labelling with Recurrent Neural Networks*. Studies in Computational Intelligence. Springer. 327, 344, 356, 359, 399

Graves, A. (2013). Generating sequences with recurrent neural networks. Technical report, arXiv:1308.0850. 171, 345, 356, 358, 362, 366

Graves, A. and Jaitly, N. (2014). Towards end-to-end speech recognition with recurrent neural networks. In *ICML'2014*. 358

Graves, A. and Schmidhuber, J. (2005). Framewise phoneme classification with bidirectional LSTM and other neural network architectures. *Neural Networks*, **18**(5), 602–610. 344

Graves, A. and Schmidhuber, J. (2009). Offline handwriting recognition with multidimensional recurrent neural networks. In D. Koller, D. Schuurmans, Y. Bengio, and L. Bottou, editors, *NIPS'2008*, pages 545–552. 344

Graves, A., Fernández, S., Gomez, F., and Schmidhuber, J. (2006). Connectionist temporal classification: Labelling unsegmented sequence data with recurrent neural networks. In *ICML'2006*, pages 369–376, Pittsburgh, USA. 399

Graves, A., Liwicki, M., Bunke, H., Schmidhuber, J., and Fernández, S. (2008). Unconstrained on-line handwriting recognition with recurrent neural networks. In J. Platt, D. Koller, Y. Singer, and S. Roweis, editors, *NIPS'2007*, pages 577–584. 344

Graves, A., Liwicki, M., Fernández, S., Bertolami, R., Bunke, H., and Schmidhuber, J. (2009). A novel connectionist system for unconstrained handwriting recognition. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, **31**(5), 855–868. 358

Graves, A., Mohamed, A.-r., and Hinton, G. (2013). Speech recognition with deep recurrent neural networks. In *ICASSP'2013*, pages 6645–6649. 344, 347, 356, 358, 359, 399

Graves, A., Wayne, G., and Danihelka, I. (2014a). Neural Turing machines. arXiv:1410.5401. 23

Graves, A., Wayne, G., and Danihelka, I. (2014b). Neural turing machines. *arXiv preprint arXiv:1410.5401*. 361

Greff, K., Srivastava, R. K., Koutník, J., Steunebrink, B. R., and Schmidhuber, J. (2015). LSTM: a search space odyssey. *arXiv preprint arXiv:1503.04069*. 360

Gregor, K. and LeCun, Y. (2010a). Emergence of complex-like cells in a temporal product network with local receptive fields. Technical report, arXiv:1006.0448. 310

Gregor, K. and LeCun, Y. (2010b). Learning fast approximations of sparse coding. In L. Bottou and M. Littman, editors, *Proceedings of the Twenty-seventh International Conference on Machine Learning (ICML-10)*. ACM. 574

Gregor, K., Danihelka, I., Mnih, A., Blundell, C., and Wierstra, D. (2014). Deep autoregressive networks. In *International Conference on Machine Learning (ICML'2014)*. 611

Gretton, A., Borgwardt, K. M., Rasch, M. J., Schölkopf, B., and Smola, A. (2012). A kernel two-sample test. *The Journal of Machine Learning Research*, **13**(1), 723–773. 618

Gülçehre, Ç. and Bengio, Y. (2013). Knowledge matters: Importance of prior information for optimization. In *International Conference on Learning Representations (ICLR'2013)*. 22

Guo, H. and Gelfand, S. B. (1992). Classification trees with neural network feature extraction. *Neural Networks, IEEE Transactions on*, **3**(6), 923–933. 390

Gupta, S., Agrawal, A., Gopalakrishnan, K., and Narayanan, P. (2015). Deep learning with limited numerical precision. *CoRR*, **abs/1502.02551**. 392

Gutmann, M. and Hyvarinen, A. (2010). Noise-contrastive estimation: A new estimation principle for unnormalized statistical models. In *Proceedings of The Thirteenth International Conference on Artificial Intelligence and Statistics (AISTATS'10)*. 544

Hadsell, R., Sermanet, P., Ben, J., Erkan, A., Han, J., Muller, U., and LeCun, Y. (2007). Online learning for offroad robots: Spatial label propagation to learn long-range traversability. In *Proceedings of Robotics: Science and Systems*, Atlanta, GA, USA. 393

Hajnal, A., Maass, W., Pudlak, P., Szegedy, M., and Turan, G. (1993). Threshold circuits of bounded depth. *J. Comput. System. Sci.*, **46**, 129–154. 192

Håstad, J. (1986). Almost optimal lower bounds for small depth circuits. In *Proceedings of the 18th annual ACM Symposium on Theory of Computing*, pages 6–20, Berkeley, California. ACM Press. 192, 474

Håstad, J. and Goldmann, M. (1991). On the power of small-depth threshold circuits. *Computational Complexity*, **1**, 113–129. 192, 474

Hastie, T., Tibshirani, R., and Friedman, J. (2001). *The elements of statistical learning: data mining, inference and prediction*. Springer Series in Statistics. Springer Verlag. 137

He, K., Zhang, X., Ren, S., and Sun, J. (2015). Delving deep into rectifiers: Surpassing human-level performance on ImageNet classification. *arXiv preprint arXiv:1502.01852*. 161, 199

Hebb, D. O. (1949). *The Organization of Behavior*. Wiley, New York. 15, 579

Henaff, M., Jarrett, K., Kavukcuoglu, K., and LeCun, Y. (2011). Unsupervised learning of sparse features for scalable audio classification. In *ISMIR'11*. 445

Henniges, M., Puertas, G., Bornschein, J., Eggert, J., and Lücke, J. (2010). Binary sparse coding. In *Latent Variable Analysis and Signal Separation*, pages 450–457. Springer. 562

Herault, J. and Ans, B. (1984). Circuits neuronaux à synapses modifiables: Décodage de messages composites par apprentissage non supervisé. *Comptes Rendus de l'Académie des Sciences*, **299(III-13)**, 525—528. 437

Hinton, G. (2012). Neural networks for machine learning. Coursera, video lectures. 264

Hinton, G., Deng, L., Dahl, G. E., Mohamed, A., Jaitly, N., Senior, A., Vanhoucke, V., Nguyen, P., Sainath, T., and Kingsbury, B. (2012a). Deep neural networks for acoustic modeling in speech recognition. *IEEE Signal Processing Magazine*, **29**(6), 82–97. 22, 399

Hinton, G., Vinyals, O., and Dean, J. (2015). Distilling the knowledge in a neural network. *arXiv preprint arXiv:1503.02531*. 389

Hinton, G. E. (1989). Connectionist learning procedures. *Artificial Intelligence*, **40**, 185–234. 439

Hinton, G. E. (2000). Training products of experts by minimizing contrastive divergence. Technical Report GCNU TR 2000-004, Gatsby Unit, University College London. 534

Hinton, G. E. and Roweis, S. (2003). Stochastic neighbor embedding. In *NIPS'2002*. 483

Hinton, G. E. and Salakhutdinov, R. (2006). Reducing the Dimensionality of Data with Neural Networks. *Science*, **313**, 504–507. 416, 459

Hinton, G. E. and Salakhutdinov, R. (2006). Reducing the dimensionality of data with neural networks. *Science*, **313**(5786), 504–507. 434, 456, 457

Hinton, G. E. and Zemel, R. S. (1994). Autoencoders, minimum description length, and Helmholtz free energy. In *NIPS'1993*. 429

Hinton, G. E., Dayan, P., Frey, B. J., and Neal, R. M. (1995). The wake-sleep algorithm for unsupervised neural networks. *Science*, **268**, 1558–1161. 573

Hinton, G. E., Osindero, S., and Teh, Y. (2006). A fast learning algorithm for deep belief nets. *Neural Computation*, **18**, 1527–1554. 12, 16, 24, 134, 456, 457, 458, 586, 588

Hinton, G. E., Deng, L., Yu, D., Dahl, G. E., Mohamed, A., Jaitly, N., Senior, A., Vanhoucke, V., Nguyen, P., Sainath, T. N., and Kingsbury, B. (2012b). Deep neural networks for acoustic modeling in speech recognition: The shared views of four research groups. *IEEE Signal Process. Mag.*, **29**(6), 82–97. 93

Hinton, G. E., Srivastava, N., Krizhevsky, A., Sutskever, I., and Salakhutdinov, R. (2012c). Improving neural networks by preventing co-adaptation of feature detectors. Technical report, arXiv:1207.0580. 213

Hinton, G. E., Vinyals, O., and Dean, J. (2014). Dark knowledge. Invited talk at the BayLearn Bay Area Machine Learning Symposium. 389

Hochreiter, S. (1991). Untersuchungen zu dynamischen neuronalen Netzen. Diploma thesis, T.U. Münich. 254, 351, 363

Hochreiter, S. and Schmidhuber, J. (1995). Simplifying neural nets by discovering flat minima. In *Advances in Neural Information Processing Systems 7*, pages 529–536. MIT Press. 220

Hochreiter, S. and Schmidhuber, J. (1997). Long short-term memory. *Neural Computation*, **9**(8), 1735–1780. 22, 356, 359

Hochreiter, S., Informatik, F. F., Bengio, Y., Frasconi, P., and Schmidhuber, J. (2000). Gradient flow in recurrent nets: the difficulty of learning long-term dependencies. In J. Kolen and S. Kremer, editors, *Field Guide to Dynamical Recurrent Networks*. IEEE Press. 359

Holi, J. L. and Hwang, J.-N. (1993). Finite precision error analysis of neural network hardware implementations. *Computers, IEEE Transactions on*, **42**(3), 281–290. 391

Holt, J. L. and Baker, T. E. (1991). Back propagation simulations using limited precision calculations. In *Neural Networks, 1991., IJCNN-91-Seattle International Joint Conference on*, volume 2, pages 121–126. IEEE. 391

Hornik, K., Stinchcombe, M., and White, H. (1989). Multilayer feedforward networks are universal approximators. *Neural Networks*, **2**, 359–366. 191, 473

Hornik, K., Stinchcombe, M., and White, H. (1990). Universal approximation of an unknown mapping and its derivatives using multilayer feedforward networks. *Neural networks*, **3**(5), 551–560. 191

Hsu, F.-H. (2002). *Behind Deep Blue: Building the Computer That Defeated the World Chess Champion*. Princeton University Press, Princeton, NJ, USA. 2

Huang, F. and Ogata, Y. (2002). Generalized pseudo-likelihood estimates for markov random fields on lattice. *Annals of the Institute of Statistical Mathematics*, **54**(1), 1–18. 541

Huang, P.-S., He, X., Gao, J., Deng, L., Acero, A., and Heck, L. (2013). Learning deep structured semantic models for web search using clickthrough data. In *Proceedings of the 22nd ACM international conference on Conference on information & knowledge management*, pages 2333–2338. ACM. 420

Hubel, D. and Wiesel, T. (1968). Receptive fields and functional architecture of monkey striate cortex. *Journal of Physiology (London)*, **195**, 215–243. 318

