UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Mathematics of Data Science
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Baran, Ágnes Éva
Syllabus	Descriptive statistics, Inferential statistics. Fundamental probability distributions, multivariate normal distribution. Interpolation. Bi- and multivariate linear regression. Regularization. Dimensionality reduction, principal component analysis. Bayes's Rule classifier, kernel functions, SVM. Logistic regression. Fundamental numerical optimization algorithms (gradient method, Newton's method, quasi-Newton methods). Stochastic optimization.
Bibliography	J. Nocedal, S. Wright, Numerical Optimization, Springer, 2006. A.J. Izenman, Modern Multivariate Statistical Techniques, Springer, 2008. W.K. Härdle, L. Simar, Applied Multivariate Statistical Analysis, Springer, 2015. I. Goodfellow, Y. Bengio, A. Courville, Deep learning, MIT Press, 2016.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Machine learning
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Harangi Balázs
Syllabus	Basic concepts of machine learning, Linear algebra. Information theory and statistics. Numerical computation. Data collection and preprocessing. Dimensionality reduction. Models of regression. Classification. Clustering. Supervised and unsupervised learning.
Bibliography	1. W. McKinney: Python for Data Analysis (1st ed.). O'Reilly Media, Inc. 2012. 2. C. Bishop: Pattern Recognition and Machine Learning, Springer, 2006. 3. D. Conway, J.M. White: Machine Learning for Hackers, O'Reilly Media, Inc., 2012. 4. I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Big Data Processing

Type of Course Compulsorily eligible

Responsible Tutor Dr. Tomán, Henrietta

Syllabus Basic concepts of big data processing, Architectures for Big data processing and storage, Sparse representations, Graph-based processing of big data, Complex networks, Distributed processing using MapReduce, Recommendation Systems, Large-scale machine learning

Bibliography

1. Rajaraman, J. D. Ullman: Mining of Massive Datasets, Cambridge University Press, 2011
2. T. White: Hadoop: The Definitive Guide, Yahoo Press, 2012.
3. I. Robinson, J. Webber, E. Eifrém: Graph Databases, O'Reilly Media, 2012.
4. L. Lovasz: Large Networks and Graph Limits, Colloquium Publications, 2012.
5. R. van der Hofstad: Random Graphs and Complex Networks, Eindhoven University of Technology, 2014.
6. Y. Bengio: Learning Deep Architectures for AI, Foundations & Trends in Machine Learning, 2009.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Topics in geometry
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Bácsó, Sándor
Syllabus	Equations of lines and planes. The distance and angle of spatial elements. Conics. Affine transformations, affine image of ellipse. Projectivity. Moebius transformations. Equations of curves and surfaces, arc length, curvature and torsion of curves. First and second fundamental forms of surfaces. Curvatures. The projection of space onto plane: Monge projection, axonometry, central projection.
Bibliography	1. Topogonov, V. A., Differential geometry of curves and surfaces, Birkhauser, 206 p., 2006. 2. Shifrin, T., Differential geometry of curves and surfaces, alpha.math.uga.edu/~shifrin/Diff.Geo.pdf, 2014. 3. Kuhnel, W.: Differential Geometry: Curves -- Surfaces -- Manifolds, American Mathematical Society, 2015. 4. Schay, G., A concise introduction to linear algebra, Birkhauser, 320p., 2012.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Low-level image processing

Type of Course Compulsorily eligible

Responsible Tutor Dr. Fazekas, Attila

Syllabus The image, its representation and properties. The digital image, its mathematical background and data structures for images. Image pre-processing (geometric transformations, pixel brightness transformations, local pre-processing). Segmentation. Shape representation and description and its application.

Bibliography

1. M. Sonka, V. Hlavac, and R. Boyle: Image Processing, Analysis, and Machine Vision. Cengage Learning, 4. edition, 2014.
2. R. C. Gonzalez, R. E. Woods: Digital Image Processing. Pearson, 4. edition, 2017.
3. J. C. Russ, F. B. Neal: The Image Processing Handbook. CRC Press, 7. edition, 2015.
4. M. Petrou, C. Petrou: Image Processing: The Fundamentals. Wiley, 2. edition, 2010.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Discrete stohastic optimization

Type of Course Compulsorily eligible

Responsible Tutor Dr. Hajdu, András

Syllabus Optimization methods, stohastic search algorithms, simulated annealing, evolutionary and particle swarm algorithms. Global optimization, convergence rate. Stohactic variants of combinatorical optimization problems. Sampling strategies, optimal allocation of computational resources, noisy evaluation of target function. Efficient algorithms in decision problems, dynamic programming, implementation in distributed environments.

Bibliography

1. James C. Spall: Introduction to Stochastic Search and Optimization, Wiley, 2003.
2. Alexander Shapiro, Darinka Dentcheva, Andrzej Ruszczynski: Lectures on Stochastic Programming: Modeling and Theory, MPS-SIAM Series on Optimization, 2009.
3. András Prékopa: Stochastic Programming, Kluwer Academic Publishers Group, 2010.
4. Panos Kouvelis, Gang Yu: Robust Discrete Optimization and Its Applications, Kluwer Academic Publishers Group, 2010.
5. Dmitrii Lozovanu, Stefan Pickl: Optimization of Stochastic Discrete Systems and Control on Complex Networks, Springer, 2015.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Image processing algorithms

Type of Course Compulsorily eligible

Responsible Tutor Dr. Hajdu András

Syllabus Preprocessing. Efficient implementations. Image manipulation. Geometrical and morphological algorithms. Biomedical image segmentation, image registration. Motion detection and tracking, background estimation. Machine learning based methods.

Bibliography

1. B. Batchelor, F. Waltz: Intelligent Machine Vision, Springer, London, 2001.
2. William K. Pratt, Digital Image Processing, John Wiley & Sons, Inc., 1991.
3. Advanced Algorithmic Approaches to Medical Image Segmentation (J.S. Suri, S.K. Setarehdan, S. Singh eds.), Springer, London, 2002.
4. I. Pitas: Digital Image Processing: Algorithms and Applications, John Wiley Sons, 2000.
5. J. R. Parker: Algorithms for Image Processing and Computer Vision, 2nd Edition, John Wiley & Sons Ltd., New York, 2010.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Discrete Mathematics

Type of Course Compulsorily eligible

Responsible Tutor Dr. Hajdu, Lajos

Syllabus Graphs, connected graphs, pairings. Paths and cycles. Graph theoretical algorithms. Enumeration problems, permutations and partitions. Latin squares and orthogonal latin squares. Recurrences and generating functions. Extremal set theory.

Bibliography

1. D. West: Introduction to Graph Theory, Pearson, 2017.
2. P. J. Cameron: Combinatorics: Topics, Techniques, Algorithms, Cambridge University Press, 1994.
3. J. L. Hirst, M. Mossinghoff, J. Harris: Combinatorics and Graph Theory, Springer-Verlag New York, 2011.
4. G. Agnarsson, R. Greenlaw: Graph Theory: Modeling, Applications, and Algorithms, Pearson, 2006.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Information and Scientific Visualization

Type of Course Compulsorily eligible

Responsible Tutor Dr. Zichar, Marianna

Syllabus The relationship between computer graphics and visualization. Basic and advanced level data representation techniques. The visualization pipeline. Scalar, vector and tensor visualization. Domain-modeling techniques. Cutting, selection, grid construction from scattered points. Basic imaging methods. Shape representation and analysis. Volume visualization. Image and object order techniques. Information visualization. The visualization of tables, graphs, and texts. Visualization of relations. Multivariate data visualization. Interactive visualization softwares.

Bibliography

1. C. Telea: Data Visualization: Principles and Practice, Second Edition, A K Peters/CRC Press, 2014.
2. G. Farin, D. Hansford: Mathematical Principles for Scientific Computing and Visualization, A K Peters/CRC Press, 2008.
3. H. Wright: Introduction to Scientific Visualization, Springer, 2007.
4. Ware: Information Visualization, Third Edition: Perception for Design (Interactive Technologies), Morgan Kaufmann, 2012.
5. M. O. Ward, G. Grinstein, Daniel Keim: Interactive Data Visualization, Foundation, Techniques, and Applications, A K Peters/CRC Press, 2010.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Computer-aided design and simulation

Type of Course Compulsorily eligible

Responsible Tutor Dr. Papp Ildikó

Syllabus Modeling in engineering and natural sciences, basic tasks and problems. Geometric modeling. Parametric models. Analytical and finite element methods. Automatic mesh generation. Simulation. Parametric dynamic systems. Curves, surfaces. Theoretical foundations of different modeling methods (NURBS, polygons, subdivision). Visualisation. Texturing. Rendering methods and optimization. Animation.

Bibliography

1. M. K. Agoston: Computer Graphics and Geometric Modelling: Mathematics , Springer, 2005.
2. M. Mortenson: Geometric Modeling, Industrial Press, 2006.
3. G. Brunnett, B. Hamann: Geometric Modeling for Scientific Visualization (Mathematics and Visualization), Springer, 2004.
4. M. Ganesh: Basics of Computer Aided Geometric Design: An Algorithmic Approach, I K International Publishing House, 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Deep Learning

Type of Course Optional

Responsible Tutor Dr. Harangi, Balázs

Syllabus Basic concepts of deep learning, Introduction into deep learning. Neural network. Feedforward network. Backpropagation algorithm. Methods of weight initialization. Regularization. Cost functions. Convolutional neural networks. Pooling and dropout layers, normalization. Representation learning. Visualization. Deep convolutional neural networks. Recurrent neural network. Ensemble methods.

Bibliography

5. Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning, MIT Press, 2016.
6. Ludmila I. Kuncheva: Combining Pattern Classifiers: Methods and Algorithms, Second Edition, Wiley, 2014.
7. Charu C. Aggarwal: Neural Networks and Deep Learning, Springer, 2018.
8. Ian H. Witten, Eibe Frank, Mark A. Hall, and Christopher J. Pal. Data Mining: Practical Machine Learning Tools and Techniques. Morgan Kaufmann, Burlington, MA, 4 edition, 2016.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Pattern analysis

Type of Course Optional

Responsible Tutor Dr. Antal, Bálint

Syllabus Object descriptors, sampling. Matching algorithms. Digitazation and morphological applications in different grids. Region and contour-based object detection. Active contour models. Template databases, machine learning, temporal analysis. Surface and volume-based object representations. Texture descriptors and detection.

