**RTU Course "Deep metric learning"**

**12309 Mākslīgā intelekta un sistēmu inženierijas katedra**

***General data***

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| Code |  |
| Course title | Deep metric learning |
| Course status in the programme | Courses of Free Choice |
| Course level | Post-graduate Studies |
| Course type | Academic |
| Field of study | Computer Science |
| Responsible instructor | Ēvalds Urtāns, PhD. Cand. |
| Volume of the course: parts and credits points | 1 part, 2.0 Credit Points, 3.0 ECTS credits |
| Language of instruction | LV, EN |
| Possibility of distance learning | Not planned |
| Maximum auditorium capacity | 64 |
| Maximum number of students per semester | 64 |
| Abstract | Deep metric learning provides the ability to reduce high-dimensional data, like photos, video, or audio recordings, to low-dimensional latent vectors and maintain semantic information within the latent space. These kinds of models are widely used in reidentification tasks where the model is trained once and then used on datasets that it has never seen before to cluster novel classes. For example, these kinds of models are capable of reidentifying a person by their face even though this person has never been seen by a model.  Deep metric machine is also important in the field of generative models where the dimensions of the latent vector should be disentangled to control the semantic features of the generated output.  For example, by changing the scalar values in one of the dimensions of a latent vector in the generated photo, the color of hair is changed, but by changing another scalar value in one of the other dimensions it changes the facial expressions. These kinds of results can be achieved by GAN, VEA, or other types of generative models. In this course, new scientists will learn all the necessary theories and tools step by step, using practical examples to start working on their own research directions. The emphasis will be on fundamental science that can be applied also in practical research work. Students will be able to start work on world-class research work using RTU supercomputer (HPC). |
| Goals and objectives of the course in terms of competences and skills | The goal of this course is to prepare new scientists to work in the field of deep metric machine learning as well as to give knowledge and practical skills to apply it to commercial problem sets.  Skills after completing the course:   * Deep metric learning methods * Generative deep learning methods * Clustering and dimension reduction methods * PyTorch framework * Usage of High Performance Cluster (HPC) |
| Structure and tasks of independent studies | After each lecture, there will be a homework that will determine most of the total grade. There will also be practical work that should be completed during the lectures. |
| Recommended literature | 1. Martinez, Aleix M. and A. Kak. “PCA versus LDA.” IEEE Trans. Pattern Anal. Mach. Intell. 23 (2001): 228-233. 2. Manmatha, R. et al. “Sampling Matters in Deep Embedding Learning.” 2017 IEEE International Conference on Computer Vision (ICCV) (2017): 2859-2867. 3. McInnes, L. et al. “hdbscan: Hierarchical density based clustering.” J. Open Source Softw. 2 (2017): 205. 4. Schroff, Florian et al. “FaceNet: A unified embedding for face recognition and clustering.” 2015 IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (2015): 815-823. 5. Movshovitz-Attias, Yair et al. “No Fuss Distance Metric Learning Using Proxies.” 2017 IEEE International Conference on Computer Vision (ICCV) (2017): 360-368. 6. Kingma, Diederik P. and M. Welling. “Auto-Encoding Variational Bayes.” CoRR abs/1312.6114 (2014): n. pag. 7. Radford, A., Metz, L., & Chintala, S. (2016). Unsupervised Representation Learning with Deep Convolutional Generative Adversarial Networks. CoRR, abs/1511.06434. 8. Arjovsky, Martín et al. “Wasserstein GAN.” ArXiv abs/1701.07875 (2017): n. pag. 9. Gao, R. et al. “Zero-VAE-GAN: Generating Unseen Features for Generalized and Transductive Zero-Shot Learning.” IEEE Transactions on Image Processing 29 (2020): 3665-3680. |
| Equipment requirements | Projector, computer for each student with internet access, trial access to RTU HPC |
| Course prerequisites | Students must be proficient in the following disciplines before starting a course:   * Machine learning methods * Calculus (partial derivatives, differential equations, integrals) * Probability theory (probabilistic distributions – Gaussian, Alpha, Beta, Uniform) * Information theory (cross-entropy, mutual information, Kolmogorov–Smirnov, Anderson-Darling, Kolmogorov–Smirnov) * Statistics (MSE, R2) * Design Patterns (MVC, Observer, Singleton) * Object Oriented Programming (OOP, UML) * PyTorch or Tensorflow framework * Python (Anaconda, multiprocessing, threading, cuda, numpy) * GIT (SourceTree or shell commands) * Linux (Aptitude, Anaconda, nVidia drivers, cuda, Ubuntu, Shell Screen) |
| Courses acquired before | DSP422 Artificial Intelligence  DSP793 Introduction in deep learning |

***Course outline***

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| --- | --- | --- | --- | --- |
| Theme | Full time studies | | Full time studies | |
|  | Contact Hours | Indep. work | Contact Hours | Indep. work |
| Dimension reduction methods: PCA, NCA | 4 | 4 | 0 | 0 |
| Clustering methods: K-Means, X-Means, G-Means | 4 | 4 | 0 | 0 |
| Clustering methods: DBSCAN, HDBSCAN | 4 | 4 | 0 | 0 |
| Deep metric learning: “Contrastive Loss” | 4 | 4 | 0 | 0 |
| Deep metric learning: “Triplet Loss” | 4 | 4 | 0 | 0 |
| Deep metric learning: “Proxy-NCA Loss” | 4 | 4 | 0 | 0 |
| Generative models: VAE | 4 | 4 | 0 | 0 |
| Generative models: GAN | 4 | 4 | 0 | 0 |
| Generative models: W-GAN | 4 | 4 | 0 | 0 |
| Kopā: | 36 | 28 | 0 | 0 |

***Learning outcomes and assessment***

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| Learning outcomes | Assessment methods |
| Ability to understand and use dimension reduction methods | Homework and practical work during lectures |
| Ability to understand and use clustering methods | Homework and practical work during lectures |
| Ability to understand and use Deep Metric Learning methods | Homework and practical work during lectures |
| Ability to understand and use Generative Deep Learning methods | Homework and practical work during lectures |
| Ability to use RTU HPC | Homework and practical work during lectures |

***Study subject structure***

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| Part | Semester | | | CP | ECTS | Hours per Week | | | Tests | | | Tests (free choice) | | |
|  | Autumn | Spring | Summer |  |  | Lectures | Practical | Lab. | Test | Exam | Work | Test | Exam | Work |
| 1. |  | \* |  | 4.0 | 6.0 | 2.0 | 2.0 | 0.0 | \* |  |  |  |  |  |