Hubel, D. H. and Wiesel, T. N. (1959). Receptive fields of single neurons in the cat's striate cortex. *Journal of Physiology*, **148**, 574–591. 318

Hubel, D. H. and Wiesel, T. N. (1962). Receptive fields, binocular interaction, and functional architecture in the cat's visual cortex. *Journal of Physiology (London)*, **160**, 106–154. 318

Hutter, F., Hoos, H., and Leyton-Brown, K. (2011). Sequential model-based optimization for general algorithm configuration. In *LION-5*. Extended version as UBC Tech report TR-2010-10. 379

Hyotyniemi, H. (1996). Turing machines are recurrent neural networks. In *STeP'96*, pages 13–24. 330

Hyvärinen, A. (1999). Survey on independent component analysis. *Neural Computing Surveys*, **2**, 94–128. 437

Hyvärinen, A. (2005a). Estimation of non-normalized statistical models using score matching. *J. Machine Learning Res.*, **6**. 449

Hyvärinen, A. (2005b). Estimation of non-normalized statistical models using score matching. *Journal of Machine Learning Research*, **6**, 695–709. 542

Hyvärinen, A. (2007a). Connections between score matching, contrastive divergence, and pseudolikelihood for continuous-valued variables. *IEEE Transactions on Neural Networks*, **18**, 1529–1531. 543

Hyvärinen, A. (2007b). Some extensions of score matching. *Computational Statistics and Data Analysis*, **51**, 2499–2512. 543

Hyvärinen, A. and Pajunen, P. (1999). Nonlinear independent component analysis: Existence and uniqueness results. *Neural Networks*, **12**(3), 429–439. 439

Hyvärinen, A., Karhunen, J., and Oja, E. (2001). *Independent Component Analysis*. Wiley-Interscience. 437

Hyvärinen, A., Hurri, J., and Hoyer, P. O. (2009). *Natural Image Statistics: A probabilistic approach to early computational vision*. Springer-Verlag. 324

Inayoshi, H. and Kurita, T. (2005). Improved generalization by adding both auto-association and hidden-layer noise to neural-network-based-classifiers. *Machine Learning for Signal Processing*, pages 141—-146. 446

Ioffe, S. and Szegedy, C. (2015). Batch normalization: Accelerating deep network training by reducing internal covariate shift. 22, 92, 370

Jacobs, R. A. (1988). Increased rates of convergence through learning rate adaptation. *Neural networks*, **1**(4), 295–307. 264

Jacobs, R. A., Jordan, M. I., Nowlan, S. J., and Hinton, G. E. (1991). Adaptive mixture of local experts. *Neural Computation*, **3**, 79–87. 170, 390

Jaeger, H. (2003). Adaptive nonlinear system identification with echo state networks. In *Advances in Neural Information Processing Systems 15*. 351, 352, 353

Jaeger, H. (2007a). Discovering multiscale dynamical features with hierarchical echo state networks. Technical report, Jacobs University. 347

Jaeger, H. (2007b). Echo state network. *Scholarpedia*, **2**(9), 2330. 351

Jaeger, H. and Haas, H. (2004). Harnessing nonlinearity: Predicting chaotic systems and saving energy in wireless communication. *Science*, **304**(5667), 78–80. 24, 351

Jaeger, H., Lukosevicius, M., Popovici, D., and Siewert, U. (2007). Optimization and applications of echo state networks with leaky- integrator neurons. *Neural Networks*, **20**(3), 335–352. 355

Jain, V., Murray, J. F., Roth, F., Turaga, S., Zhigulin, V., Briggman, K. L., Helmstaedter, M. N., Denk, W., and Seung, H. S. (2007). Supervised learning of image restoration with convolutional networks. In *Computer Vision, 2007. ICCV 2007. IEEE 11th International Conference on*, pages 1–8. IEEE. 314

Janzing, D., Peters, J., Sgouritsa, E., Zhang, K., Mooij, J. M., and Schölkopf, B. (2012). On causal and anticausal learning. In *ICML'2012*, pages 1255–1262. 466, 468

Jarrett, K., Kavukcuoglu, K., Ranzato, M., and LeCun, Y. (2009a). What is the best multi-stage architecture for object recognition? In *ICCV'09*. 14, 162, 445

Jarrett, K., Kavukcuoglu, K., Ranzato, M., and LeCun, Y. (2009b). What is the best multi-stage architecture for object recognition? In *Proc. International Conference on Computer Vision (ICCV'09)*, pages 2146–2153. IEEE. 21, 24, 197, 317, 318

Jarzynski, C. (1997). Nonequilibrium equality for free energy differences. *Phys. Rev. Lett.*, **78**, 2690–2693. 551

Jaynes, E. T. (2003). *Probability Theory: The Logic of Science*. Cambridge University Press. 48

Jean, S., Cho, K., Memisevic, R., and Bengio, Y. (2014). On using very large target vocabulary for neural machine translation. arXiv:1412.2007. 339, 413

Jelinek, F. and Mercer, R. L. (1980). Interpolated estimation of markov source parameters from sparse data. In E. S. Gelsema and L. N. Kanal, editors, *Pattern Recognition in Practice*. North-Holland, Amsterdam. 401, 412

Jia, Y., Huang, C., and Darrell, T. (2012). Beyond spatial pyramids: Receptive field learning for pooled image features. In *Computer Vision and Pattern Recognition (CVPR), 2012 IEEE Conference on*, pages 3370–3377. IEEE. 305

Jim, K.-C., Giles, C. L., and Horne, B. G. (1996). An analysis of noise in recurrent neural networks: convergence and generalization. *IEEE Transactions on Neural Networks*, **7**(6), 1424–1438. 216, 219

Jordan, M. I. (1998). *Learning in Graphical Models*. Kluwer, Dordrecht, Netherlands. 16

Jozefowicz, R., Zaremba, W., and Sutskever, I. (2015a). An empirical evaluation of recurrent network architectures. In *ICML'2015*. 360

Jozefowicz, R., Zaremba, W., and Sutskever, I. (2015b). An empirical exploration of recurrent network architectures. In *Proceedings of The 32nd International Conference on Machine Learning*, pages 2342–2350. 286, 359

Judd, J. S. (1989). *Neural Network Design and the Complexity of Learning*. MIT press. 256

Jutten, C. and Herault, J. (1991). Blind separation of sources, part I: an adaptive algorithm based on neuromimetic architecture. *Signal Processing*, **24**, 1–10. 437

Kahou, S. E., Pal, C., Bouthillier, X., Froumenty, P., Gülçehre, c., Memisevic, R., Vincent, P., Courville, A., Bengio, Y., Ferrari, R. C., Mirza, M., Jean, S., Carrier, P.-L., Dauphin, Y., Boulanger-Lewandowski, N., Aggarwal, A., Zumer, J., Lamblin, P., Raymond, J.-P., Desjardins, G., Pascanu, R., Warde-Farley, D., Torabi, A., Sharma, A., Bengio, E., Côté, M., Konda, K. R., and Wu, Z. (2013). Combining modality specific deep neural networks for emotion recognition in video. In *Proceedings of the 15th ACM on International Conference on Multimodal Interaction*. 193

Kalchbrenner, N. and Blunsom, P. (2013). Recurrent continuous translation models. In *EMNLP'2013*. 339, 413

Kamyshanska, H. and Memisevic, R. (2015). The potential energy of an autoencoder. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 449, 625

Karpathy, A. and Li, F.-F. (2015). Deep visual-semantic alignments for generating image descriptions. In *CVPR'2015*. arXiv:1412.2306. 94

Karpathy, A., Toderici, G., Shetty, S., Leung, T., Sukthankar, R., and Fei-Fei, L. (2014). Large-scale video classification with convolutional neural networks. In *CVPR*. 19

Karush, W. (1939). *Minima of Functions of Several Variables with Inequalities as Side Constraints*. Master's thesis, Dept.~of Mathematics, Univ.~of Chicago. 89

Katz, S. M. (1987). Estimation of probabilities from sparse data for the language model component of a speech recognizer. *IEEE Transactions on Acoustics, Speech, and Signal Processing*, **ASSP-35**(3), 400–401. 401, 412

Kavukcuoglu, K., Ranzato, M., and LeCun, Y. (2008). Fast inference in sparse coding algorithms with applications to object recognition. Technical report, Computational and Biological Learning Lab, Courant Institute, NYU. Tech Report CBLL-TR-2008-12-01. 445

Kavukcuoglu, K., Ranzato, M.-A., Fergus, R., and LeCun, Y. (2009). Learning invariant features through topographic filter maps. In *CVPR'2009*. 445

Kavukcuoglu, K., Sermanet, P., Boureau, Y.-L., Gregor, K., Mathieu, M., and LeCun, Y. (2010a). Learning convolutional feature hierarchies for visual recognition. In *Advances in Neural Information Processing Systems 23 (NIPS'10)*, pages 1090–1098. 318

Kavukcuoglu, K., Sermanet, P., Boureau, Y.-L., Gregor, K., Mathieu, M., and LeCun, Y. (2010b). Learning convolutional feature hierarchies for visual recognition. In *NIPS'2010*. 445

Kelley, H. J. (1960). Gradient theory of optimal flight paths. *ARS Journal*, **30**(10), 947–954. 199

Khan, F., Zhu, X., and Mutlu, B. (2011). How do humans teach: On curriculum learning and teaching dimension. In *Advances in Neural Information Processing Systems 24 (NIPS'11)*, pages 1449–1457. 292

Kim, S. K., McAfee, L. C., McMahon, P. L., and Olukotun, K. (2009). A highly scalable restricted Boltzmann machine FPGA implementation. In *Field Programmable Logic and Applications, 2009. FPL 2009. International Conference on*, pages 367–372. IEEE. 391

Kindermann, R. (1980). *Markov Random Fields and Their Applications (Contemporary Mathematics ; V. 1)*. American Mathematical Society. 500

Kingma, D. and Ba, J. (2014). Adam: A method for stochastic optimization. *arXiv preprint arXiv:1412.6980*. 265

Kingma, D. and LeCun, Y. (2010a). Regularized estimation of image statistics by score matching. In *NIPS'2010*. 449

Kingma, D. and LeCun, Y. (2010b). Regularized estimation of image statistics by score matching. In J. Lafferty, C. K. I. Williams, J. Shawe-Taylor, R. Zemel, and A. Culotta, editors, *Advances in Neural Information Processing Systems 23*, pages 1126–1134. 544

Kingma, D., Rezende, D., Mohamed, S., and Welling, M. (2014). Semi-supervised learning with deep generative models. In *NIPS'2014*. 371

Kingma, D. P. (2013). Fast gradient-based inference with continuous latent variable models in auxiliary form. Technical report, arxiv:1306.0733. 188

Kingma, D. P. and Welling, M. (2014a). Auto-encoding variational bayes. In *Proceedings of the International Conference on Learning Representations (ICLR)*. 188, 484, 485