Bibliography

7. R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, John Wiley and Sons, 2001.
8. J. Serra: Image Analysis and Mathematical Morphology, Academic Press, Volume 1 (1982), Volume 2 (1988).
9. Digital Image Analysis (W.G. Kropatsch, H. Bischof, eds.), Springer, New York, 2001.
10. Blake, M. Isard: Active Contours, Springer-Verlag London, 1998.
11. Handbook of Medical Imaging (I. Bankman ed.), Academic Press, San Diego, 2000.
12. B. Cyganek: Object Detection and Recognition in Digital Images: Theory and Practice, John Wiley & Sons Ltd., New York, 2013.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Image processing in medicine and biology
Type of Course	Optional
Responsible Tutor	Dr. Szeghalmy, Szilvia
Syllabus	Imaging. Efficient image storage. Segmentation of biological and medical images. Feature extraction. Lesion detection. Analysis of image sequences, object tracking. Classification. Comparison of classifiers. Quantitative analysis. Evaluation and validation. Open source frameworks and software for medical imaging.
Bibliography	6. Isaac N. Bankman (Ed.), Handbook of Medical Image Processing and Analysis, Elsevier, 2008. 7. Wu, Qiang, Fatima Merchant, and Kenneth Castleman. Microscope image processing. Elsevier, 2010. 8. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer-Verlag New York, 2006. 9. Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning, MIT Press, 2016.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Applied descriptive and projective geometry

Type of Course Optional

Responsible Tutor Dr. Bácsó, Sándor

Syllabus The projective plane. Homogeneous coordinates. The Laguerre formula. The cross ratio. Projective geometry of conics. Collineations and projective transformations. The Plücker coordinates. The Laguerre formula. The projective space. The mapping of projective space onto a projective plane. Matrices of projective mappings.

Bibliography

1. Earle, F., Rule, S. B., Descriptive geometry, Prentice Hall, New York, 2014.
2. Holliday-Darr, K. A., Applied Descriptive Geometry, Cengage Learning, 1998.
3. Coxeter, H. S. M., Projective Geometry, Springer, 2013.
4. Wylie, C. R., Introduction to projective geometry, Dower Publications, 2008.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Digital Geometry and Mathematical Morphology

Type of Course Optional

Responsible Tutor Dr. Fazekas, Attila

Syllabus Grids, metrics, adjacency relation. Elements of the digital topology. Curves and surfaces. Straightness. Curvature and Corners in 2D. Surface area and curvature in 3D. Hulls and diagrams. Deformations. Morphologic operators. Distance transformation. Morphological shape description.

Bibliography

1. R. Klette, A. Rosenfeld: Digital Geometry: Geometric Methods for Digital Picture Analysis. Morgan Kaufmann, 1. edition, 2004.
2. J. Serra: Image Analysis and Mathematical Morphology, Vol. 1-2. Academic Press, 1984.
3. L. Najman, H. Talbot: Mathematical Morphology: From Theory to Applications. Wiley-ISTE, 1 edition. 2010.
4. L. M. Chen: Digital and Discrete Geometry. Springer, 2014.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Loops and nets

Type of Course Optional

Responsible Tutor Dr. Figula, Ágota

Syllabus

Coordinatization of nets with loops. Isotopy classes of loops.

Closeness theorems and weakening associativity. Bol-, Moufang-, Bruck loops and nets. Geometry of binary systems. Projective transformations, collineations. Coordinatization structures of non-Desarguesian affine planes. Translation planes and quasifields. Latin squares and quasigroups. Matroids. Steiner systems and the corresponding affine and projective loops. Loops and codes.

Bibliography

1. Nagy, P., Strambach, K.: Loops in Group Theory and Lie Theory. Expositions in Mathematics, 35. Walter de Gruyter, Berlin, 2002.
2. Smith, J. D. H.: An Introduction to Quasigroups and their Representations. Chapman & Hall/CRC Press. 2007.
3. Colbourn, C. J., Rosa, A., Triple systems, Oxford University Press, 1999.
4. Ball, S.: Finite Geometry and Combinatorial Applications, Cambridge University Press, 2015.
5. Drapal, A., Vojtechovsky, P.: Code loops in both parities, J. Algebr. Comb. 31 (2010), 585-611.
6. Quasigroups and Loops: Theory and Applications. eds. Chein, O., Pflugfelder, H. O., Smith, J. D. H., Sigma Series in Pure Mathematics, 8., Heldermann Verlag, Berlin, 1990.
7. Topics on Steiner Systems. eds: Lindner, C. C., Rosa, A., Annals of Discrete Math. 7. North-Holland Publishing Company. 1980.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Bioinformatics

Type of Course Optional

Responsible Tutor Dr. Hajdu, András

Syllabus Basics on genetics and proteomics, Algorithms and complexity, Exhaustive search, Greedy algorithms, Dynamic programming algorithms, Divide and conquer algorithms, Graph algorithms, Combinatorical pattern matching, Clustering and trees, Hidden Markov Models, Randomized algorithms, Approximating algorithms, Distributed bioinformatic algorithms.

Bibliography

1. D. Mount: Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor, 2001.
2. G.R. Grant, W.J. Ewens: Statistical Methods in Bioinformatics: An Introduction, Springer-Verlag, 2005.
3. S. Letovsky: Bioinformatics: Databases and Systems, Springer-Verlag, 1999.
4. Neil C. Jones and Pavel A. Pevzner: An Introduction to Bioinformatics Algorithms, MIT Press, 2004.
5. P. Compeau, P. Pevzner: Bioinformatics Algorithms: An Active Learning Approach, Active Learning Publishers, USA, 2014.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Discrete tomography

Type of Course Optional

Responsible Tutor Dr. Hajdu, Lajos

Syllabus The basic questions of discrete tomography. The problem of unique reconstruction in the classical tomography and in the tomography with absorption. The structure of the tomographically equivalent sets. Convex and HV-convex sets. Algorithmic and complexity questions.

Bibliography

1. Discrete Tomography, International Journal of Imaging Systems and Technology 9, No. 2/3, Special Issue, (G. T. Herman and A. Kuba, eds.), 1998.
2. G. T. Herman and A. Kuba, Discrete Tomography: Foundations, Algorithms and Applications, Birkhäuser, Boston, 1999.
3. Linear Algebra and its Applications 339, Special issue on Discrete Tomography (A. Del Lungo, P. Gronchi and G. T. Herman, eds.), 2001.
4. Workshop on Discrete Tomography and Its Applications, Electronic Notes in Discrete Mathematics, Special Issue, (G. T. Herman and A. Kuba, eds.), 2005.
5. Advances in Discrete Tomography and Its Applications, (G.T. Herman, A. Kuba, eds.), Birkhäuser, 2007.
6. Hajdu L. and R. Tijdeman: Bounds for approximate discrete tomography solutions, SIAM Journal on Discrete Mathematics 27 (2013), 1055-1066.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Lattices

Type of Course Optional

Responsible Tutor Dr. Hajdu, Lajos

Syllabus Basic notions, lattice bases, unimodular transformations, lattice determinant. Lattice points and convex sets. Algorithms for lattices. The LLL-algorithm and its applications: finding an optimally fitting lattice, pattern recognition on digital images.

Bibliography

7. J. W. S. Cassels: An Introduction to the Geometry of Numbers, Springer, 1959.
8. P. M. Gruber, C. G. Lekkerkerker: Geometry of Numbers, North-Holland Publishing Co., 1987.
9. H. Cohen: A Course in Computational Algebraic Number Theory, Springer, 1995.
10. L. Hajdu; B. Harangi; A. Tiba; A. Hajdu, Detecting Periodicity in Digital Images by the LLL Algorithm, ECMI 2018, 6 pp., 2018.
11. A. Hajdu, L. Hajdu, R. Tijdeman, Finding well approximating lattices for a finite set of points, Mathematics of Computations 88 (2019), 369-387.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Computer aided modelling of curves and surfaces

Type of Course Optional

Responsible Tutor Dr. Hoffmann, Miklós

Syllabus Standard types of curves and surfaces in computer aided geometric modelling and animattion. Curves and surfaces given by the combination of control points and basis functions: Bézier, B-spline, NURBS curves and surfaces, their computation and description. Recently developed curve and surface types. Application of subdivison curves and surfaces in animation.

Bibliography

1. Farin, G. Curves and Surface for Computer-Aided Geometric Design, 4th edition, Academic Press, New York, 1997.
2. Piegl, L., Tiller, W. The NURBS book, Springer-Verlag, Berlin, 1995.
3. Zorin, D., Schröder, P.: Subdvision for Modeling and Animation, SIGGRAPH Course Notes, 2000
4. Peters, J., Reif, U.: Subdivision surfaces, Springer-Verlag, Berlin, 2008.
5. Huang, W., Russell, R.: Adaptive Moving Mesh Methods, Springer-Verlag, Berlin, 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Finite geometries

Type of Course Optional

Responsible Tutor Dr. Kunkli, Roland

Syllabus Finite affine and projective geometries. Orthogonal latin squares. Arcs and ovals, Segre's theorem. Maximum distance separable codes. Polar, symplectic and unitary spaces. Generalised quadrangles. Inversive planes. Combinatorial applications.

Bibliography

1. L. M. Batten: Combinatorics of Finite Geometries, Cambridge University Press, 1997.
2. L. M. Blumenthal: A Modern View of Geometry, Dover Publications, 2017.
3. S. Ball: Finite Geometry and Combinatorial Applications, London Mathematical Society Student Texts (Book 82), Cambridge University Press, 2015.
4. S. Ball, Weiner: An introduction to finite geometry, http://www.cs.elte.hu/~weiner/publications.html, 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Topics in Computer Graphics

Type of Course Optional

Responsible Tutor Dr. Papp, Ildikó

Syllabus Analytic description of spatial elements. Conics. Affine and projective transformations. The projection of space onto plane: Monge projection, axonometry, central projection. Bézier, B-spline, NURBS curves and surfaces, their computation and description. Interpolation, approximation.

