DOCTORAL (PHD) STUDIES

COURSE UNIT DESCRIPTION

Course unit title	Scientific areas	Faculty	Institute, department
Deep Neural Networks	Informatics (N 009)	Faculty of Mathematics and Informatics	Institute of Data Science and Digital Technologies

Study method	Number of credits	Study method	Number of credits
Lectures	1 (spring)	Consultations	1
Individual works	4	Seminars	1

Summary

Even though the idea of artificial neural networks rose more than 50 years ago, lately, they become popular due to developed theological computational solutions. Artificial neural networks are attributed to the class of computational intelligence methods. During the course, students will be introduced not only to simple structure neural networks but also to those of complex structure. The focus of the course will be on neural networks and their structures that allows solving rather complex data classification, image, sound analysis or other tasks.

1. Introduction to artificial neural networks
   a. Artificial and biological neuron relation, concepts.
   b. Machine learning fundamentals: training, validation, testing, supervised and unsupervised learning.
   c. Perceptron, multilayer perceptron, activation functions, learning by back propagation, stochastic gradient descent, hyperparameters.
   d. Linear and logistic regression relation with neural networks, random variable, probabilities, information theory, Bayes statistics.
2. Autoencoders
   a. Factor analysis and factor models
   b. Encoder, decoders, latent variables and vectors (codebook, bottleneck).
   c. Noise reduction, region inpainting.
   d. Variational autoencoders
      i. Latent vector separation, distribution based parameter estimation, reparameterization and stochastics.
   e. Disentangled variational autoencoders
      i. Uncorrelated neurons of the latent distribution.
      ii. Reinforcement learning.
3. Convolutional neural networks
   a. Convolution, pooling and strides.
   b. Optimization functions and accuracy metrics.
   c. Reguliarization: dropout, batch normalization.
   d. Parameter space probability density and Bayesian networks.
4. Deep belief and generative adversal networks
   a. Boltzmann machines, restricted, convolutional and deep Boltzmann machines
   b. Discriminator and generative stochastic networks, conditional neural networks
5. Deep reinforced learning

   a. Markov decision process, Q-learning, policy gradients, credit assignment problem, reward shaping and sparsity, the alignment problem.
6. Recurrent and recursive neural networks
   a. Bidirectional and deep recurrent networks,
   b. Recursive networks, time dimension modelling, multiple time scales, Long-Short-Term-Memory dependencies, backpropagation through time and structure.

Practical task: students will be asked to solve the specified tasks using image analysis and processing methods.

Main literature
Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, "Dive into Deep Learning", 2021. https://d2l.ai/index.html
Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", MIT Press, 2016 http://www.deeplearningbook.org
Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, "Dive into Deep Learning", 2021. https://d2l.ai/index.html
Higgins, I., Matthey, L., Pal, A., Burgess, C., Glorot, X., Botvinick, M., Mohamed, S. & Lerchner, A. (2016). beta-VAE: Learning basic visual concepts with a constrained variational framework. https://openreview.net/forum?id=Sy2fzU9gl
Liu, X., Li, Y., & Wang, Q. (2018). Multi-View Hierarchical Bidirectional Recurrent Neural Network for Depth Video Sequence Based Action Recognition. International Journal of Pattern Recognition and Artificial Intelligence. https://doi.org/10.1142/S0218001418500337
Olabiyi, O., & Martinson, E. (2018). U.S. Patent Application No. 15/362,720. https://patents.google.com/patent/US20180053108A1/en
Graves, A., & Schmidhuber, J. (2005). Framewise phoneme classification with bidirectional LSTM and other neural network architectures. Neural Networks, 18(5-6), 602-610. https://doi.org/10.1016/j.neunet.2005.06.042
Mikolov, T., Kombrink, S., Burget, L., Černocký, J., & Khudanpur, S. (2011, May). Extensions of recurrent neural network language model. In Acoustics, Speech and Signal Processing (ICASSP), 2011 IEEE International Conference on (pp. 5528-5531). IEEE. https://doi.org/10.1109/ICASSP.2011.5947611
Zaremba, W., Sutskever, I., & Vinyals, O. (2014). Recurrent neural network regularization. arXiv preprint arXiv:1409.2329. https://arxiv.org/abs/1409.2329
Masci, J., Meier, U., Cireşan, D., & Schmidhuber, J. (2011, June). Stacked convolutional auto-encoders for hierarchical feature extraction. In International Conference on Artificial Neural Networks (pp. 52-59). Springer, Berlin, Heidelberg. https://link.springer.com/chapter/10.1007%2F978-3-642-21735-7_7
Liu, Y., Feng, X., & Zhou, Z. (2016). Multimodal video classification with stacked contractive autoencoders. Signal Processing, 120, 761-766. https://doi.org/10.1016/j.sigpro.2015.01.001
Xie, J., Xu, L., & Chen, E. (2012). Image denoising and inpainting with deep neural networks. In Advances in neural information processing systems (pp. 341-349). http://papers.nips.cc/paper/4686-image-denoising-and-inpainting-with-deep-neural-networks
Karpathy, A. (2016). Deep reinforcement learning: Pong from pixels. http://karpathy.github.io/2016/05/31/rl/

Lecturer(s) (name, surname)	Science degree	Main publications
Povilas Treigys	dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Povilas+Treigys
Olga Kurasova	dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Olga+Kurasova
Viktor Medvedev	dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Viktor+Medvedev