Kingma, D. P. and Welling, M. (2014b). Efficient gradient-based inference through transformations between bayes nets and neural nets. Technical report, arxiv:1402.0480. 188

Kirkpatrick, S., Jr., C. D. G., , and Vecchi, M. P. (1983). Optimization by simulated annealing. *Science*, **220**, 671–680. 291

Kiros, R., Salakhutdinov, R., and Zemel, R. (2014a). Multimodal neural language models. In *ICML'2014*. 94

Kiros, R., Salakhutdinov, R., and Zemel, R. (2014b). Unifying visual-semantic embeddings with multimodal neural language models. *arXiv:*`1411.2539` `[cs.LG]`. 94, 358

Klementiev, A., Titov, I., and Bhattarai, B. (2012). Inducing crosslingual distributed representations of words. In *Proceedings of COLING 2012*. 414, 463

Knowles-Barley, S., Jones, T. R., Morgan, J., Lee, D., Kasthuri, N., Lichtman, J. W., and Pfister, H. (2014). Deep learning for the connectome. *GPU Technology Conference*. 23

Koller, D. and Friedman, N. (2009). *Probabilistic Graphical Models: Principles and Techniques*. MIT Press. 514, 524, 568

Konig, Y., Bourlard, H., and Morgan, N. (1996). REMAP: Recursive estimation and maximization of A posteriori probabilities – application to transition-based connectionist speech recognition. In *NIPS'95*. MIT Press, Cambridge, MA. 398

Koren, Y. (2009). 1 the bellkor solution to the netflix grand prize. 232, 419

Koutnik, J., Greff, K., Gomez, F., and Schmidhuber, J. (2014). A clockwork RNN. In *ICML'2014*. 349, 367

Kočiský, T., Hermann, K. M., and Blunsom, P. (2014). Learning Bilingual Word Representations by Marginalizing Alignments. In *Proceedings of ACL*. 414

Krause, O., Fischer, A., Glasmachers, T., and Igel, C. (2013). Approximation properties of DBNs with binary hidden units and real-valued visible units. In *ICML'2013*. 473

Krizhevsky, A. (2010). Convolutional deep belief networks on CIFAR-10. Technical report, University of Toronto. Unpublished Manuscript: http://www.cs.utoronto.ca/ kriz/conv-cifar10-aug2010.pdf. 387

Krizhevsky, A. and Hinton, G. (2009). Learning multiple layers of features from tiny images. Technical report, University of Toronto. 19, 496

Krizhevsky, A., Sutskever, I., and Hinton, G. (2012a). ImageNet classification with deep convolutional neural networks. In *Advances in Neural Information Processing Systems 25 (NIPS'2012)*. 21, 24, 92, 325, 393, 397

Krizhevsky, A., Sutskever, I., and Hinton, G. (2012b). ImageNet classification with deep convolutional neural networks. In *NIPS'2012*. 22, 193

Krueger, K. A. and Dayan, P. (2009). Flexible shaping: how learning in small steps helps. *Cognition*, **110**, 380–394. 292

Kuhn, H. W. and Tucker, A. W. (1951). Nonlinear programming. In *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, pages 481–492, Berkeley, Calif. University of California Press. 89

Kumar, A., Irsoy, O., Su, J., Bradbury, J., English, R., Pierce, B., Ondruska, P., Iyyer, M., Gulrajani, I., and Socher, R. (2015). Ask me anything: Dynamic memory networks for natural language processing. *arXiv:1506.07285*. 424

Kumar, M. P., Packer, B., and Koller, D. (2010). Self-paced learning for latent variable models. In *NIPS'2010*. 292

Lang, K. J. and Hinton, G. E. (1988). The development of the time-delay neural network architecture for speech recognition. Technical Report CMU-CS-88-152, Carnegie-Mellon University. 321, 326, 354

Langford, J. and Zhang, T. (2008). The epoch-greedy algorithm for contextual multi-armed bandits. In *NIPS'2008*, pages 1096—1103. 420

Lappalainen, H., Giannakopoulos, X., Honkela, A., and Karhunen, J. (2000). Nonlinear independent component analysis using ensemble learning: Experiments and discussion. In *Proc. ICA*. Citeseer. 439

Larochelle, H. and Bengio, Y. (2008a). Classification using discriminative restricted Boltzmann machines. In *ICML'2008*. 230, 609, 629

Larochelle, H. and Bengio, Y. (2008b). Classification using discriminative restricted Boltzmann machines. In *ICML'08*, pages 536–543. ACM. 465

Larochelle, H. and Murray, I. (2011). The Neural Autoregressive Distribution Estimator. In *AISTATS'2011*. 620, 622, 623

Larochelle, H., Erhan, D., and Bengio, Y. (2008). Zero-data learning of new tasks. In *AAAI Conference on Artificial Intelligence*. 463

Lasserre, J. A., Bishop, C. M., and Minka, T. P. (2006). Principled hybrids of generative and discriminative models. In *Proceedings of the Computer Vision and Pattern Recognition Conference (CVPR'06)*, pages 87–94, Washington, DC, USA. IEEE Computer Society. 228, 465

Le, Q., Ngiam, J., Chen, Z., hao Chia, D. J., Koh, P. W., and Ng, A. (2010). Tiled convolutional neural networks. In J. Lafferty, C. K. I. Williams, J. Shawe-Taylor, R. Zemel, and A. Culotta, editors, *Advances in Neural Information Processing Systems 23 (NIPS'10)*, pages 1279–1287. 310

Le, Q., Ngiam, J., Coates, A., Lahiri, A., Prochnow, B., and Ng, A. (2011). On optimization methods for deep learning. In *Proc. ICML'2011*. ACM. 275

Le, Q., Ranzato, M., Monga, R., Devin, M., Corrado, G., Chen, K., Dean, J., and Ng, A. (2012). Building high-level features using large scale unsupervised learning. In *ICML'2012*. 21, 24

Le Roux, N. and Bengio, Y. (2008). Representational power of restricted Boltzmann machines and deep belief networks. *Neural Computation*, **20**(6), 1631–1649. 578

Le Roux, N. and Bengio, Y. (2010). Deep belief networks are compact universal approximators. *Neural Computation*, **22**(8), 2192–2207. 473

LeCun, Y. (1985). Une procédure d'apprentissage pour Réseau à seuil assymétrique. In *Cognitiva 85: A la Frontière de l'Intelligence Artificielle, des Sciences de la Connaissance et des Neurosciences*, pages 599–604, Paris 1985. CESTA, Paris. 200

LeCun, Y. (1987). *Modèles connexionistes de l'apprentissage*. Ph.D. thesis, Université de Paris VI. 16, 429, 446

LeCun, Y., Jackel, L. D., Boser, B., Denker, J. S., Graf, H. P., Guyon, I., Henderson, D., Howard, R. E., and Hubbard, W. (1989). Handwritten digit recognition: Applications of neural network chips and automatic learning. *IEEE Communications Magazine*, **27**(11), 41–46. 321

LeCun, Y., Bottou, L., Orr, G. B., and Müller, K.-R. (1998a). Efficient backprop. In *Neural Networks, Tricks of the Trade*, Lecture Notes in Computer Science LNCS 1524. Springer Verlag. 373

LeCun, Y., Bottou, L., Bengio, Y., and Haffner, P. (1998b). Gradient-based learning applied to document recognition. *Proceedings of the IEEE*, **86**(11), 2278–2324. 14, 24, 397

LeCun, Y., Bottou, L., Bengio, Y., and Haffner, P. (1998c). Gradient-based learning applied to document recognition. *Proceedings of the IEEE*, **86**(11), 2278–2324. 16, 19, 399

LeCun, Y., Bottou, L., Bengio, Y., and Haffner, P. (1998d). Gradient based learning applied to document recognition. *Proc. IEEE*. 325

LeCun, Y., Kavukcuoglu, K., and Farabet, C. (2010). Convolutional networks and applications in vision. In *Circuits and Systems (ISCAS), Proceedings of 2010 IEEE International Symposium on*, pages 253–256. IEEE. 325

L'Ecuyer, P. (1994). Efficiency improvement and variance reduction. In *Proceedings of the 1994 Winter Simulation Conference*, pages 122—132. 189

Lee, C.-Y., Xie, S., Gallagher, P., Zhang, Z., and Tu, Z. (2014). Deeply-supervised nets. *arXiv preprint arXiv:1409.5185*. 289

Lee, H., Battle, A., Raina, R., and Ng, A. (2007). Efficient sparse coding algorithms. In *NIPS'06*, pages 801–808. MIT Press. 560

Lee, H., Ekanadham, C., and Ng, A. (2008). Sparse deep belief net model for visual area V2. In *NIPS'07*. 230

Lee, H., Grosse, R., Ranganath, R., and Ng, A. Y. (2009). Convolutional deep belief networks for scalable unsupervised learning of hierarchical representations. In L. Bottou and M. Littman, editors, *ICML 2009*. ACM, Montreal, Canada. 318, 607, 608

Lee, Y. J. and Grauman, K. (2011). Learning the easy things first: self-paced visual category discovery. In *CVPR'2011*. 292

Leibniz, G. W. (1676). Memoir using the chain rule. (Cited in TMME 7:2&3 p 321-332, 2010). 199

Lenat, D. B. and Guha, R. V. (1989). *Building large knowledge-based systems; representation and inference in the Cyc project*. Addison-Wesley Longman Publishing Co., Inc. 2

Leshno, M., Lin, V. Y., Pinkus, A., and Schocken, S. (1993). Multilayer feedforward networks with a nonpolynomial activation function can approximate any function. *Neural Networks*, **6**, 861—867. 192, 193

Levenberg, K. (1944). A method for the solution of certain non-linear problems in least squares. *Quarterly Journal of Applied Mathematics*, **II**(2), 164–168. 272

L'Hôpital, G. F. A. (1696). *Analyse des infiniment petits, pour l'intelligence des lignes courbes*. Paris: L'Imprimerie Royale. 199

Li, Y., Swersky, K., and Zemel, R. S. (2015). Generative moment matching networks. *CoRR*, **abs/1502.02761**. 618

Lin, T., Horne, B. G., Tino, P., and Giles, C. L. (1996). Learning long-term dependencies is not as difficult with NARX recurrent neural networks. *IEEE Transactions on Neural Networks*, **7**(6), 1329–1338. 354

Lin, Y., Liu, Z., Sun, M., Liu, Y., and Zhu, X. (2015). Learning entity and relation embeddings for knowledge graph completion. In *Proc. AAAI'15*. 423

Linde, N. (1992). The machine that changed the world, episode 3. Documentary miniseries. 2

Lindsey, C. and Lindblad, T. (1994). Review of hardware neural networks: a user's perspective. In *Proc. Third Workshop on Neural Networks: From Biology to High Energy Physics*, pages 195—202, Isola d'Elba, Italy. 391