Bibliography

6. Huang, W., Russell, R.: Adaptive Moving Mesh Methods, Springer-Verlag, Berlin, 2011.

7. Guo, H. G.: Modern Mathematics and Applications in Computer Graphics and Vision, World Scientific Pub. Co. Inc., 2014.

8. Farin, G.: Curves and Surface for Computer-Aided Geometric Design, Academic Press, New York, 1997.

9. Boehm, W., Prautzsch, H.: Geometric Concepts for Geometric Design, A. K. Peters, Wellesley, 1994.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Finite Element Analysis

Type of Course Optional

Responsible Tutor Dr. Mankovits, Tamás

Syllabus The brief history of the finite element method, the purpose of the application of finite element analysis. Unknown fields of the linear elasticity, the basic equation system and the boundary conditions. Analytical solution of an elastic boundary value problem. Total potential energy, linear approximation and variational principles. The displacement based finite element method. Isoparametric finite elements. General purpose finite element software. Error analysis. Problems and solutions.

Bibliography

[1] T. Mankovits: *Numerical Analysis of Engineering Structures: Linear Elasticity and the Finite Element Method*, University of Debrecen, 2014.

[2] K.J. Bathe: *Finite Element Procedures*, Prentice Hall, 2014.

[3] O.C. Zienkiewicz, R.L. Taylor: *The Finite Element Method: The Basis*, Butterworth-Heinemann, 2000.

[4] O.C. Zienkiewicz, R.L. Taylor: *The Finite Element Method: Solid Mechanics*, Butterworth-Heinemann, 2000.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Data Fusion Models

Type of Course Optional

Responsible Tutor Dr. Tomán, Henrietta

Syllabus Data and information fusion. Multisensor data fusion. Learning and prediction models. Bound and unbound fusion. Heterogeneity, diversity measures. Similarity-based fusion, similarity matrix, SVM. Low-level fusion, data integration. Intermediate and high-level fusion. Kernel methods, graph-based approaches, Bayesian networks. Dempster-Shafer models. Decision-level fusion, decision rules, ensemble methods. Fuzzy models. Decision support systems.

Bibliography

1. Mitchell, H. B.: Data Fusion: Concepts and Ideas, Springer, 2012.
2. Zhou, Z. H.: Ensemble Methods: Foundations and Algorithms, Chapman & Hall/Crc, 2012.
3. Bossae, A., Solaiman, B.: Information Fusion and Analytics for Big Data and IoT, Artech House, 2016.
4. Liggins, M., Hall, D., Llinas, J.: Handbook of Multisensor Data Fusion: Theory and Practice, CRC Press, 2008.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Sensor-based data collection and processing

Type of Course Optional

Responsible Tutor Dr. Tomán, Henrietta

Syllabus Sensors, microelectronic sensors. Static characteristics, noise and error models. Multi-sensors. Smart sensors. Data collection. Sensor data preprocessing, dimension reduction, thresholding, Fourier transform. Sensor Fusion. Sensor data redundancy, data aggregation. Data Fusion models. Kalman filtering. Sensor data post-processing, visualization.

Bibliography

1. Boginski, V. L., Commander, C. W.: Sensors: Theory, Algorithms, and Applications, Springer, 2014.
2. Dunn, P. F.: Measurement, Data Analysis, and Sensor Fundamentals for Engineering and Science, CRC Press, 2014.
3. Klein, L. A.: Sensor and Data Fusion: A Tool for Information Assessment and Decision Making, SPIE Press, 2012.
4. Mitchell, H. B.: Multi-sensor Data Fusion: An Introduction, Springer, 2007.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Graphics Accelerators

Type of Course Optional

Responsible Tutor Dr. Tornai, Róbert

Syllabus Introduction into graphics accelerators. Schematics of graphics accelerators. Programming the fixed pipeline of OpenGL. Replacing stages of the fixed pipeline with GLSL. General usage by OpenCL. Introduction into Mantle API. General low level coding by Vulkan API. Web usage with WebGL and WebCL languages.

Bibliography

10. D. Shreiner, G. Sellers, J. M. Kessenich, B. M. Licea-Kane: OpenGL Programming Guide: The Official Guide to Learning OpenGL, Version 4.3, Addison-Wesley Professional, 2013.
11. David Wolff: OpenGL 4 Shading Language Cookbook, Packt Publishing, 2013.
12. D. R. Kaeli, P. Mistry: Heterogeneous Computing with OpenCL 2.0, Morgan Kaufmann, 2015.
13. T. Parisi: Programming 3D Applications with HTML5 and WebGL: 3D Animation and Visualization for Web Pages, O'Reilly Media, 2014.
14. https://www.khronos.org/webcl/

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Geoinformatics

Type of Course Optional

Responsible Tutor Dr. Zichar, Marianna

Syllabus The nature of geographic data. Georeferencing. Geographic data modeling and spatial data analysis, Principles, key elements and case studies in geodatabase design. Analysing vector, raster data and geodatabases. Spatial data acquiring, GPS technology, remote sensing. Location based services. Current issues on geovisualization. Geospatial web services, mashups. Geoportals. Open source solutions in GIS, Data mining, machine learning, knowledge representation in GIS. Hot topics in geoinformatics. Applications of geoinformatics.

Bibliography

1. Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind: Geographic Information Science and Systems, Wiley, 2015.
2. David Arctur, Michael Zeiler: Designing Geodatabases, ESRI Press, Redlands, California 2004.
3. Erik Westra: Python Geospatial Development, Packt Publishing, 2013.
4. Pinde Fu, Jiulin Sun: Web GIS, ESRI Press, Redlands, California, 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Visual analytics methods

Type of Course Optional

Responsible Tutor Dr. Kunkli, Roland

Syllabus

Basic information visualization and scientific visualization methods. The purpose, the usage and the process of visual analytics, analytical pipelines. Data management, database technologies and data mining, respect to visual analytics. Spatio-temporal applications. Infrastructural and efficiency issues. Perception and cognitive aspects. Deviation and pattern analysis. Interaction and navigation. Case studies: volume visualization, classification and clustering, dimensionality reduction, trees, graphs. Time-series, correlation and multivariate analysis. Analytical software systems. Future challenges, recommendations and possible solutions.

Bibliography

1. D. Keim, J. Kohlhammer, G. Ellis, F. Mansmann (szerk.): Mastering the information age - Solving problems with visual analytics. Eurographics Association, 2010.

   URL: http://www.vismaster.eu/wp-content/uploads/2010/11/VisMaster-book-lowres.pdf
2. J. J. Thomas, K. A. Cook (szerk.): Illuminating the Path: The Research and Development Agenda for Visual Analytics. National Visualization and Analytics Ctr, 2005.
3. T. Munzner: Visualization Analysis and Design (AK Peters Visualization Series), A K Peters/CRC Press, 2014.
4. C. Ware: Information Visualization, Third Edition: Perception for Design (Interactive Technologies), Morgan Kaufmann, 2012.
5. S. Few: Now You See It: Simple Visualization Techniques for Quantitative Analysis. Analytics Press, 2009.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Stochastic data mining
Type of Course	Compulsory
Responsible Tutor	Márton Ispány
Syllabus	During the course, students will learn about the state-of-the-art stochastic data mining models and algorithms. They acquire their theoretical properties and learn to apply them in practice. Supervised data mining models: regression and regularization, kernel method and radial basis function, sparse kernels (SVM and RVM), graphical models and Bayesian networks, high-dimensional problems. With special emphasis on modern stochastic optimization methods, e.g., stochastic gradient descent and Bayesian and nonparametric learning. Unsupervised data mining models: mixtures and EM-algorithm, clustering, Kohonen network, principal components analysis and its variant (kernel-PCA), singular valued decomposition, non-negative matrix faktorization, independent component analysis, multidimensional scaling. Using a data science software, e.g. the Anaconda Python distribution.
Bibliography	Bishop, C. M., Pattern Recognition and Machine Learning, Springer, 2006. Hastie, T., Tibshirani, R., Friedman, J., The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer-Verlag, 2009. Koski, T., Noble, J.M., Bayesian Networks. An Introduction. Wiley, 2009. Gorelick, Micha, Ozsvald, Ian, High Performance Python: Practical Performant Programming for Humans (1st ed.). O'Reilly Media, 2014.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Statistics with application to Infromation Technology

Type of Course Compulsory

Responsible Tutor György Terdik

Syllabus

Simple and multiple linear regression

Method of least squares and applications.

Nonlinear regression

Testing hypothesis for regression.

Preliminary analysis of time series with non-random components.

Linear time series, AR, MA, ARMA, SARIMA models.

