DOCTORAL (PHD) STUDIES

COURSE UNIT DESCRIPTION

Course unit title	Scientific areas	Faculty	Institute, department
Image analysis and processing	Informatics engineering (T 007)	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

During the course, the doctoral students will be provided with knowledge on the field of image analysis, processing and computer vision. Various topics will be discussed such as image segmentation, motion detection, feature extraction, automatic image inpainting. Artificial intelligence methods used in image processing such, a histogram of oriented gradients, a bag of words, and deep convolutional networks will be presented as well.

1. Introduction to computer vision
    a. Image understanding, machine vision, robot vision, image analysis and understanding, colour spaces.
    b. Fundamental image processing steps, digital image representation, spatial and intensity resolution, image interpolation.
    c. Basic pixel relationships, neighbours, adjacency, connectivity and regions, distance measures, convolution.
2. Filtering
    a. Noise, noise models, model estimation, derivatives.
    b. Spatial filtering and frequency filtering: intensity transformations, histogram processing, smoothing and sharpening, filter combinations.
3. Image segmentation
    a. Metrics, pixel intensity and histogram based object segmentation.
    b. First order derivate based operators: Prewitt, Sobel.
    c. Second order derivative operators LoG, Marr-Hildreth.
    d. Image thresholding: Otsu and other adaptive methods.
    e. Gaussian gradient and Canny edge detection.
    f. Edge detection based object segmentation.
4. Image morphology
    a. Structuring elements
    b. Binary morphology: dilation, erosion, opening and closing, Hit&Miss transform, region boundaries, conditional opening and closing, iterative morphology (skeletonisation).
    c. Grey and colour morphology.
5. Image pyramids
    a. Gaussian and Laplacian pyramid: reduce and expand.

b. Wavelets and image compression, entropy.

6. Descriptors
    a. Feature vectors and points of interest, corner descriptors.
    b. Region descriptors: ORB, SURF, SIFT.
    c. Principal component analysis.
7. Optical flow
    a. Image displacement and motion-based segmentation, alignment and video compression
    b. Horn&Schunck optical flow, Lucas and Kanade method
8. Motion models
    a. Spatial image transforms homogenous coordinates, rotation, translation, affine, projection, perspective projection, etc.
    b. Global motion
    c. Image mosaics
9. Object trackers
    a. Kanade-Lucas-Tomasi
    b. Multiple camera tracking
10. Object recognition
    a. Histograms of oriented gradients, Bag of words
    b. Statistical classifiers
    c. Convolutional neural networks
11. Camera calibration
    a. Extrinsic and intrinsic parameters
    b. Object transfer
    c. Pose estimation
    d. Camera model, camera location, camera orientation, image and camera coordinates
    e. Computation of camera parameters
12. Fundamental matrix
    a. Image and 3D point relation
    b. Epipolar geometry
    c. Normalized 8-point algorithm
    d. Robust matrix estimation
    e. Stereo imaging (geometry) and depth
    f. Image rectification and stereo methods (correlation, Bernard‘s, simulated annealing methods)

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

Main literature
Gonzales, R., Woods, R. Digital Image Processing 4th Edition. Pearson; 4th edition (2017)
Hau, C. C. (Ed.). (2015). *Handbook of pattern recognition and computer vision*. World Scientific.
Talebi, H., & Milanfar, P. (2014). Global image denoising. *IEEE Transactions on Image Processing*, *23*(2), 755-768.
Starck, J. L., Candès, E. J., & Donoho, D. L. (2002). The curvelet transform for image denoising. *IEEE Transactions on image processing*, *11*(6), 670-684.

Pal, N. R., & Pal, S. K. (1993). A review on image segmentation techniques. *Pattern recognition*, *26*(9), 1277-1294
Shi, J., & Malik, J. (2000). Normalized cuts and image segmentation. *IEEE Transactions on pattern analysis and machine intelligence*, *22*(8), 888-905.
Protter, M., & Elad, M. (2009). Image sequence denoising via sparse and redundant representations. *IEEE Transactions on Image Processing*, *18*(1), 27-35.
Soille, P. (2013). *Morphological image analysis: principles and applications*. Springer Science & Business Media.
Rosenfeld, A. (Ed.). (2013). Multiresolution image processing and analysis (Vol. 12). Springer Science & Business Media.
Cimpoi, M., Maji, S., & Vedaldi, A. (2015, June). Deep filter banks for texture recognition and segmentation. In *Computer Vision and Pattern Recognition (CVPR), 2015 IEEE Conference on* (pp. 3828-3836). IEEE.
Wu, Y., Lim, J., & Yang, M. H. (2015). Object tracking benchmark. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *37*(9), 1834-1848.
Fortun, D., Bouthemy, P., & Kervrann, C. (2015). Optical flow modeling and computation: a survey. *Computer Vision and Image Understanding*, *134*, 1-21.
Mahendran, A., & Vedaldi, A. (2015). Understanding deep image representations by inverting them.
Chen, L. C., Papandreou, G., Kokkinos, I., Murphy, K., & Yuille, A. L. (2018). Deeplab: Semantic image segmentation with deep convolutional nets, atrous convolution, and fully connected crfs. *IEEE transactions on pattern analysis and machine intelligence*, *40*(4), 834-848.
Zhang, Z. (2014). Camera calibration. In *Computer vision* (pp. 76-77). Springer US.
Yamaguchi, K., McAllester, D., & Urtasun, R. (2014, September). Efficient joint segmentation, occlusion labeling, stereo and flow estimation. In *European Conference on Computer Vision* (pp. 756-771). Springer, Cham.

Lecturer(s) (name, surname)	Science degree	Main publications
Povilas Treigys	Dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Povilas+Treigys
Jolita Bernatavičienė	Dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Jolita+Bernatavi%C4%8Dien%C4%97
Gintautas Tamulevičius	Dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Gintautas+Tamulevičius