Linnainmaa, S. (1976). Taylor expansion of the accumulated rounding error. *BIT Numerical Mathematics*, **16**(2), 146–160. 199

Long, P. M. and Servedio, R. A. (2010). Restricted Boltzmann machines are hard to approximately evaluate or simulate. In *Proceedings of the 27th International Conference on Machine Learning (ICML'10)*. 581

Lovelace, A. (1842). Notes upon L. F. Menabrea's "Sketch of the Analytical Engine invented by Charles Babbage". 1

Lu, T., Pál, D., and Pál, M. (2010). Contextual multi-armed bandits. In *International Conference on Artificial Intelligence and Statistics*, pages 485–492. 420

Luenberger, D. G. (1984). *Linear and Nonlinear Programming*. Addison Wesley. 276

Lukoševičius, M. and Jaeger, H. (2009). Reservoir computing approaches to recurrent neural network training. *Computer Science Review*, **3**(3), 127–149. 352

Luo, H., Shen, R., Niu, C., and Ullrich, C. (2011). Learning class-relevant features and class-irrelevant features via a hybrid third-order rbm. In *International Conference on Artificial Intelligence and Statistics*, pages 470–478. 609

Luo, H., Carrier, P.-L., Courville, A., and Bengio, Y. (2013). Texture modeling with convolutional spike-and-slab RBMs and deep extensions. In *AISTATS'2013*. 94

Lyness, J. N. and Moler, C. B. (1967). Numerical differentiation of analytic functions. *SIAM J.Numer. Anal.*, **4**, 202—210. 183

Lyu, S. (2009). Interpretation and generalization of score matching. In *UAI'09*. 543

Maas, A. L., Hannun, A. Y., and Ng, A. Y. (2013). Rectifier nonlinearities improve neural network acoustic models. In *ICML Workshop on Deep Learning for Audio, Speech, and Language Processing*. 161, 199

Maass, W. (1992). Bounds for the computational power and learning complexity of analog neural nets (extended abstract). In *Proc. of the 25th ACM Symp. Theory of Computing*, pages 335–344. 193

Maass, W., Schnitger, G., and Sontag, E. D. (1994). A comparison of the computational power of sigmoid and boolean threshold circuits. *Theoretical Advances in Neural Computation and Learning*, pages 127–151. 193

Maass, W., Natschlaeger, T., and Markram, H. (2002). Real-time computing without stable states: A new framework for neural computation based on perturbations. *Neural Computation*, **14**(11), 2531–2560. 351

MacKay, D. (2003). *Information Theory, Inference and Learning Algorithms*. Cambridge University Press. 65

Maclaurin, D., Duvenaud, D., and Adams, R. P. (2015). Gradient-based hyperparameter optimization through reversible learning. *arXiv preprint arXiv:1502.03492*. 378

Mao, J., Xu, W., Yang, Y., Wang, J., Huang, Z., and Yuille, A. L. (2015). Deep captioning with multimodal recurrent neural networks. In *ICLR'2015*. arXiv:1410.1090. 94

Marcotte, P. and Savard, G. (1992). Novel approaches to the discrimination problem. *Zeitschrift für Operations Research (Theory)*, **36**, 517–545. 242

Marlin, B., Swersky, K., Chen, B., and de Freitas, N. (2010). Inductive principles for restricted Boltzmann machine learning. In *Proceedings of The Thirteenth International Conference on Artificial Intelligence and Statistics (AISTATS'10)*, volume 9, pages 509–516. 538, 543, 582

Marquardt, D. W. (1963). An algorithm for least-squares estimation of non-linear parameters. *Journal of the Society of Industrial and Applied Mathematics*, **11**(2), 431–441. 272

Marr, D. and Poggio, T. (1976). Cooperative computation of stereo disparity. *Science*, **194**. 321

Martens, J. (2010). Deep learning via Hessian-free optimization. In L. Bottou and M. Littman, editors, *Proceedings of the Twenty-seventh International Conference on Machine Learning (ICML-10)*, pages 735–742. ACM. 284

Martens, J. and Medabalimi, V. (2014). On the expressive efficiency of sum product networks. *arXiv:1411.7717*. 193, 474

Martens, J. and Sutskever, I. (2011). Learning recurrent neural networks with Hessian-free optimization. In *Proc. ICML'2011*. ACM. 363

Mase, S. (1995). Consistency of the maximum pseudo-likelihood estimator of continuous state space Gibbsian processes. *The Annals of Applied Probability*, **5**(3), pp. 603–612. 541

McCullagh, P. and Nelder, J. (1989). *Generalized Linear Models*. Chapman and Hall, London. 164

McCulloch, W. S. and Pitts, W. (1943). A logical calculus of ideas immanent in nervous activity. *Bulletin of Mathematical Biophysics*, **5**, 115–133. 13

Mead, C. and Ismail, M. (2012). *Analog VLSI implementation of neural systems*, volume 80. Springer Science & Business Media. 391

Mesnil, G., Dauphin, Y., Glorot, X., Rifai, S., Bengio, Y., Goodfellow, I., Lavoie, E., Muller, X., Desjardins, G., Warde-Farley, D., Vincent, P., Courville, A., and Bergstra, J. (2011). Unsupervised and transfer learning challenge: a deep learning approach. In *JMLR W&CP: Proc. Unsupervised and Transfer Learning*, volume 7. 193, 462

Mesnil, G., Rifai, S., Dauphin, Y., Bengio, Y., and Vincent, P. (2012). Surfing on the manifold. Learning Workshop, Snowbird. 625

Miikkulainen, R. and Dyer, M. G. (1991). Natural language processing with modular PDP networks and distributed lexicon. *Cognitive Science*, **15**, 343–399. 400

Mikolov, T. (2012). *Statistical Language Models based on Neural Networks*. Ph.D. thesis, Brno University of Technology. 171, 365

Mikolov, T., Deoras, A., Kombrink, S., Burget, L., and Cernocky, J. (2011a). Empirical evaluation and combination of advanced language modeling techniques. In *Proc. 12th annual conference of the international speech communication association (INTERSPEECH 2011)*. 411

Mikolov, T., Deoras, A., Povey, D., Burget, L., and Cernocky, J. (2011b). Strategies for training large scale neural network language models. In *Proc. ASRU'2011*. 292, 411

Mikolov, T., Le, Q. V., and Sutskever, I. (2013). Exploiting similarities among languages for machine translation. Technical report, arXiv:1309.4168. 463

Minka, T. (2005). Divergence measures and message passing. *Microsoft Research Cambridge UK Tech Rep MSRTR2005173*, **72**(TR-2005-173). 548

Minsky, M. L. and Papert, S. A. (1969). *Perceptrons*. MIT Press, Cambridge. 13

Mirza, M. and Osindero, S. (2014). Conditional generative adversarial nets. *arXiv preprint arXiv:1411.1784*. 616

Misra, J. and Saha, I. (2010). Artificial neural networks in hardware: A survey of two decades of progress. *Neurocomputing*, **74**(1), 239–255. 391

Mitchell, T. M. (1997). *Machine Learning*. McGraw-Hill, New York. 91

Mnih, A. and Gregor, K. (2014). Neural variational inference and learning in belief networks. In *ICML'2014*. 190, 191, 611

Mnih, A. and Kavukcuoglu, K. (2013). Learning word embeddings efficiently with noise-contrastive estimation. In C. Burges, L. Bottou, M. Welling, Z. Ghahramani, and K. Weinberger, editors, *Advances in Neural Information Processing Systems 26*, pages 2265–2273. Curran Associates, Inc. 411, 546

Mnih, A. and Teh, Y. W. (2012). A fast and simple algorithm for training neural probabilistic language models. In *ICML'2012*, pages 1751–1758. 411

Mnih, V. and Hinton, G. (2010). Learning to detect roads in high-resolution aerial images. In *Proceedings of the 11th European Conference on Computer Vision (ECCV)*. 94

Mnih, V., Larochelle, H., and Hinton, G. (2011). Conditional restricted Boltzmann machines for structure output prediction. In *Proc. Conf. on Uncertainty in Artificial Intelligence (UAI)*. 608

Mnih, V., Heess, N., Graves, A., and kavukcuoglu, k. (2014). Recurrent models of visual attention. In Z. Ghahramani, M. Welling, C. Cortes, N. Lawrence, and K. Weinberger, editors, *NIPS'2014*, pages 2204–2212. 191

Mnih, V., Kavukcuoglo, K., Silver, D., Rusu, A. A., Veness, J., Bellemare, M. G., Graves, A., Riedmiller, M., Fidgeland, A. K., Ostrovski, G., Petersen, S., Beattie, C., Sadik, A., Antonoglou, I., King, H., Kumaran, D., Wierstra, D., Legg, S., and Hassabis, D. (2015). Human-level control through deep reinforcement learning. *Nature*, **518**, 529–533. 23

Mobahi, H. and Fisher III, J. W. (2015). A theoretical analysis of optimization by gaussian continuation. In *AAAI'2015*. 291

Mobahi, H., Collobert, R., and Weston, J. (2009). Deep learning from temporal coherence in video. In L. Bottou and M. Littman, editors, *Proceedings of the 26th International Conference on Machine Learning*, pages 737–744, Montreal. Omnipress. 439

Mohamed, A., Dahl, G., and Hinton, G. (2012). Acoustic modeling using deep belief networks. *IEEE Trans. on Audio, Speech and Language Processing*, **20**(1), 14–22. 398

Moller, M. F. (1993). A scaled conjugate gradient algorithm for fast supervised learning. *Neural Networks*, **6**, 525–533. 275

Montúfar, G. (2014). Universal approximation depth and errors of narrow belief networks with discrete units. *Neural Computation*, **26**. 473

Montúfar, G. and Ay, N. (2011). Refinements of universal approximation results for deep belief networks and restricted Boltzmann machines. *Neural Computation*, **23**(5), 1306–1319. 473

Montufar, G. and Morton, J. (2014). When does a mixture of products contain a product of mixtures? *SIAM Journal on Discrete Mathematics*, **29**(1), 321–347. 473

Montufar, G. F., Pascanu, R., Cho, K., and Bengio, Y. (2014). On the number of linear regions of deep neural networks. In *NIPS'2014*. 17, 193, 474, 475

Mor-Yosef, S., Samueloff, A., Modan, B., Navot, D., and Schenker, J. G. (1990). Ranking the risk factors for cesarean: logistic regression analysis of a nationwide study. *Obstet Gynecol*, **75**(6), 944–7. 2

Morin, F. and Bengio, Y. (2005). Hierarchical probabilistic neural network language model. In *AISTATS'2005*. 406, 408

Mozer, M. C. (1992). The induction of multiscale temporal structure. In *NIPS'91*, pages 275–282, San Mateo, CA. Morgan Kaufmann. 355, 356, 367

Murphy, K. P. (2012). *Machine Learning: a Probabilistic Perspective*. MIT Press, Cambridge, MA, USA. 91, 137