Statistics of spatial temporal processes in frequency domain. Basic properties of data produced by sensors. Estimation of variogram. Spectral representations of isotropic processes. Predictions in time and space

Usage of corresponding R-packages

Bibliography

D. C. Montgomery / G. C. Runger, Applied Statistics and Probability for Engineers, Wiley | ISBN 0471204544 | 3 edition (2002)

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Shumway, R. H. & Stoffer, Time Series Analysis and Its Applications: With R Examples, D.S., Springer, 2011, 3e

N. Cressie and C. K. Wikle. Statistics for Spatio-Temporal Data. Wiley Series in Probability and Statistics, 2011.

T. Subba Rao and Gy. Terdik (2012), Statistical Analysis of Spatio-temporal Models and Their Applications, Ch. 18, Handbook of Statistics, Vol. 30, ISSN: 0169-7161 18, 2012 Elsevier B.V., DOI: 10.1016/B978-0-444-53858-1.00018-1, p.521-541,

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Statistical Analysis of the Distributed Systems
Type of Course	Compulsory
Responsible Tutor	Zoltán Gál
Syllabus	Characteristics, behaviour and properties of the Distributed Information Systems (DIS). Distributed information system (multiprocessor systems, cloud systems, sensor networks, etc.) technologies, case studies and applications in practice. State values and resource management in DIS environment. Measurement process and interpretation possibilities of the data set by time series methods (wavelet, Fourier, dynamics, trends, rationalization, etc.). Physical processes of the resources of the loosely or tightly coupled DIS systems, analysis and determination of the optimal state trajectories. Problematics and influence of the M2M (Machine-to-Machine) connection scheduling to the communication quality.
Bibliography	[1] Ovidiu Vermesan, Joël Bacquet: Cognitive Hyperconnected Digital Transformation, Internet of Things Intelligence Evolution, River Publishers Series in Communications, 2017. [2] Eric D. Kolaczyk, Statistical Analysis of Network Data: Methods and Models, Springer Science+Business Media, 2009. [3] George Bachmann, Lawrence Narici, Edward Beckenstein, Fourier and Wavelet Analysis, Springer, 2000. [4] Robert E. Melchers, Andre T. Beck: Structural Reliability Analysis and Prediction, 3rd Edition, 2018.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Developing computational thinking

Type of Course Compulsory

Responsible Tutor Csernoch Maria

Syllabus One of the aims of the course is the introduction of the different methods and approaches which would serve the effective developing of computational thinking in traditional and non-traditional programming interfaces. Beyond that the focus is on providing the theoretical background and the measuring tools for the analyses of the different computer problem solving approaches. The comparison of the deep and surface approach methods, the effects of these methods on the mind and on computer problem solving.

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Backhouse, R. (2011). Algorithmic Problem Solving. Wiley. United Kingdom.

Csernoch, M. & Biro, P. (2015) Sprego Programming. Spreadsheets in Education (eJSiE): Vol. 8: Iss. 1, Article 4.

Doignon, J., & Falmagne, J. (1999). Knowledge Spaces. Berlin: Springer-Verlag.

Fives, H. Gill, M. G. (2015) International Handbook of Research on Teachers' Beliefs. Routledge.

Hattie, J. (2012). Visible Learning for Teachers. Routledge.

Merribenboer, J. & Sweller J. (2005). Cognitive Load Theory and Complex Learning: Recent developments and future directions. Educational Psychology Review, 17, 147-177.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Novel approaches for Internet-based applications
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. ADAMKÓ, Attila
Syllabus	Web applications; modelling ways for web-based applications, RUP and descendants. Development strategies; solutions for improving efficiency. Domain specific languages; domain driven design. IoT and sensor networks; efficient handling of large data. Modern database solutions; graph databases and their relation of the Sematic Web.
Bibliography	Gerti Kappel, et all: Web Engineering: The Discipline of Systematic Development of Web Applications, Wiley; 1 edition (June 16, 2006), 0470015543 Eric Evans: Domain-Driven Design: Tackling Complexity in the Heart of Software, Addison-Wesley Professional; 1 edition (August 30, 2003), 0321125215 Dr Adamkó Attila, Kollár Lajos: Different approaches to MDWE: bridging the gap; STUDIA UNIVERSITATIS BABES-BOLYAI SERIES INFORMATICA LVIII:(2) pp. 9-19. (2013) Adamkó Attila, Kollár Lajos:Extensible Data Management Architecture for Smart Campus Applications: A Crowdsourcing based Solution;In: Valérie Monfort, Karl-Heinz Krempels (szerk.) Proceedings of the 10th International Conference on Web Information Systems and Technologies. Konferencia helye, ideje: Barcelona, Spanyolország, 2014.04.03-2014.04.05. Portugal: SciTePress, 2014. pp. 226-232.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Virtual reality systems
Type of Course	Compulsorily eligible
Responsible Tutor	Attila Gilanyi
Syllabus	The topic of this course is related to the creation of virtual spaces. Geometrical properties of such spaces are considered, graphical tools and methods are investigated that can be used to create them, the management of lights and shadows is studied and it is examined how objects in the spaces can be attributed with physical properties. The interactions associated with virtual reality and the possibility of collaboration with virtual reality is also investigated.
Bibliography	Steven M. LaValle, *Virtual Reality*, Cambridge University Press, 2017. Tony Parisi, *Learning Virtual Reality*, O'Reilly Media, 2015. Jason Jerald, *The VR Book: Human-Centered Design for Virtual Reality*, ACM Books, Morgan and Claypool Publishers, 2015. William R. Sherman, Alan B. Craig, *Understanding Virtual Reality: Interface, Application, and Design*, Morgan Kaufmann, 2018.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Advanced data mining methods and applications
Type of Course	Compulsory / Compulsorily eligible / Optional
Responsible Tutor	Márton Ispány
Syllabus	During the course, students will learn about the latest data mining techniques and their applications to real problems. Decision trees, additive models, boosting, random forests. Neural networks and learning methods, e.g. perceptron, linear autoassociative memory, lineáris heteroassociative memory, Hopfield-model and backpropagation. Deep learning. Mining in ustructured data, text-mining. Data mining of semi-structured data, web-mining. Using a data science software, e.g. the Anaconda Python distribution.
Bibliography	Bishop, C. M., Pattern Recognition and Machine Learning, Springer, 2006. Feldman, R., Sanger, J., The Text Mining Handbook. Advanced Approaches in Analyzing Unstructured Data. Cambridge, 2006. Hastie, T., Tibshirani, R., Friedman, J., The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer-Verlag, 2009. Liu, Bing, Web Data Mining, Exploring Hyperlinks, Contents, and Usage Data, Springer 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Symbolic Data Mining

Type of Course optional

Responsible Tutor Dr. László Szathmáry

Syllabus Data mining; knowledge discovery in databases (KDD); symbolic data mining methods. Frequent itemsets; frequent association rules. Algorithms for finding frequent itemsets: Apriori, Apriori-Close, Eclat, Charm, Touch. Galois lattices, algorithms for constructing Galois lattices. The Snow algorithm; hypergraphs. Rare itemsets, rare association rules. Levelwise and depth-first algorithms for finding rare itemsets: Apriori-Rare, Walky-G. Case studies; the Coron system.

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1. Szathmary, L., Valtchev, P., Napoli, A., Godin, R., Boc, A. and Makarenkov, V. A fast compound algorithm for mining generators, closed itemsets, and computing links between equivalence classes. *Ann. Math. Artif. Intell. (AMAI)*, 70(1-2):81-105, 2014.
2. Petko Valtchev, Rokia Missaoui, Robert Godin: A framework for incremental generation of closed itemsets. Discrete Applied Mathematics 156(6): 924-949 (2008)
3. Towards Rare Itemset Mining. Szathmary, L., Napoli, A. and Valtchev, P. In Proc. of the 19th IEEE Intl. Conf. on Tools with Artificial Intelligence (ICTAI '07), pages 305-312, Patras, Greece, Oct 2007.
4. Zaki, Mohammed Javeed, and Ching-Jiu Hsiao. "CHARM: An Efficient Algorithm for Closed Itemset Mining." In SDM, vol. 2, pp. 457-473. 2002.
5. Petko Valtchev, Rokia Missaoui, Robert Godin, Mohamed Meridji: Generating frequent itemsets incrementally: two novel approaches based on Galois lattice theory. J. Exp. Theor. Artif. Intell. 14(2-3): 115-142 (2002)
6. Tan, P.-N., Steinbach, M., Karpatne, A., Kumar, V.: Introduction to Data Mining, 2nd ed., Pearson, 2018.
7. Han, J., Kamber, M., Pei, J.: Data Mining: Concepts and Techniques, 3rd ed., Morgan Kaufmann, 2011.
8. Liu, B.: Web Data Mining, Exploring Hyperlinks, Contents, and Usage Data, 2nd ed., Springer 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Statistics for high speed network data
Type of Course	Compulsorily eligible
Responsible Tutor	György Terdik
Syllabus	Data measured in dynamical systems, general properties. Deterministic and stochastic models, ARMA models, ACF, PACF, frequency domain methods. Network and HPC data monitoring. High speed network data, fractal properties and parameter estimation.
Bibliography	P.J. Brockwell and R. A. Davis, Time Series Analysis and Forecasting. 2002. Springer Verlag. Shumway, R. H. & Stoffer, Time Series Analysis and Its Applications: With R Examples, D.S., Springer, 2011, 3e E. A. Lee and P. Variya, Structure and interpretation of Signals and Systems, 2000, UC Berkeley, Gy. Terdik, T. Gyires, Lévy Flights and Fractal Modeling of Internet Traffic, IEEE/ACM Transactions on Networking, VOL. 17, NO. 1, 120—129, February 2009

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Doctoral Subject Sprego Programming

Type of Course Compulsorily eligible

Responsible Tutor Csernoch Maria

Syllabus

Sprego is a programming tool in spreadsheet interfaces. It carries all the advantages of the functional languages and the user-friendly graphical environments. The approach fits the requirements of novice and end-user programmers, since the focus is not on the coding details but on the problem. Beyond the simplicity of the language, the border environment offers unlimited amount of authentic tables, in which real world problem solving can be carried out. Considering the advantages of Sprego, it can be used from a very early age to adult education. The methodological questions of Sprego, the developing of Sprego problems, and the analyses of its effectiveness are in the focus of the subject.

Bibliography

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Csernoch, M. & Biro, P. (2015) Sprego Programming. Spreadsheets in Education (eJSiE): Vol. 8: Iss. 1, Article 4.

Fives, H. Gill, M. G. (2015) International Handbook of Research on Teachers' Beliefs. Routledge.

Hattie, J. (2012). Visible Learning for Teachers. Routledge.

Merribenboer, J. & Sweller J. (2005). Cognitive Load Theory and Complex Learning: Recent developments and future directions. Educational Psychology Review, 17, 147-177.

Panko, R.R. (2008) What We Know About Spreadsheet Errors. Journal of End User Computing's. Special issue on Scaling Up End User Development. (10)2, pp. 15–21.