Murray, B. U. I. and Larochelle, H. (2014). A deep and tractable density estimator. In *ICML'2014*. 171, 624, 625

Nair, V. and Hinton, G. (2010a). Rectified linear units improve restricted Boltzmann machines. In *ICML'2010*. 162

Nair, V. and Hinton, G. E. (2010b). Rectified linear units improve restricted Boltzmann machines. In L. Bottou and M. Littman, editors, *Proceedings of the Twenty-seventh International Conference on Machine Learning (ICML-10)*, pages 807–814. ACM. 14

Narayanan, H. and Mitter, S. (2010). Sample complexity of testing the manifold hypothesis. In *NIPS'2010*. 152, 478

Navigli, R. and Velardi, P. (2005). Structural semantic interconnections: a knowledge-based approach to word sense disambiguation. *IEEE Trans. Pattern Analysis and Machine Intelligence*, **27**(7), 1075—1086. 424

Neal, R. and Hinton, G. (1999). A view of the EM algorithm that justifies incremental, sparse, and other variants. In M. I. Jordan, editor, *Learning in Graphical Models*. MIT Press, Cambridge, MA. 557

Neal, R. M. (1990). Learning stochastic feedforward networks. Technical report. 610

Neal, R. M. (1996). *Bayesian Learning for Neural Networks*. Lecture Notes in Statistics. Springer. 235

Neal, R. M. (2001). Annealed importance sampling. *Statistics and Computing*, **11**(2), 125–139. 550, 551

Neal, R. M. (2005). Estimating ratios of normalizing constants using linked importance sampling. 552

Nedic, A. and Bertsekas, D. (2000). Convergence rate of incremental subgradient algorithms. In *Stochastic Optimization: Algorithms and Applications*, pages 263–304. Kluwer. 260

Nesterov, Y. (1983). A method for unconstrained convex minimization problem with the rate of convergence $o(1/k^2)$. *Doklady AN SSSR (translated as Soviet. Math. Docl.)*, **269**, 543–547. 259, 262

Netzer, Y., Wang, T., Coates, A., Bissacco, A., Wu, B., and Ng, A. Y. (2011). Reading digits in natural images with unsupervised feature learning. Deep Learning and Unsupervised Feature Learning Workshop, NIPS. 19

Ney, H. and Kneser, R. (1993). Improved clustering techniques for class-based statistical language modelling. In *European Conference on Speech Communication and Technology (Eurospeech)*, pages 973–976, Berlin. 403

Ng, A. (2015). Advice for applying machine learning. https://see.stanford.edu/materials/aimlcs229/ML-advice.pdf. 368

Niesler, T. R., Whittaker, E. W. D., and Woodland, P. C. (1998). Comparison of part-of-speech and automatically derived category-based language models for speech recognition. In *International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pages 177–180. 403

Ning, F., Delhomme, D., LeCun, Y., Piano, F., Bottou, L., and Barbano, P. E. (2005). Toward automatic phenotyping of developing embryos from videos. *Image Processing, IEEE Transactions on*, **14**(9), 1360–1371. 314

Niranjan, M. and Fallside, F. (1990). Neural networks and radial basis functions in classifying static speech patterns. *Computer Speech and Language*, **4**, 275–289. 162

Nocedal, J. and Wright, S. (2006). *Numerical Optimization*. Springer. 86, 89

Norouzi, M. and Fleet, D. J. (2011). Minimal loss hashing for compact binary codes. In *ICML'2011*. 417

Nowlan, S. J. (1990). Competing experts: An experimental investigation of associative mixture models. Technical Report CRG-TR-90-5, University of Toronto. 390

Olshausen, B. and Field, D. J. (2005). How close are we to understanding V1? *Neural Computation*, **17**, 1665–1699. 14

Olshausen, B. A. and Field, D. J. (1996). Emergence of simple-cell receptive field properties by learning a sparse code for natural images. *Nature*, **381**, 607–609. 230, 323, 441

Olshausen, B. A. and Field, D. J. (1997). Sparse coding with an overcomplete basis set: a strategy employed by V1? *Vision Research*, **37**, 3311–3325. 431

Opper, M. and Archambeau, C. (2009). The variational gaussian approximation revisited. *Neural computation*, **21**(3), 786–792. 188

Osindero, S. and Hinton, G. E. (2008). Modeling image patches with a directed hierarchy of markov random field. In *NIPS'07*, pages 1121–1128, Cambridge, MA. MIT Press. 555

Paccanaro, A. and Hinton, G. E. (2000). Extracting distributed representations of concepts and relations from positive and negative propositions. In *International Joint Conference on Neural Networks (IJCNN)*, Como, Italy. IEEE, New York. 423

Parker, D. B. (1985). Learning-logic. Technical Report TR-47, Center for Comp. Research in Economics and Management Sci., MIT. 200

Pascanu, R. and Bengio, Y. (2012). On the difficulty of training recurrent neural networks. Technical Report arXiv:1211.5063, Universite de Montreal. 171

Pascanu, R., Mikolov, T., and Bengio, Y. (2013a). On the difficulty of training recurrent neural networks. In *ICML'2013*. 171, 256, 351, 356, 365, 367

Pascanu, R., Montufar, G., and Bengio, Y. (2013b). On the number of inference regions of deep feed forward networks with piece-wise linear activations. Technical report, U. Montreal, arXiv:1312.6098. 193

Pascanu, R., Gülçehre, Ç., Cho, K., and Bengio, Y. (2014a). How to construct deep recurrent neural networks. In *ICLR'2014*. 17, 235, 347, 348, 349, 358, 399, 474

Pascanu, R., Montufar, G., and Bengio, Y. (2014b). On the number of inference regions of deep feed forward networks with piece-wise linear activations. In *ICLR'2014*. 471

Pearl, J. (1985). Bayesian networks: A model of self-activated memory for evidential reasoning. In *Proceedings of the 7th Conference of the Cognitive Science Society, University of California, Irvine*, pages 329–334. 498

Pearl, J. (1988). *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference*. Morgan Kaufmann. 49

Petersen, K. B. and Pedersen, M. S. (2006). The matrix cookbook. Version 20051003. 28

Peterson, G. B. (2004). A day of great illumination: B. F. Skinner's discovery of shaping. *Journal of the Experimental Analysis of Behavior*, **82**(3), 317–328. 292

Pham, D.-T., Garat, P., and Jutten, C. (1992). Separation of a mixture of independent sources through a maximum likelihood approach. In *EUSIPCO*, pages 771–774. 438

Pham, P.-H., Jelaca, D., Farabet, C., Martini, B., LeCun, Y., and Culurciello, E. (2012). Neuflow: dataflow vision processing system-on-a-chip. In *Circuits and Systems (MWS-CAS), 2012 IEEE 55th International Midwest Symposium on*, pages 1044–1047. IEEE. 391

Pinheiro, P. H. O. and Collobert, R. (2014). Recurrent convolutional neural networks for scene labeling. In *ICML'2014*. 314

Pinheiro, P. H. O. and Collobert, R. (2015). From image-level to pixel-level labeling with convolutional networks. In *Conference on Computer Vision and Pattern Recognition (CVPR)*. 314

Pinto, N., Cox, D. D., and DiCarlo, J. J. (2008). Why is real-world visual object recognition hard? *PLoS Comput Biol*, **4**. 396, 608

Pinto, N., Stone, Z., Zickler, T., and Cox, D. (2011). Scaling up biologically-inspired computer vision: A case study in unconstrained face recognition on facebook. In *Computer Vision and Pattern Recognition Workshops (CVPRW), 2011 IEEE Computer Society Conference on*, pages 35–42. IEEE. 317

Pollack, J. B. (1990). Recursive distributed representations. *Artificial Intelligence*, **46**(1), 77–105. 349

Polyak, B. T. (1964). Some methods of speeding up the convergence of iteration methods. *USSR Computational Mathematics and Mathematical Physics*, **4**(5), 1–17. 260

Poole, B., Sohl-Dickstein, J., and Ganguli, S. (2014). Analyzing noise in autoencoders and deep networks. *CoRR*, **abs/1406.1831**. 216

Poon, H. and Domingos, P. (2011). Sum-product networks: A new deep architecture. In *UAI'2011*, Barcelona, Spain. 193, 474

Poundstone, W. (2005). *Fortune's Formula: The untold story of the scientific betting system that beat the casinos and Wall Street*. Macmillan. 66

Powell, M. (1987). Radial basis functions for multivariable interpolation: A review. 162

Presley, R. K. and Haggard, R. L. (1994). A fixed point implementation of the backpropagation learning algorithm. In *Southeastcon'94. Creative Technology Transfer-A Global Affair., Proceedings of the 1994 IEEE*, pages 136–138. IEEE. 391

Price, R. (1958). A useful theorem for nonlinear devices having gaussian inputs. *IEEE Transactions on Information Theory*, **4**(2), 69–72. 188

Quiroga, R. Q., Reddy, L., Kreiman, G., Koch, C., and Fried, I. (2005). Invariant visual representation by single neurons in the human brain. *Nature*, **435**(7045), 1102–1107. 319

Raiko, T., Yao, L., Cho, K., and Bengio, Y. (2014). Iterative neural autoregressive distribution estimator (NADE-k). Technical report, arXiv:1406.1485. 603, 623

Raina, R., Madhavan, A., and Ng, A. Y. (2009). Large-scale deep unsupervised learning using graphics processors. In L. Bottou and M. Littman, editors, *ICML 2009*, pages 873–880, New York, NY, USA. ACM. 24, 386

Rall, L. B. (1981). *Automatic Differentiation: Techniques and Applications*. Lecture Notes in Computer Science 120, Springer. 183

Ramsey, F. P. (1926). Truth and probability. In R. B. Braithwaite, editor, *The Foundations of Mathematics and other Logical Essays*, chapter 7, pages 156–198. McMaster University Archive for the History of Economic Thought. 50

Ranzato, M., Poultney, C., Chopra, S., and LeCun, Y. (2007a). Efficient learning of sparse representations with an energy-based model. In *NIPS'2006*. 12, 16, 431, 456, 457, 458

Ranzato, M., Huang, F., Boureau, Y., and LeCun, Y. (2007b). Unsupervised learning of invariant feature hierarchies with applications to object recognition. In *Proceedings of the Computer Vision and Pattern Recognition Conference (CVPR'07)*. IEEE Press. 318

Ranzato, M., Boureau, Y., and LeCun, Y. (2008). Sparse feature learning for deep belief networks. In *NIPS'2007*. 431

Rao, C. (1945). Information and the accuracy attainable in the estimation of statistical parameters. *Bulletin of the Calcutta Mathematical Society*, **37**, 81–89. 125, 260

Rasmus, A., Valpola, H., Honkala, M., Berglund, M., and Raiko, T. (2015). Semi-supervised learning with ladder network. *arXiv preprint arXiv:1507.02672*. 371

Recht, B., Re, C., Wright, S., and Niu, F. (2011). Hogwild: A lock-free approach to parallelizing stochastic gradient descent. In *NIPS'2011*. 388

Reichert, D. P., Seriès, P., and Storkey, A. J. (2011). Neuronal adaptation for sampling-based probabilistic inference in perceptual bistability. In *Advances in Neural Information Processing Systems*, pages 2357–2365. 593

Rezende, D. J., Mohamed, S., and Wierstra, D. (2014). Stochastic backpropagation and approximate inference in deep generative models. In *ICML'2014*. 188

Rifai, S., Vincent, P., Muller, X., Glorot, X., and Bengio, Y. (2011a). Contractive auto-encoders: Explicit invariance during feature extraction. In *ICML'2011*. 451, 452, 453

Rifai, S., Mesnil, G., Vincent, P., Muller, X., Bengio, Y., Dauphin, Y., and Glorot, X. (2011b). Higher order contractive auto-encoder. In *ECML PKDD*. 451, 452

Rifai, S., Dauphin, Y., Vincent, P., Bengio, Y., and Muller, X. (2011c). The manifold tangent classifier. In *NIPS'2011*. 491, 492

Rifai, S., Bengio, Y., Dauphin, Y., and Vincent, P. (2012). A generative process for sampling contractive auto-encoders. In *ICML'2012*. 625

Ringach, D. and Shapley, R. (2004). Reverse correlation in neurophysiology. *Cognitive Science*, **28**(2), 147–166. 322

Roberts, S. and Everson, R. (2001). *Independent component analysis: principles and practice*. Cambridge University Press. 439

Robinson, A. J. and Fallside, F. (1991). A recurrent error propagation network speech recognition system. *Computer Speech and Language*, **5**(3), 259–274. 24, 398

Rockafellar, R. T. (1997). Convex analysis. princeton landmarks in mathematics. 86

Romero, A., Ballas, N., Ebrahimi Kahou, S., Chassang, A., Gatta, C., and Bengio, Y. (2015). Fitnets: Hints for thin deep nets. In *ICLR'2015, arXiv:1412.6550*. 288

Rosen, J. B. (1960). The gradient projection method for nonlinear programming. part i. linear constraints. *Journal of the Society for Industrial and Applied Mathematics*, **8**(1), pp. 181–217. 87

Rosenblatt, F. (1958). The perceptron: A probabilistic model for information storage and organization in the brain. *Psychological Review*, **65**, 386–408. 12, 13, 24

Rosenblatt, F. (1962). *Principles of Neurodynamics*. Spartan, New York. 13, 24

Roweis, S. and Saul, L. K. (2000). Nonlinear dimensionality reduction by locally linear embedding. *Science*, **290**(5500). 152, 482

Rubin, D. B. *et al.* (1984). Bayesianly justifiable and relevant frequency calculations for the applied statistician. *The Annals of Statistics*, **12**(4), 1151–1172. 630

Rumelhart, D., Hinton, G., and Williams, R. (1986a). Learning representations by back-propagating errors. *Nature*, **323**, 533–536. 12, 16, 22, 200, 400, 422

Rumelhart, D. E., Hinton, G. E., and Williams, R. J. (1986b). Learning internal representations by error propagation. In D. E. Rumelhart and J. L. McClelland, editors, *Parallel Distributed Processing*, volume 1, chapter 8, pages 318–362. MIT Press, Cambridge. 19, 24, 200

Rumelhart, D. E., Hinton, G. E., and Williams, R. J. (1986c). Learning representations by back-propagating errors. *Nature*, **323**, 533–536. 156, 326

Rumelhart, D. E., McClelland, J. L., and the PDP Research Group (1986d). *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*. MIT Press, Cambridge. 15, 200

Rumelhart, D. E., McClelland, J. L., and the PDP Research Group (1986e). *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, volume 1. MIT Press, Cambridge. 156

Russakovsky, O., Deng, J., Su, H., Krause, J., Satheesh, S., Ma, S., Huang, Z., Karpathy, A., Khosla, A., Bernstein, M., Berg, A. C., and Fei-Fei, L. (2014a). ImageNet Large Scale Visual Recognition Challenge. 19

Russakovsky, O., Deng, J., Su, H., Krause, J., Satheesh, S., Ma, S., Huang, Z., Karpathy, A., Khosla, A., Bernstein, M., *et al.* (2014b). Imagenet large scale visual recognition challenge. *arXiv preprint arXiv:1409.0575*. 25

Russel, S. J. and Norvig, P. (2003). *Artificial Intelligence: a Modern Approach*. Prentice Hall. 87

Rust, N., Schwartz, O., Movshon, J. A., and Simoncelli, E. (2005). Spatiotemporal elements of macaque V1 receptive fields. *Neuron*, **46**(6), 945–956. 321

Sainath, T., rahman Mohamed, A., Kingsbury, B., and Ramabhadran, B. (2013). Deep convolutional neural networks for LVCSR. In *ICASSP 2013*. 399

Salakhutdinov, R. and Hinton, G. (2009a). Deep Boltzmann machines. In *Proceedings of the International Conference on Artificial Intelligence and Statistics*, volume 5, pages 448–455. 21, 24, 457, 589, 593, 598, 600

Salakhutdinov, R. and Hinton, G. (2009b). Deep Boltzmann machines. In *Proceedings of the Twelfth International Conference on Artificial Intelligence and Statistics (AISTATS 2009)*, volume 8. 596

Salakhutdinov, R. and Hinton, G. E. (2007). Semantic hashing. In *SIGIR'2007*. 417

Salakhutdinov, R. and Hinton, G. E. (2008). Using deep belief nets to learn covariance kernels for Gaussian processes. In *NIPS'07*, pages 1249–1256, Cambridge, MA. MIT Press. 465

Salakhutdinov, R. and Larochelle, H. (2010). Efficient learning of deep Boltzmann machines. In *Proceedings of the Thirteenth International Conference on Artificial Intelligence and Statistics (AISTATS 2010), JMLR W&CP*, volume 9, pages 693–700. 574

Salakhutdinov, R. and Mnih, A. (2008). Probabilistic matrix factorization. In *NIPS'2008*. 419

Salakhutdinov, R. and Murray, I. (2008). On the quantitative analysis of deep belief networks. In W. W. Cohen, A. McCallum, and S. T. Roweis, editors, *ICML 2008*, volume 25, pages 872–879. ACM. 551, 589

Salakhutdinov, R., Mnih, A., and Hinton, G. (2007). Restricted Boltzmann machines for collaborative filtering. In *ICML*. 419

Sanger, T. D. (1994). Neural network learning control of robot manipulators using gradually increasing task difficulty. *IEEE Transactions on Robotics and Automation*, **10**(3). 292

Saul, L. K. and Jordan, M. I. (1996). Exploiting tractable substructures in intractable networks. In *NIPS'95*. MIT Press, Cambridge, MA. 560

Saul, L. K., Jaakkola, T., and Jordan, M. I. (1996). Mean field theory for sigmoid belief networks. *Journal of Artificial Intelligence Research*, **4**, 61–76. 24, 611

Savich, A. W., Moussa, M., and Areibi, S. (2007). The impact of arithmetic representation on implementing mlp-bp on fpgas: A study. *Neural Networks, IEEE Transactions on*, **18**(1), 240–252. 391

Saxe, A. M., Koh, P. W., Chen, Z., Bhand, M., Suresh, B., and Ng, A. (2011). On random weights and unsupervised feature learning. In *Proc. ICML'2011*. ACM. 317

Saxe, A. M., McClelland, J. L., and Ganguli, S. (2013). Exact solutions to the nonlinear dynamics of learning in deep linear neural networks. In *ICLR*. 248, 249, 283

Schmidhuber, J. (1992). Learning complex, extended sequences using the principle of history compression. *Neural Computation*, **4**(2), 234–242. 347

Schmidhuber, J. (1996). Sequential neural text compression. *IEEE Transactions on Neural Networks*, **7**(1), 142–146. 400

Schölkopf, B. and Smola, A. J. (2002). *Learning with kernels: Support vector machines, regularization, optimization, and beyond*. MIT press. 618

Schölkopf, B., Smola, A., and Müller, K.-R. (1998). Nonlinear component analysis as a kernel eigenvalue problem. *Neural Computation*, **10**, 1299–1319. 152, 482

Schölkopf, B., Burges, C. J. C., and Smola, A. J. (1999). *Advances in Kernel Methods — Support Vector Learning*. MIT Press, Cambridge, MA. 16, 134, 162

Schulz, H. and Behnke, S. (2012). Learning two-layer contractive encodings. In *ICANN'2012*, pages 620–628. 452

Schuster, M. (1999). On supervised learning from sequential data with applications for speech recognition. 345

Schuster, M. and Paliwal, K. (1997). Bidirectional recurrent neural networks. *IEEE Transactions on Signal Processing*, **45**(11), 2673–2681. 344

Schwenk, H. (2007). Continuous space language models. *Computer speech and language*, **21**, 492–518. 401, 405

Schwenk, H. (2010). Continuous space language models for statistical machine translation. *The Prague Bulletin of Mathematical Linguistics*, **93**, 137–146. 401, 412

Schwenk, H. (2014). Cleaned subset of wmt '14 dataset. 19

Schwenk, H. and Bengio, Y. (1998). Training methods for adaptive boosting of neural networks. In *NIPS'97*, pages 647–653. MIT Press. 232

Schwenk, H. and Gauvain, J.-L. (2002a). Connectionist language modeling for large vocabulary continuous speech recognition. In *International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, volume 1, pages 765–768. 401

Schwenk, H. and Gauvain, J.-L. (2002b). Connectionist language modeling for large vocabulary continuous speech recognition. In *International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pages 765–768, Orlando, Florida. 405

Schwenk, H. and Gauvain, J.-L. (2005). Building continuous space language models for transcribing european languages. In *Interspeech*, pages 737–740. 401

Schwenk, H., Costa-jussà, M. R., and Fonollosa, J. A. R. (2006). Continuous space language models for the iwslt 2006 task. In *International Workshop on Spoken Language Translation*, pages 166–173. 401, 412

Seide, F., Li, G., and Yu, D. (2011). Conversational speech transcription using context-dependent deep neural networks. In *Interspeech 2011*, pages 437–440. 22

Sejnowski, T. (1987). Higher-order boltzmann machines. In *AIP Conference Proceedings 151 on Neural Networks for Computing*, pages 398–403. American Institute of Physics Inc. 609

Series, P., Reichert, D. P., and Storkey, A. J. (2010). Hallucinations in charles bonnet syndrome induced by homeostasis: a deep boltzmann machine model. In *Advances in Neural Information Processing Systems*, pages 2020–2028. 593

Sermanet, P., Chintala, S., and LeCun, Y. (2012). Convolutional neural networks applied to house numbers digit classification. *CoRR*, **abs/1204.3968**. 396