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UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Verifying Systems by Modern Formal Methods
Type of Course	Compulsorily eligible
Responsible Tutor	Gergely Kovásznai
Syllabus	In this course, students get acquainted with formal methods and actual software tools that industry employs in verifying complex systems (e.g., hardware, software, sensor networks, etc). They include symbolic model checking approaches such as bounded model checking (BMC), which is extremely successful due to the robustness of modern SAT solvers. Students will learn about certain solutions in CDCL SAT solvers (e.g. clause learning, non-chronological backjump, VSIDS heuristics, etc.) as well as SMT approaches and solvers, and we will see how they are employed in different application areas and the verification of concrete systems (e.g. neural networks).
Bibliography	E. M. Clarke, Th. A. Henzinger, H. Veith, R. Bloem. Handbook of Model Checking. Springer, 2018, ISBN 978-3-319-10575-8 A. Biere, M. Heule, H. van Maaren, T. Walsh. Handbook of Satisfiability. IOS Press, 2009, ISBN 978-1-58603-929-5 Donald E. Knuth. The Art of Computer Programming, Volume 4, Fascicle 6: Satisfiability. Addison-Wesley Professional, 2015, ISBN 0134397606, 978- 0134397603 G. Kovásznai, A. Fröhlich, A. Biere. Complexity of Fixed-Size Bit-Vector Logics. Theory of Computing Systems, Springer, Vol. 59 (2), pp. 323-376, 2016.

N. Narodytska, S. Kasiviswanathan, L. Ryzhyk, M. Sagiv, T. Walsh. Verifying Properties of Binarized Deep Neural Networks. 32nd AAAI Conference on Artificial Intelligence (AAAI-18), pp. 6615-6624, 2018.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Knowledge space theory in practice

Type of Course Optional

Responsible Tutor Kálmán Abari

Syllabus One of the methods of knowledge assessment is the application of knowledge space theory. Its most important elements is the construction of knowledge structure, which presupposes a prerequisite relation system between knowledge items. This course reviews the main ideas of knowledge space theory for the assessment of a student's knowledge in a selected topic and gives details on creating prerequisite relation in practice. The aim of the course is the introduction of the software packages which provide basic functionalities to generate, handle, manipulate and validate knowledge structures and knowledge spaces.

Bibliography

Doignon, J., & Falmagne, J. (1999). *Knowledge spaces*. Springer Verlag.

Falmagne, J., & Doignon, J. (2010). *Learning spaces: Interdisciplinary applied mathematics*. Springer Berlin Heidelberg.

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Ünlü, A., & Sargin, A. (2010). DAKS: An R package for data analysis methods in knowledge space theory. *Journal of Statistical Software*, *37*(2), 1–31.

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Tóth, Z. (2005). A tudásszerkezet és a tudás szerveződésének vizsgálata a tudástér-elmélet alapján. *Magyar Pedagógia*, *105*.(1.), 59–82.

Tóth, Z. (2012). *Alkalmazott tudástérelmélet*. Gondolat Kiadói Kör Kft.

Máth, J., & Abari, K. (2011). Knowledge spaces and historical knowledge in practice. *Applied Psychology in Hungary*, *2011*(1), 126–152.

Abari, K., & Máth, J. (2010). A történelmi tudás mérése a tudástér-elmélet segítségével. In Á. Münnich & G. Hunyady (Eds.), *A nemzeti emlékezet vizsgálatának pszichológiai szempontjai* (pp. 191–216). Budapest: ELTE Eötvös K.

Bibliography on Knowledge Spaces maintained by Cord Hockemeyer. Retrieved from http://www.uni-graz.at/ cord.hockemeyer/ KST_Bibliographie/kst-bib.html

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Development and usage of Content Management Systems

Type of Course Optional

Responsible Tutor Dr. Biró Piroska

Syllabus

The aim of the course is to introduce those methods which can be used for the development and effective usage of general and educational content management systems.

During the course we can be acquainted with the basic requirements of the development of CMS (Content Management Systems): high availability, high number of user capacity, parallel services, scalability, possibilities of extending infrastructure (hardware, software), user-friendly interface, usability, simplicity, easy management, motivation, interoperability, managing different contents, stability, reliability, security, ensuring, limited and unlimited availability, platform independency, etc.

The Content Management Systems used in education are build-up of different modules, which are now a basic requirement: administration, content management, content development, statistics, testing, questionnaire, evaluation, user activity registration, user profile, profile editing, communication modules.

The objective in the course is to learn about the above mentioned concepts, followed by the practical usage.

Bibliography

1. Anderson, T. and Elloumi, F. (Eds). (2008). Theory and practice of online learning (2nd edn). (Free book: http://biblioteca.ucv.cl/site/colecciones/manuales_u/99Z_Anderson_2008-Theory_and_Practice_of_Online_Learning.pdf)

2. Farooq A, Javed F, Hussain M, Abbas T, Hussain A (2012). Open source content management systems: a canvass. International Journal of Multidisciplinary Sciences and Engineering 3(10):38–43.

3. Garrison, D. R. (2011). E-Learning in the 21st Century: A Framework

for Research and Practice. (2nd edn). New York NY, Abingdon, Oxon: Routledge.

4. Harrison, H. Y., Shuyan, W. (2013). Cases on E-Learning Management: Development and Implementation, 525 pp.

5. Lee, M., McLoughlin, C. (2011). Web 2.0-Based E-Learning: Applying Social Informatics for Tertiary Teaching, 518 pp.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Informatics education in ICT rich environment

Type of Course Optional

Responsible Tutor Dr. Biró Piroska

Syllabus The aim of the course is to introduce the possibilities of using ICT (Information and Communication Technology) devices in informatics education.

During the course the most widely spread ICT devices and applications are presented: interactive whiteboard and supplements, interactive board software, computer+projector combined possibilities, webcamera, digital camera, students' notebook, teachers' notebook, CMS (Content Management System), using and editing digital teaching material, etc.

Bibliography

6. Cogill, J. (2003). How is the Interactive Whiteboard Being Used in the Primary School and How Does This Affect Teachers and Teaching. http://www.juliecogill.com/IFS_Interactive_whiteboards_in_the_primary_school.pdf. Retrieved 2 June 2010.

7. Hu, X., Gong, Y., Lai, C., & Leung, F.K. (2018). The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: A multilevel analysis. *Computers & Education*, 125, 1-13.

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9. Shazia Mumtaz (2000). Factors affecting teachers' use of information and communications technology: a review of the literature, Journal of Information Technology for Teacher Education, 9:3, 319-342, DOI: 10.1080/14759390000200096.

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UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Doctoral Subject	Online and virtual environments in knowledge transfer
Type of course	Optional
Course director	Gyöngyi Bujdosó
Syllabus	Possibilities of development of virtual environments for knowledge transfer. Basic features and functionalities of VLEs. VLEs in practice. Applications of systems and standards of eLearning: LMS, LCMS, LOM, SID, SCORM. Theory and practice of scenarios. Design and development of online courses. Linear and iterative methods. On-line technologies in education. Learning methods in the 21st century. Quality control. Student support in online courses. E-learning in practice: methods and applications.
Bibliography	Anderson, T. and Elloumi, F. (Eds). (2008). Theory and practice of online learning (2nd edn). http://biblioteca.ucv.cl/site/colecciones/manuales_u/99Z_Anderson_2008-Theory_and_Practice_of_Online_Learning.pdf Harasim, L. (2012) Learning Theory and Online Technologies. New York NY, Abingdon, Oxon: Routledge. Dick, W., Carey, L., & Carey, J. O. (2004). The systematic design of instruction (6th edn). Boston, MA: Allyn & Bacon. Garrison, D. R. (2011). E-Learning in the 21st Century: A Framework for Research and Practice. (2nd edn). New York NY, Abingdon, Oxon: Routledge. Roblyer, M. D. (2014). Introduction to Systematic Instructional Design for Traditional, Online, and Blended Environments, Pearson.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Doctoral Subject	Knowledge-Transfer Items in Teaching Informatics
Type of Course	Optional
Responsible Tutor	Csernoch Maria
Syllabus	Recognizing knowledge-transfer items within informatics and computer sciences and between non-informatics school subjects and sciences. Developing knowledge-transfer-based methods and approaches which support real connection in traditional and non-traditional programming, digital data management, and computer problem solving. Creating knowledge-transfer-based competency measuring tools for testing and developing students' computational thinking skills, their computer problem solving abilities, and revealing informatics- and computer-related misconceptions. Analyzing teaching-support documents, focusing on the National Base Curriculum, the frame curricula, and additional teaching-learning documents, especially course books and online materials.
Bibliography	Csernoch, M. (2017) Thinking Fast and Slow in Computer Problem Solving. Journal of Software Engineering and Applications, Vol.10 No. 01 (2017), Article ID:73749, 30 pages 10.4236/jsea.2017.101002 Fives, H. Gill, M. G. (2015) International Handbook of Research on Teachers' Beliefs. Routledge. Hattie, J. (2012). Visible Learning for Teachers. Routledge.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Applications of virtual and augmented reality systems
Type of Course	Optional
Responsible Tutor	Attila Gilanyi
Syllabus	In the framework of this course, we review the most modern tools for creating virtual spaces. We investigate applications of virtual and augmented reality systems in various scientific disciplines (among others, in medicine, in engineering, in archeology and in history), in architecture and in education.
Bibliography	Steven M. LaValle, *Virtual Reality*, Cambridge University Press, 2017. Tony Parisi, *Learning Virtual Reality*, O'Reilly Media, 2015. Jason Jerald, *The VR Book: Human-Centered Design for Virtual Reality*, ACM Books, Morgan and Claypool Publishers, 2015. William R. Sherman, Alan B. Craig, *Understanding Virtual Reality: Interface, Application, and Design*, Morgan Kaufmann, 2018.

Name of Course	Informatics in life sciences
Type of Course	Optional
Responsible Tutor	Dr. Godó Zoltán Attila
Syllabus	**The course aims to:** Learning opportunities for the application of information technology in the field of life sciences. Issues, problems and their solutions to biological information processing. Developing special IT approach, due to the nature of biological field of study.