Sermanet, P., Kavukcuoglu, K., Chintala, S., and LeCun, Y. (2013). Pedestrian detection with unsupervised multi-stage feature learning. In *Proc. International Conference on Computer Vision and Pattern Recognition (CVPR'13)*. IEEE. 22, 193

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, **27**(3), 379—-423. 66

Shannon, C. E. (1949). Communication in the presence of noise. *Proceedings of the Institute of Radio Engineers*, **37**(1), 10–21. 66

Shilov, G. (1977). *Linear Algebra*. Dover Books on Mathematics Series. Dover Publications. 28

Siegelmann, H. (1995). Computation beyond the Turing limit. *Science*, **268**(5210), 545–548. 330

Siegelmann, H. and Sontag, E. (1991). Turing computability with neural nets. *Applied Mathematics Letters*, **4**(6), 77–80. 330

Siegelmann, H. T. and Sontag, E. D. (1995). On the computational power of neural nets. *Journal of Computer and Systems Sciences*, **50**(1), 132–150. 256, 330

Simard, D., Steinkraus, P. Y., and Platt, J. C. (2003). Best practices for convolutional neural networks. In *ICDAR'2003*. 325

Simard, P. and Graf, H. P. (1994). Backpropagation without multiplication. In *Advances in Neural Information Processing Systems*, pages 232–239. 391

Simard, P., Victorri, B., LeCun, Y., and Denker, J. (1992). Tangent prop - A formalism for specifying selected invariances in an adaptive network. In *NIPS'1991*. 489, 490, 492

Simard, P. Y., LeCun, Y., and Denker, J. (1993). Efficient pattern recognition using a new transformation distance. In *NIPS'92*. 489

Simard, P. Y., LeCun, Y. A., Denker, J. S., and Victorri, B. (1998). Transformation invariance in pattern recognition — tangent distance and tangent propagation. *Lecture Notes in Computer Science*, **1524**. 489

Simonyan, K. and Zisserman, A. (2015). Very deep convolutional networks for large-scale image recognition. In *ICLR*. 287

Sjöberg, J. and Ljung, L. (1995). Overtraining, regularization and searching for a minimum, with application to neural networks. *International Journal of Control*, **62**(6), 1391–1407. 225

Skinner, B. F. (1958). Reinforcement today. *American Psychologist*, **13**, 94–99. 292

Smolensky, P. (1986). Information processing in dynamical systems: Foundations of harmony theory. In D. E. Rumelhart and J. L. McClelland, editors, *Parallel Distributed Processing*, volume 1, chapter 6, pages 194–281. MIT Press, Cambridge. 505, 517, 580

Snoek, J., Larochelle, H., and Adams, R. P. (2012). Practical Bayesian optimization of machine learning algorithms. In *NIPS'2012*. 379

Socher, R., Huang, E. H., Pennington, J., Ng, A. Y., and Manning, C. D. (2011a). Dynamic pooling and unfolding recursive autoencoders for paraphrase detection. In *NIPS'2011*. 349

Socher, R., Manning, C., and Ng, A. Y. (2011b). Parsing natural scenes and natural language with recursive neural networks. In *Proceedings of the Twenty-Eighth International Conference on Machine Learning (ICML'2011)*. 349

Socher, R., Pennington, J., Huang, E. H., Ng, A. Y., and Manning, C. D. (2011c). Semi-supervised recursive autoencoders for predicting sentiment distributions. In *EMNLP'2011*. 349

Socher, R., Perelygin, A., Wu, J. Y., Chuang, J., Manning, C. D., Ng, A. Y., and Potts, C. (2013a). Recursive deep models for semantic compositionality over a sentiment treebank. In *EMNLP'2013*. 349, 351

Socher, R., Ganjoo, M., Manning, C. D., and Ng, A. Y. (2013b). Zero-shot learning through cross-modal transfer. In *27th Annual Conference on Neural Information Processing Systems (NIPS 2013)*. 463

Sohl-Dickstein, J., Weiss, E. A., Maheswaranathan, N., and Ganguli, S. (2015). Deep unsupervised learning using nonequilibrium thermodynamics. 629

Sohn, K., Zhou, G., and Lee, H. (2013). Learning and selecting features jointly with point-wise gated Boltzmann machines. In *ICML'2013*. 609

Solla, S. A., Levin, E., and Fleisher, M. (1988). Accelerated learning in layered neural networks. *Complex Systems*, **2**, 625–639. 166

Solomonoff, R. J. (1989). A system for incremental learning based on algorithmic probability. 292

Sontag, E. D. and Sussman, H. J. (1989). Backpropagation can give rise to spurious local minima even for networks without hidden layers. *Complex Systems*, **3**, 91–106. 248

Sordoni, A., Bengio, Y., Vahabi, H., Lioma, C., Simonsen, J., and Nie, J.-Y. (2015). A hierarchical recurrent encoder-decoder for generative context-aware query suggestion. In *Proc. of CIKM*. 417

Spall, J. C. (1992). Multivariate stochastic approximation using a simultaneous perturbation gradient approximation. *IEEE Transactions on Automatic Control*, **37**, 332–341. 183

Spitkovsky, V. I., Alshawi, H., and Jurafsky, D. (2010). From baby steps to leapfrog: how "less is more" in unsupervised dependency parsing. In *HLT'10*. 292

Squire, W. and Trapp, G. (1998). Using complex variables to estimate derivatives of real functions. *SIAM Rev.*, **40**(1), 110—112. 382

Srivastava, N. and Salakhutdinov, R. (2012). Multimodal learning with deep Boltzmann machines. In *NIPS'2012*. 463

Srivastava, N., Hinton, G., Krizhevsky, A., Sutskever, I., and Salakhutdinov, R. (2014). Dropout: A simple way to prevent neural networks from overfitting. *Journal of Machine Learning Research*, **15**, 1929–1958. 232, 234, 235, 600

Srivastava, R. K., Greff, K., and Schmidhuber, J. (2015). Highway networks. *arXiv:1505.00387*. 289

Steinkrau, D., Simard, P. Y., and Buck, I. (2005). Using gpus for machine learning algorithms. *2013 12th International Conference on Document Analysis and Recognition*, **0**, 1115–1119. 386

Stoyanov, V., Ropson, A., and Eisner, J. (2011). Empirical risk minimization of graphical model parameters given approximate inference, decoding, and model structure. In *Proceedings of the 14th International Conference on Artificial Intelligence and Statistics (AISTATS)*, volume 15 of *JMLR Workshop and Conference Proceedings*, pages 725–733, Fort Lauderdale. Supplementary material (4 pages) also available. 602, 614

Supancic, J. and Ramanan, D. (2013). Self-paced learning for long-term tracking. In *CVPR'2013*. 292

Sussillo, D. (2014). Random walks: Training very deep nonlinear feed-forward networks with smart initialization. *CoRR*, **abs/1412.6558**. 284, 286

Sutskever, I. (2012). *Training Recurrent Neural Networks*. Ph.D. thesis, Department of computer science, University of Toronto. 353, 354, 364

Sutskever, I. and Tieleman, T. (2010). On the Convergence Properties of Contrastive Divergence. In Y. W. Teh and M. Titterington, editors, *Proc. of the International Conference on Artificial Intelligence and Statistics (AISTATS)*, volume 9, pages 789–795. 537

Sutskever, I., Martens, J., Dahl, G., and Hinton, G. (2013). On the importance of initialization and momentum in deep learning. In *ICML*. 262, 353, 354, 364

Sutskever, I., Vinyals, O., and Le, Q. V. (2014a). Sequence to sequence learning with neural networks. Technical report, arXiv:1409.3215. 22, 93, 356, 358, 359

Sutskever, I., Vinyals, O., and Le, Q. V. (2014b). Sequence to sequence learning with neural networks. In *NIPS'2014*. 339, 345, 413, 414

Sutton, R. and Barto, A. (1998). *Reinforcement Learning: An Introduction*. MIT Press. 98

Sutton, R. S., Mcallester, D., Singh, S., and Mansour, Y. (2000). Policy gradient methods for reinforcement learning with function approximation. In *NIPS'1999*, pages 1057––1063. MIT Press. 190

Swersky, K. (2010). *Inductive Principles for Learning Restricted Boltzmann Machines*. Master's thesis, University of British Columbia. 449

Swersky, K., Ranzato, M., Buchman, D., Marlin, B., and de Freitas, N. (2011). On autoencoders and score matching for energy based models. In *ICML'2011*. ACM. 544

Swersky, K., Snoek, J., and Adams, R. P. (2014). Freeze-thaw bayesian optimization. *arXiv preprint arXiv:1406.3896*. 379

Szegedy, C., Liu, W., Jia, Y., Sermanet, P., Reed, S., Anguelov, D., Erhan, D., Vanhoucke, V., and Rabinovich, A. (2014a). Going deeper with convolutions. Technical report, arXiv:1409.4842. 21, 22, 24, 193, 238, 289, 306

Szegedy, C., Zaremba, W., Sutskever, I., Bruna, J., Erhan, D., Goodfellow, I. J., and Fergus, R. (2014b). Intriguing properties of neural networks. *ICLR*, **abs/1312.6199**. 238

Taigman, Y., Yang, M., Ranzato, M., and Wolf, L. (2014). Deepface: Closing the gap to human-level performance in face verification. In *CVPR'2014*. 92

Tang, Y. and Eliasmith, C. (2010). Deep networks for robust visual recognition. In *Proceedings of the 27th International Conference on Machine Learning, June 21-24, 2010, Haifa, Israel*. 215

Taylor, G. and Hinton, G. (2009). Factored conditional restricted Boltzmann machines for modeling motion style. In L. Bottou and M. Littman, editors, *ICML 2009*, pages 1025–1032. ACM. 415

Taylor, G., Hinton, G. E., and Roweis, S. (2007). Modeling human motion using binary latent variables. In *NIPS'06*, pages 1345–1352. MIT Press, Cambridge, MA. 415, 416

Tenenbaum, J., de Silva, V., and Langford, J. C. (2000). A global geometric framework for nonlinear dimensionality reduction. *Science*, **290**(5500), 2319–2323. 152, 458, 483

Theis, L., van den Oord, A., and Bethge, M. (2015). A note on the evaluation of generative models. arXiv:1511.01844. 632

Thompson, J., Jain, A., LeCun, Y., and Bregler, C. (2014). Joint training of a convolutional network and a graphical model for human pose estimation. In *NIPS'2014*. 314

Thrun, S. (1995). Learning to play the game of chess. In *NIPS'1994*. 490

Tibshirani, R. J. (1995). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society B*, **58**, 267–288. 210

Tieleman, T. (2008). Training restricted Boltzmann machines using approximations to the likelihood gradient. In W. W. Cohen, A. McCallum, and S. T. Roweis, editors, *ICML 2008*, pages 1064–1071. ACM. 537, 586

Tieleman, T. and Hinton, G. (2009). Using fast weights to improve persistent contrastive divergence. In L. Bottou and M. Littman, editors, *ICML 2009*, pages 1033–1040. ACM. 539

Tipping, M. E. and Bishop, C. M. (1999). Probabilistic principal components analysis. *Journal of the Royal Statistical Society B*, **61**(3), 611–622. 437

Tom Schaul, Ioannis Antonoglou, D. S. (2014). Unit tests for stochastic optimization. In *International Conference on Learning Representations*. 267

Torabi, A., Pal, C., Larochelle, H., and Courville, A. (2015). Using descriptive video services to create a large data source for video annotation research. *arXiv preprint arXiv: 1503.01070*. 140

Torralba, A., Fergus, R., and Weiss, Y. (2008). Small codes and large databases for recognition. In *Proceedings of the Computer Vision and Pattern Recognition Conference (CVPR'08)*, pages 1–8. 417

Tu, K. and Honavar, V. (2011). On the utility of curricula in unsupervised learning of probabilistic grammars. In *IJCAI'2011*. 292

Turaga, S. C., Murray, J. F., Jain, V., Roth, F., Helmstaedter, M., Briggman, K., Denk, W., and Seung, H. S. (2010). Convolutional networks can learn to generate affinity graphs for image segmentation. *Neural Computation*, **22**(2), 511–538. 314

Töscher, A., Jahrer, M., and Bell, R. M. (2009). The bigchaos solution to the netflix grand prize. 419

Uria, B., Murray, I., and Larochelle, H. (2013). Rnade: The real-valued neural autoregressive density-estimator. In *NIPS'2013*. 622, 624

van den Oörd, A., Dieleman, S., and Schrauwen, B. (2013). Deep content-based music recommendation. In *NIPS'2013*. 420

van der Maaten, L. and Hinton, G. E. (2008). Visualizing data using t-SNE. *J. Machine Learning Res.*, **9**. 400, 483

Vanhoucke, V., Senior, A., and Mao, M. Z. (2011). Improving the speed of neural networks on cpus. In *Proc. Deep Learning and Unsupervised Feature Learning NIPS Workshop*. 385, 392

Vapnik, V. N. (1982). *Estimation of Dependences Based on Empirical Data*. Springer-Verlag, Berlin. 105

Vapnik, V. N. (1995). *The Nature of Statistical Learning Theory*. Springer, New York. 105

Vapnik, V. N. and Chervonenkis, A. Y. (1971). On the uniform convergence of relative frequencies of events to their probabilities. *Theory of Probability and Its Applications*, **16**, 264–280. 105

Vincent, P. (2011a). A connection between score matching and denoising autoencoders. *Neural Computation*, **23**(7). 447, 449, 451, 625

Vincent, P. (2011b). A connection between score matching and denoising autoencoders. *Neural Computation*, **23**(7), 1661–1674. 544, 626

Vincent, P. and Bengio, Y. (2003). Manifold Parzen windows. In *NIPS'2002*. MIT Press. 482

Vincent, P., Larochelle, H., Bengio, Y., and Manzagol, P.-A. (2008). Extracting and composing robust features with denoising autoencoders. In *ICML 2008*. 216, 446

Vincent, P., Larochelle, H., Lajoie, I., Bengio, Y., and Manzagol, P.-A. (2010). Stacked denoising autoencoders: Learning useful representations in a deep network with a local denoising criterion. *J. Machine Learning Res.*, **11**. 446

Vinyals, O., Kaiser, L., Koo, T., Petrov, S., Sutskever, I., and Hinton, G. (2014a). Grammar as a foreign language. Technical report, arXiv:1412.7449. 358

Vinyals, O., Toshev, A., Bengio, S., and Erhan, D. (2014b). Show and tell: a neural image caption generator. arXiv 1411.4555. 358

Vinyals, O., Toshev, A., Bengio, S., and Erhan, D. (2015). Show and tell: a neural image caption generator. In *CVPR'2015*. arXiv:1411.4555. 94

Viola, P. and Jones, M. (2001). Robust real-time object detection. In *International Journal of Computer Vision*. 390

Von Melchner, L., Pallas, S. L., and Sur, M. (2000). Visual behaviour mediated by retinal projections directed to the auditory pathway. *Nature*, **404**(6780), 871–876. 14

Waibel, A., Hanazawa, T., Hinton, G. E., Shikano, K., and Lang, K. (1989). Phoneme recognition using time-delay neural networks. *IEEE Transactions on Acoustics, Speech, and Signal Processing*, **37**, 328–339. 326, 393, 398

Wan, L., Zeiler, M., Zhang, S., LeCun, Y., and Fergus, R. (2013). Regularization of neural networks using dropconnect. In *ICML'2013*. 236

Wang, S. and Manning, C. (2013). Fast dropout training. In *ICML'2013*. 235

Wang, Z., Zhang, J., Feng, J., and Chen, Z. (2014a). Knowledge graph and text jointly embedding. In *Proc. EMNLP'2014*. 423

Wang, Z., Zhang, J., Feng, J., and Chen, Z. (2014b). Knowledge graph embedding by translating on hyperplanes. In *Proc. AAAI'2014*. 423

Warde-Farley, D., Goodfellow, I. J., Lamblin, P., Desjardins, G., Bastien, F., and Bengio, Y. (2011). pylearn2. `http://deeplearning.net/software/pylearn2`. 387

Wawrzynek, J., Asanovic, K., Kingsbury, B., Johnson, D., Beck, J., and Morgan, N. (1996). Spert-ii: A vector microprocessor system. *Computer*, **29**(3), 79–86. 391

Weaver, L. and Tao, N. (2001). The optimal reward baseline for gradient-based reinforcement learning. In *Proc. UAI'2001*, pages 538–545. 190

Weinberger, K. Q. and Saul, L. K. (2004). Unsupervised learning of image manifolds by semidefinite programming. In *CVPR'2004*, pages 988–995. 152, 483

Weiss, Y., Torralba, A., and Fergus, R. (2008). Spectral hashing. In *NIPS*, pages 1753–1760. 417

Welling, M., Zemel, R. S., and Hinton, G. E. (2002). Self supervised boosting. In *Advances in Neural Information Processing Systems*, pages 665–672. 616

Welling, M., Rosen-Zvi, M., and Hinton, G. E. (2005). Exponential family harmoniums with an application to information retrieval. In *NIPS'04*, volume 17, Cambridge, MA. MIT Press. 603

Werbos, P. J. (1981). Applications of advances in nonlinear sensitivity analysis. In *Proceedings of the 10th IFIP Conference, 31.8 - 4.9, NYC*, pages 762–770. 199

Weston, J., Ratle, F., and Collobert, R. (2008). Deep learning via semi-supervised embedding. In W. W. Cohen, A. McCallum, and S. T. Roweis, editors, *ICML 2008*, pages 1168–1175, New York, NY, USA. ACM. 465

Weston, J., Bengio, S., and Usunier, N. (2010). Large scale image annotation: learning to rank with joint word-image embeddings. *Machine Learning*, **81**(1), 21–35. 351

Weston, J., Chopra, S., and Bordes, A. (2014). Memory networks. *arXiv preprint arXiv:1410.3916*. 361, 424

Widrow, B. and Hoff, M. E. (1960). Adaptive switching circuits. In *1960 IRE WESCON Convention Record*, volume 4, pages 96–104. IRE, New York. 13, 19, 21, 24

Wikipedia (2015). List of animals by number of neurons — wikipedia, the free encyclopedia. [Online; accessed 4-March-2015]. 21, 24

Williams, C. K. I. and Rasmussen, C. E. (1996). Gaussian processes for regression. In *NIPS'95*, pages 514–520. MIT Press, Cambridge, MA. 134

Williams, R. J. (1992). Simple statistical gradient-following algorithms connectionist reinforcement learning. *Machine Learning*, **8**, 229–256. 188, 362

Wilson, J. R. (1984). Variance reduction techniques for digital simulation. *American Journal of Mathematical and Management Sciences*, **4**(3), 277—312. 189

Wiskott, L. and Sejnowski, T. J. (2002). Slow feature analysis: Unsupervised learning of invariances. *Neural Computation*, **14**(4), 715–770. 439, 440

Wolpert, D. and MacReady, W. (1997). No free lunch theorems for optimization. *IEEE Transactions on Evolutionary Computation*, **1**, 67–82. 256

Wolpert, D. H. (1996). The lack of a priori distinction between learning algorithms. *Neural Computation*, **8**(7), 1341–1390. 107

Wu, R., Yan, S., Shan, Y., Dang, Q., and Sun, G. (2015). Deep image: Scaling up image recognition. arXiv:1501.02876. 22, 388

Wu, Z. (1997). Global continuation for distance geometry problems. *SIAM Journal of Optimization*, **7**, 814–836. 291

Xiong, H. Y., Barash, Y., and Frey, B. J. (2011). Bayesian prediction of tissue-regulated splicing using RNA sequence and cellular context. *Bioinformatics*, **27**(18), 2554–2562. 235

Xu, K., Ba, J. L., Kiros, R., Cho, K., Courville, A., Salakhutdinov, R., Zemel, R. S., and Bengio, Y. (2015a). Show, attend and tell: Neural image caption generation with visual attention. In *ICML'2015*. 94, 191

Xu, K., Ba, J. L., Kiros, R., Cho, K., Courville, A., Salakhutdinov, R., Zemel, R. S., and Bengio, Y. (2015b). Show, attend and tell: Neural image caption generation with visual attention. arXiv:1502.03044. 358

Yosinski, J., Clune, J., Bengio, Y., and Lipson, H. (2014). How transferable are features in deep neural networks? In *NIPS'2014*. 288

Younes, L. (1998). On the convergence of Markovian stochastic algorithms with rapidly decreasing ergodicity rates. In *Stochastics and Stochastics Models*, pages 177–228. 537, 586

Yu, D., Wang, S., and Deng, L. (2010). Sequential labeling using deep-structured conditional random fields. *IEEE Journal of Selected Topics in Signal Processing*. 287

Zaremba, W. and Sutskever, I. (2014). Learning to execute. arXiv 1410.4615. 292

Zaremba, W. and Sutskever, I. (2015). Reinforcement learning neural turing machines. *arXiv:1505.00521*. 362

Zaslavsky, T. (1975). *Facing Up to Arrangements: Face-Count Formulas for Partitions of Space by Hyperplanes*. Number no. 154 in Memoirs of the American Mathematical Society. American Mathematical Society. 471

Zeiler, M. D. and Fergus, R. (2014). Visualizing and understanding convolutional networks. In *ECCV'14*. 6

Zhou, B., Khosla, A., Lapedriza, A., Oliva, A., and Torralba, A. (2015). Object detectors emerge in deep scene CNNs. ICLR'2015, arXiv:1412.6856. 472

Zhou, J. and Troyanskaya, O. G. (2014). Deep supervised and convolutional generative stochastic network for protein secondary structure prediction. In *ICML'2014*. 629

Zöhrer, M. and Pernkopf, F. (2014). General stochastic networks for classification. In *NIPS'2014*. 629