Course content: Evaluation and essence of technical works and evolutionary solutions. Designing or ad hoc development. Catalysts of evolution of technology. Darwin's black box. Inorganic - organic - live: free will or random quantum level. Genetic information and its operation. Gene manipulation, genetic engineering, information processing. Sensors, bio-sensors, receptors, biological signals. Bioelectrical and bio-informational activities. Nerves, ion channels and synapses in information flow. The information technological function of the nervous system. Errors and brilliant solutions to the systems. Computer vs. nervous system. Neural networks, CNN, biochip etc. Multielectrode leads and firing pattern. Diagnostic imaging, CT, MRI and PET. High levels of neural organization. The mysteries of the human brain and the potentials in "artificial intelligence".

Bibliography

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- N.C. Jones, A. Pavel, A. Pevzner: An Introduction to Bioinformatics Algorithms, MIT Press, 2004.
- P. Baldi, S. Brunak, S. Brunak: Bioinformatics: The Machine Learning Approach, S.E. (Adaptive Computation and Machine Learning), MIT Press, 1998.
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UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Functional Programming Languages and its Applications
Type of Course	Optional
Responsible Tutor	Dr. Kósa Márk
Syllabus	Fundamentals of the functional programming paradigm. Mathematical functions. Atoms and lists in LISP. Functional syntax, which is based on lambda notation. Introduction to Scheme programming language, the Scheme interpreter. Primitive numeric functions, numeric predicate functions, defining functions, list functions, predicate functions for symbolic atoms and lists. Tail recursion in Scheme. Functional forms, functional composition, examples. Introduction to COMMON LISP, ML, and Haskell. Applications of functional programming languages. Comparison of functional and imperative programming languages.
Bibliography	Robert W. Sebesta: *Concepts of Programming Languages*, 10th edition, Addison-Wesley, 2012. Greg Michaelson: *An Introduction to Functional Programming Through Lambda Calculus*, Dover Publications, 2011. R. Kent Dybvig: *The Scheme Programming Language*, 4th edition, MIT Press, 2009. David S. Touretzky: *Common LISP: A Gentle Introduction to Symbolic Computation*, Dover Publications, 2013.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Doctoral Subject Examining qualitative variables

Supervisor Máth János

Syllabus

Qualitative variables mean variables measured on nominal level, like gender of people, or the preference of party. On the course students learn to basics of modelling relations between these variables.

The most important concepts:

Connection between two qualitative variables

Dependence, independence, odds

Examining more than two qualitative variables

Loglinear models, connection between the model and odds

Latent variables

Loglinear models with latent variables

Hierarchical models

Applied software: LEM

Bibliography

Jacques Hagenaars: Loglinear models with latent variables – Sage Publications, 1993

Máth János: Kvalitatív változók elemzése – Alkalmazott Pszichológia

The paper can be downloaded:
http://pszichologia.unideb.hu/pszoc/mathja/index.htm

Jeroen K. Vermunt: LEM: A General Program for the Analysis of Categorical Data

The paper can be downloaded:
https://www.researchgate.net/publication/228391002_LEM_A_General_Program_for_the_Analysis_of_Categorical_Data

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Eduard Gröller1 , Silvia Miksch1 and Martin Suntinger :
Contingency Wheel: Visual Analysis of Large Contingency Tables

The paper can be downloaded:

https://publik.tuwien.ac.at/files/PubDat_198069.pdf

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Multiparadigm Programming in F#

Type of Course Optional

Responsible Tutor Dr. Pánovics János

Syllabus Core concepts in functional programming. Tuples, lists, and functions in F#. Discriminated union and option types in F#. Lambda functions. Function composition and partial application. Functions as values, higher-order functions. F# object types. Lazy values, sequence expressions, and alternative workflows. Imperative programming in F#. Common techniques: equality, hashing, and comparison; efficient precomputation and caching; resource management; tail calls and recursion; event handling. Language-oriented programming. Asynchronous and data-driven programming. Writing parallel functional programs. Developing reactive functional programs.

Bibliography

Robert W. Sebesta: *Concepts of Programming Languages*, 10th edition, Addison-Wesley, 2012.

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Robert Pickering: *Foundations of F#*, Apress, 2007.

Don Syme, Adam Granicz, Antonio Cisternino: *Expert F# 3.0*, Apress, 2012.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Statistics and time series with applications

Type of Course Optional

Responsible Tutor György Terdik

Syllabus

Staitstics of spatial temporal processes in frequency domain. Basic properties of data produced by sensors. Estimation of variogram. Spectral representations of isotropic processes. Predictions in time and space

.Multiple Wiener-Ito integrals and stationary processes. Realization of bilinear time series

Bispectrum and estimation of spectra. Identification by higher order spectra. Test for Gaussianity and linearity in frequency domain. Software using and developing.

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Shumway, R. H. & Stoffer, Time Series Analysis and Its Applications: With R Examples, D.S., Springer, 2011, 3e

N. Cressie and C. K. Wikle. Statistics for Spatio-Temporal Data. Wiley Series in Probability and Statistics, 2011.

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Terdik, Gy. Bilinear stochastic models and related problems of nonlinear time series analysis, Lecture Notes in Statistics, 142, Springer, 1999.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Data warehouses
Type of Course	Optional
Responsible Tutor	Anikó Vágner
Syllabus	Architecture of data warehouses, multidimensional model, data warehouse design. SQL/OLAP operations, querying data warehouses. Physical data warehouse design, ETL process. Dashboards. Method for data warehouse design. New data warehouse technologies.
Bibliography	• Alejandro Vaisman and Esteban Zimányi. Data Warehouse Systems: Design and Implementation. Springer. 2014 • Krish Krishnan: Data Warehousing in the age of Big Data. Elsevier. 2013 • Lawrence Corr and Jim Stagnitto: Agile Data Warehouse Design: Collaborative Dimensional Modeling, from Whiteboard to Star Schema Paperback, DecisionOne Press, 2011 • Ramez Elmasri and Shamkant B. Navathe: Fundamentals of Database Systems, Pearson, 2015

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Automata Networks
Tantárgy típusa	Compulsorily eligible
Tantárgyfelelős	Pál Dömösi
Tematika	Automata and automata mappings. Automata and semigroups. Automata networks and products of automata. Krohn-Rhodes Theory and classes of completeness. Letichevski criteria and classes of automata fulfilling Letichevski criteria. Primitive product and temporary product. State-Homogeneous Networks. Asynchronous automata networks.
Irodalom	1. P. Dömösi, C. L. Nehaniv : Automata Networks, SIAM Monographs on Discrete Math., SIAM, Philadelphia, 2005. 2. F. Gécseg, I. Peák : Algebraic Theory of Automata. Akadémiai Kiadó, Budapest, 1973. 3. F. Gécseg : Products of Automata. EATCS Monograph Ser., Springer, 1986. 4. J. E. Hopcroft, R. Motwani, J. D. Ullman: Introduction to Automata Theory, Languages, and Computation. 3rd ed., Pearson Education Ltd. London, 2014. 5. Dömösi, Pál; Maróti, György: On $\alpha_2 - \nu_2$ -products of automata. Acta Inf. 48(7-8) (2011): 397-408.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Automata and Languages
Tantárgy típusa	Compulsorily eligible
Tantárgyfelelős	Pál Dömösi
Tematika	Definition of formal system, main types. Algorithm, grammar, automata, Chomsky hierarchy. Automatan as algebraic structure. Mappings induced on automaton. Minimalization of automata, equivalence, analysis, synthesis. Mappings induced on finite automata. Regular expressions. Building of languages in automata. Products of automata, automata networks. Connection of automata and languages: Regular grammar and finite automata. Contex-free grammar and pushdown automata, context-sensitive languages and linearly limited automata, sentences in languages and Turing machines. Universal Turing machine. Halting problem of Turing machines. Problem of algorithmic decision. Recursive languages, irrecursive languages. Combinatorics of words, combinatorics of languages, Iteration lemmas of regular and context-sensitive languages. Homomorphic description of context-free languages. Language consisting of primitive words, language consisting of non-primitive words.
Irodalom	1. P. Dömösi, C. L. Nehaniv : Automata Networks, SIAM, Philadelphia, 2005. 2. F. Gécseg, I. Peák : Algebraic Theory of Automata. Akadémiai Kiadó, Budapest, 1973. 3. J. E. Hopcroft, R. Motwani, J. D. Ullman: Introduction to Automata Theory, Languages, and Computation. 3rd ed., Pearson Education Ltd. London, 2014. 4. H. J. Shyr : Free Monoids and Languages, national Chu-Hsing University, Taichung, Taiwan, ROC, Ho Min Book Company, 1991.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Dynamic Logic
Tantárgy típusa	Compulsorily eligible
Tantárgyfelelős	Dr. László Aszalós
Tematika	syntax, semantics, elementary programs, control structures, properties of operators, satisfiability, validity, proof methods, complexity classes, decidable and undecidable extensions, variants
Irodalom	• DOUTRE, Sylvie; MAFFRE, Faustine; MCBURNEY, Peter. A Dynamic Logic Framework for Abstract Argumentation: Adding and Removing Arguments. In: *International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems*. Springer, Cham, 2017. p. 295-305. • QIAN, Sai; DE GROOTE, Philippe; AMBLARD, Maxime. Modal Subordination in Type Theoretic Dynamic Logic. *Linguistic Issues in Language Technology*, 2016, 14: 54. • D. Harel, D. Kozen, and J. Tiuryn, „Dynamic Logic”. MIT Press, 2000 • ULBRICH, Mattias: Dynamic Logic for an Intermediate Language: Verification, Interaction and Refinement PhD Thesis, Karlsruhe Institute of Technology, 2013, isbn:978-3844297034

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	DNA computing
Type of Course	Választható
Responsible Tutor	Dr. György Vaszil
Syllabus	The structure of DNA molecules, operations with DNA strands. Abstract models: filtering type models, splicing based models, self-assembly type models. Complexity aspects, problems of laboratory implementations. Watson-Crick automata. Gene assembly in ciliates.
Bibliography	1. M. Amos: Theoretical and experimental DNA computation, Springer, Berlin Heidelberg, 2005 2. A. Ehrenfeucht, T. Harju, I. Petre, D.M. Prescott és G. Rozenberg: Computation in living cells: Gene assembly in ciliates, Springer, 2004. 3. G. Paun.; G. Rozenberg, A. Salomaa: DNA computing. New computing paradigms. Springer, Berlin Heidelberg, 1998. 4. G. Rozenberg, T. Back, J.N. Kok, (eds.): Handbook of Natural Computing I-IV. Springer, 2012.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Rough Set Theory
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Tamás Mihálydeák
Syllabus	Treatment of uncertain/vague information: theory of rough sets. Pawlak's original theory of rough sets. Covering systems. General (partial) theory of rough sets. Decision theoretic rough sets. Rough sets in data analysis. The role of correlation clustering in the theory of rough sets. First-order (partial) logical systems relying on rough sets.

Bibliography

- Pawlak, Zdzislaw: Rough sets, Theoretical Aspects reasoning about Data, Springer, (1991)
- Pawlak, Zdzislaw and Skowron, Andrzej: Rudiments of rough sets, Information Sciences, vol. 177, No. 1 3-27 pp., (2007)
- Mani, A, Cattaneo, Gianpiero, Düntsch, Ivo (Eds.): Algebraic Methods in General Rough Sets, Birkhauser, (2018)
- Polkowski, Lech: Rough Sets, Mathematical Foundations, Springer, (2002)
- Pagliani, Piero, Chakraborty, Mihir: A Geometry of Approximation, Rough Set Theory: Logic, Algebra and Topology of Conceptual Patterns, Springer, (2008)

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Network Security
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Tamás Kádek
Syllabus	Information security, penetration testing and etics, networks, operation systems (Windows, Linux), steps and techniques of penetration testing – reconaissance, scanning, exploitation, maintaining access, covering tracks, making a report, use cases.
Bibliography	• *Edward Skoudis, Tom Liston: Counter Hack Reloaded: A Step-by-Step Guide to Computer Attacks and Effective Defenses (2nd Edition), Pearson 2002* • *Ross J. Anderson, Security Engineering: A Guide to Building Dependable Distributed Systems, Wiley 2008* • *Patrick Engebretson: The Basics of Hacking and Penetration Testing, Second Edition: Ethical Hacking and Penetration Testing Made Easy, Elsevier 2013* • *Georgia Weidman: Penetration Testing: A Hands-On Introduction to Hacking, No Starch 2014* • *Peter Kim: The Hacker Playbook: Practical Guide To Penetration Testing, CreateSpace 2014*

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Information theory and coding
Type of Course	Compulsorily eligible
Responsible Tutor	Attila Pethő
Syllabus	Uniqualy decodable and prefix codes. The huffman-code. Properties of the entropy. Data compression with dictionary. Applications of non-uniquely decodable codes. Voice, picture and video compression. Error-correcting codes. Linear, Hamming, Reed-Solomon and Goppa codes. Decoding methods.
Bibliography	Györfi László, Győri Sándor, Vajda István, Információ- és kódelmélet, Typotex, 2000. Cover, Thomas M.; Thomas, Joy A. Elements of information theory. Second edition. Wiley-Interscience [John Wiley & Sons], Hoboken, NJ, 2006. xxiv+748 pp. Borda, Monica, Fundamentals in information theory and coding. Springer-Verlag, Berlin, 2011. xxiv+489 pp Csiszár Imre, Körner János, Information Theory: Coding Theorems for Discrete Memoryless Systems, Akadémiai Kiadó, 1981.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Theory of computability and its applications in logic
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Tamás Mihálydeák
Syllabus	Turing machine, universal Turing machine, halting problem. Primitive recursive, partial recursive and recursive functions. Recursive enumerable and recursive decidable sets. Arithmetic hierarchy (Kleene-Mostowski). The connection between recursivity and Turing computability. Decidable and undecidable theories, methods for proving undecidability. Gödel numbers: logic as arithmetic. The problem of decidability. Church's theorem, Gödel-Rosser theorem, Tarski's theorem.
Bibliography	• Mendelson, Elliott: Introduction to Mathemetical Logic, (Sixth Edition), CRC Press 2015. • George G. Boolos, George G., Burgess, John P., Jeffrey, Richard C.: Computability and Logic, 5th Edition, Cambridge, 2007. • S. Abramsky, Dov M Gabbay, T.S. Maibaum: Handbook of Logic in Computer Science Vol. 1, Oxford University Press, 1992. • Ben-Ari, Mordechai: Mathematical Logic for Computer Science, 3rd Edition, Springer, 2012. • Jon Barwise: Handbook of Mathematical Logic, Elsevier, 1993 • Ruzsa Imre: Logikai szintaxis és szemantika 1. kötet, Akadémiai Kiadó, Budapest, 1988.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Cryptographic algorithms
Type of Course	Compulsory / Compulsorily eligible / Optional
Responsible Tutor	Pethő Attila
Syllabus	One way and one way trapdoor functions, symmetric and asymmetric systems. Basics of DES, AES, RSA, ElGamal and ont he DELP based encryption, choice of the parameters and known attacks. Authentication, hash functions, hash chanes, digital signature, secret sharing, key exchange, bit commitment. Public key infrastructure. Introduction to post-quantum cryptography.
Bibliography	Johannes Buchmann, Introduction to cryptography. Second edition. Undergraduate Texts in Mathematics. Springer-Verlag, New York, 2012. Jonathan Katz and Yehuda Lindell, Introduction to modern cryptography, CRC Press, Second edition, 2015. Menezes, Alfred J.; van Oorschot, Paul C.; Vanstone, Scott A. Handbook of applied cryptography. With a foreword by Ronald L. Rivest. CRC Press Series on Discrete Mathematics and its Applications. CRC Press, Boca Raton, FL, 1997 Stinson, Douglas R. Cryptography. Theory and practice. Third edition. Discrete Mathematics and its Applications (Boca Raton). Chapman & Hall/CRC, Boca Raton, FL, 2006.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Design and analysis of cryptographic protocols
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Andrea Pintér-Huszti
Syllabus	Key transfer and key agreement protocols, entity authentication and zero-knowledge protocols. Protocols for secure electronic commerce, e-auctions, e-voting protocols. Formal security analysis: formal security definitions for asymmetric encryptions and digital signatures, formal methods for entity authentication protocols
Bibliography	• Jonathan Katz, Yehuda Lindell: Introduction to Modern Cryptography: Principles and Protocols, Chapman and Hall/CRC, 2007 • Mostafa Hasham Sherif: Protocols for secure electronic commerce, Second Edition, CRC Press, 2004 • Colin Boyd, Anish Marthuria: Protocols for Authentication and Key Establishment, Springer-Verlag, 2003. • Ling Dong, Kefei Chen: Cryptographic Protocol Security Analysis Based on Trusted Freshness, Springer, 2012

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Cryptographic protocols
Type of Course	László Csirmaz
Responsible Tutor	Compulsorily eligible
Syllabus	Systems of encryption use strong rules, for one or more users. Studying and documenting these rules is object of this course. Protocols with three or more users, Byzantine Agreement Protocol, simulation of message spread, unrealizable protocols. Authentication, key exchange. Protocols using symmetric and asymmetric coding. Famous protocol errors. Formal verification of protocols.
Bibliography	Colin Boyd, Anish Marthuria: Protocols for Authentication and Key Establishment, Springer-Verlag, 2003. Adam Young, Moti Young: Malicious Cryptography, John Wiley & Sons, Inc., 2004 Mahalingam Ramkumar: Symmetric Cryptographic Protocols, Springer, 2014 Ling Dong, Kefei Chen: Cryptographic Protocol Security Analysis Based on Trusted Freshness, Springer, 2012

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Introduction to Membrane Computing

Type of Course Compulsorily eligible

Responsible Tutor Dr. György Vaszil

Syllabus Cooperative and non-cooperative, catalytic membrane systems; priorities, membrane dissolution, the role of synchronization; active membranes, computational complexity, efficient solution of computationally hard problems. Symport/antiport systems; automata-like membrane systems. Membrane algorithms, applications of membrane computing.

Bibliography

1. P. Frisco, M. Gheorghe, M.J. Pérez-Jiménez: Applications of Membrane Computing in Systems and Synthetic Biology. Springer International Publishing, 2014.
2. Gh. Paun: Membrane Computing: An Introduction. Springer-Verlag Berlin Heidelberg, 2002.
3. Gh. Paun, G. Rozenberg, A. Salomaa (szerk.): The Oxford Handbook of Membrane Computing. Oxford University Press, 2010.
4. G. Zhang, M.J. Pérez-Jiménez, M. Gheorghe: Real-life Applications with Membrane Computing. Springer International Publishing, 2017.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Title of the course Finite fields and applications

Type of the course optional

Syllabus Basic properties of finite fields; structural results, construction, the theorem of Wedderburn. Order of polynomials, irreducible polynomials, factorization. Equations over finite fields, number of solutions. Linear recurring sequences over finite fields. Characteristic polynomials, generating functions, periodicity, minimal recursion. Representation and operations on objects from finite fields, basic algorithms. Linear and cyclic codes over finite fields. Cryptographic apllications.

Literature

Lidl-Niederreiter: Finite Fields; Cambridge, England: Cambridge University Press, 1997

Dieter Jungnickel: Finite fields : Structure and arithmetics; Wissenschafts-verlag, Mannheim, 1993

Igor Shparlinski: Finite fields : theory and computation : the meeting point of numbertheory, computer science, coding theory, and cryptography; Dordrecht ; Boston : Kluwer Academic Publishers, 1999

Joachim von zur Gathen: Modern Computer Algebra, Cambridge University Press, 2013

Igor Shparlinski : Computational and Algorithmic Problems in Finite Fields, Springer Netherlands, 1992

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Problems of Data Security

Responsible Tutor József Ködmön

Type of Course Optional

Syllabus Principles concerning data security (laws, agreements, rules, standards). Physical, management and algorithmic protection in practice. Networks of computers (SSL, https, IPSec, VPN protocols). Protection of mobile devices, EU General Data Protection Regulation (GDPR).

Bibliography

D. Zhang, *Big Data Security and Privacy Protection*, ICMCS 2018, Shenyang, China

C. Galdi, M. Nappi, J-L. Dugelay, et all, *Exploring New Authentication Protocols for Sensitive Data Protection on Smartphones*, IEEE Communications Magazine, 56, 1, pp136-142. 2018.

P. Voigt, A. von dem Bussche, *The EU General Data Protection Regulation (GDPR), A Practical Guide*, Springer, 2017.

E. Bertino, *Data Security and Privacy in the IoT,* EDBT 2016. Bordeaux, France

2011. évi CXII. törvény az információs önrendelkezési jogról és az információszabadságról

Magyar Informatikai Biztonsági Ajánlások (MIBA) - a Közigazgatási Informatikai Bizottság (KIB) 25. számú ajánlása

N. Ferguson, B. Schneier, T. Kohno, *Cryptography Engineering: Design Principles and Practical Applications,* Wiley, 2010.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Automated Theorem Proving
Type of Course	Optional
Responsible Tutor	Dr. Magda Várterész
Syllabus	The classical first-order logic. Terms, formulas, models. Hilbert systems, natural deduction, sequent calculus, semantic tableaux. Resolution. SLD resolution, logic programming. Algorithms and implementations.

Bibliography

- M. Fitting: First-Order Logic and Automated Theorem Proving. Springer. 2nd ed. 1996.
- A. Nerode, R.A. Shore: Logic for Applications. Springer. 2nd ed. 1997.
- A. Robinson and A. Voronkov (eds.): Handbook of Automated Reasoning Volume I & II. Elsevier and MIT Press. 2001.
- U. Nilsson, J. Maluszynski: Logic, Programming and Prolog. Wiley & Sons Ltd. 2nd ed. 2012.
- M. Ben-Ari: Mathematical Logic in Computer Science. Springer. 3rd ed. 2012.
- J.H. Gallier: Logic for Computer Science: Foundations of Automatic Theorem Proving. Dover Publ. 2nd ed. 2015.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Boolean Functions in Computer Science
Type of Course	Optional
Responsible Tutor	Dr. Magda Várterész
Syllabus	Boolean functions, representations, evaluation. Normal forms. SAT solvers. Binary decision diagrams. Algorithms and implementations.

Bibliography

- M. Huth, M. Ryan: Logic in Computer Science. Cambridge University Press. 2002.
- D.E. Knuth: The Art of Computer Programming, Vol. 4 Fasc. 0, Introduction to Combinatorial Algorithms and Boolean Functions. 2008.
- D.E. Knuth: The Art of Computer Programming, Vol. 4 Fasc. 1, Bitwise Tricks & Techniques; Binary Decision Diagrams. 2009.
- Y. Crama, P.L. Hammer: Boolean Functions: Theory, Algorithms, and Applications. Cambridge University Press. 2011.
- M. Ben-Ari: Mathematical Logic in Computer Science. Springer. 3rd ed. 2012.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	E-business
Type of Course	Optional
Responsible Tutor	Attila Pethő
Syllabus	Reasons of the development of e-business. Informatics, communication, mobile technology and business: the decisive actors of e-business. The most important branches: e-shops, e-warehouses and e-markets. Processes, which support e-business. The law regulation of e-business. Commercial models, especially B2B and B2C models. Public procurement in Hungary and int he EU.
Bibliography	R.T. Watson, P. Berthon, L.F. Pitt and G.M. Zinkhan, Electronic Commerce: The Strategic Perspective, Global Text Project, 2008. Faisal Hoque, e-Enterprise, Business Models, Architecture, and Components, Cambridge Univ. Press, 2000. Marc Lanhorst, Enterprise Architecture at Work, Modelling, Communication and Analysis, Springer, 2009. Meier, Andreas, Stormer, Henrik : eBusiness & eCommerce *Managing the Digital Value Chain*, Springer, 2009

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Combinatorial Properties of Formal Languages
Type of Course	Optional
Responsible Tutor	Pál Dömösi
Syllabus	Combinatorics of words. Theorems of Fine and Wilf, generalization of these. Theorem of Lyndon-Schützenberger. Primitive, repetitive, palindrome, Lyndon words. Partial words. Theorem of Berstel and Boisson. Theorem of Blanchet-Sadri. Languages and codes. Multiset languages. Combinatorics of languages. Slim, caric, polycaric languages, palindroma languages. Iteration lemmas of regular and context-sensitive languages. Homomorphic description of context-free languages. Theorem of Chomsky-Schützenberger-Stanley and its generalizations. Language of primitive words and sublanguages. Roots and powers. Decision questions. Primitive multisets.
Bibliography	1. P. Dömösi and M. Ito. Context-free languages and primitive words. World Scientific, NJ, London, Singapore, etc., 2014. 2. Dömösi Pál, Falucskai János, Horváth Géza, Mecsei Zoltán, Nagy Benedek: Formális nyelvek és automaták. TAMOP 4.2.5 Pályázat könyvei, Debrecen, 2011. http://www.tankonyvtar.hu/en/tartalom/tamop425/0046_formalis_nyelvek_es_automatak/adatok.html 3. J. E. Hopcroft, R. Motwani, J. D. Ullman: Introduction to Automata Theory, Languages, and Computation. 3rd ed., Pearson Education Ltd. London, 2014. 4. H. J. Shyr : Free Monoids and Languages, National Chu-Hsing University, Taichung, Taiwan, ROC, Ho Min Book Company, 1991.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Classical First-order Logic
Type of Course	Optional
Responsible Tutor	Dr. Tamás Mihálydeák

Syllabus

The language of classical first-order logic, the most important syntactical notions. The semantics of first-order logic. Frege-Hilbert style calculus of first-order logic. Natural deduction. Gentzen's calculus. Soundness and completeness: the connection between syntax and semantics of first-order logic. Gödel's completeness theorem. Compactness theorem. Formal theories: Peano arithmetics, Zermelo-Fraenkel set theory.

Bibliography

- Mendelson, Elliott: Introduction to Mathemetical Logic, (Sixth Edition), CRC Press 2015.
- Ben-Ari, Mordechai: Mathematical Logic for Computer Science, 3rd Edition, Springer, 2012.
- George G. Boolos, George G., Burgess, John P., Jeffrey, Richard C.: Computability and Logic, 5th Edition, Cambridge, 2007.
- Jon Barwise: Handbook of Mathematical Logic, Elsevier, 1993
- S. Abramsky, Dov M Gabbay, T.S. Maibaum: Handbook of Logic in Computer Science Vol. 1, Oxford University Press, 1992.
- Ruzsa Imre: Logikai szintaxis és szemantika 1. kötet, Akadémiai Kiadó, Budapest, 1988.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Computational number theoretical and algebraic program packages

Type of Course Optional

Responsible Tutor Dr. Carolin Hannusch

Syllabus Investigation of number theoretical and algebraic problems by using computer program packages. Use of these packages in current research. Solving problems by the help of computers and the handling of these proofs. Some program packeges are discussed in details (MAPLE, MAGMA, gap, Sage)

Bibliography

- Edward Skoudis, Tom Liston: Counter Hack Reloaded: A Step-by-Step Guide to Computer Attacks and Effective Defenses (2nd Edition), Pearson 2002
- Ross J. Anderson, Security Engineering: A Guide to Building Dependable Distributed Systems, Wiley 2008
- Patrick Engebretson: The Basics of Hacking and Penetration Testing, Second Edition: Ethical Hacking and Penetration Testing Made Easy, Elsevier 2013
- Georgia Weidman: Penetration Testing: A Hands-On Introduction to Hacking, No Starch 2014
- Peter Kim: The Hacker Playbook: Practical Guide To Penetration Testing, CreateSpace 2014

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Context-free Languages
Tantárgy típusa	Optional
Tantárgyfelelős	Dr. Géza Horváth
Tematika	Context-free languages generated by context-free grammars. Context-free languages accepted by pushdown automata. Equivalence of pushdown automata and context-free grammars. The Bar-Hillel lemma, and the family of pumping lemmas for different language classes. The word problem for context-free languages. Polynomial time solution: the Early algorithm for context-free grammars. The Chomsky normal form, and its application, the CYK algorithm. Closure properties.
Irodalom	1., Grzegorz Rozenberg and Arto Salomaa (Editors): Handbook of Formal Languages, 3 volumes, Springer, Heidelberg, 1997. 2., John E. Hopcroft, Rajeev Motwani and Jeffrey D. Ullman: Introduction to Automata Theory, Languages and Computation (3rd edition). Addison-Wesley, 2006. 3., Michael Sipser: Introduction to the Theory of Computation (3rd edition). Cengage Learning, 2013. 4., Géza Horváth and Benedek Nagy: Formal Languages and Automata Theory. Typotex, 2014.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Context-sensitive Languages
Tantárgy típusa	Optional
Tantárgyfelelős	Dr. Géza Horváth
Tematika	Context-sensitive languages generated by context-sensitive grammars. Monotone grammars. Equivalence of monotone grammars and context-sensitive grammars. The Kuroda normal form. Linear bounded automata. Equivalence of linear bounded automata and context-sensitive grammars. The word problem for context-sensitive languages. Closure properties.
Irodalom	1., Grzegorz Rozenberg and Arto Salomaa (Editors): Handbook of Formal Languages, 3 volumes, Springer, Heidelberg, 1997. 2., John E. Hopcroft, Rajeev Motwani and Jeffrey D. Ullman: Introduction to Automata Theory, Languages and Computation (3rd edition). Addison-Wesley, 2006. 3., György E. Révész: Introduction to Formal Languages, Dover Publications, New York, 2012. 4., Géza Horváth and Benedek Nagy: Formal Languages and Automata Theory. Typotex, 2014.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Quantum computers
Type of Course	Optional
Responsible Tutor	Kruppa András
Syllabus	The basic of quantum mechanics. Quantum registers, qubits. Quantum states, measurements and density operator. Quantum teleportation, dense coding and Bell's inequality. Classical Boolean and quantum networks. Quantum algorithms.
Bibliography	M. Hirvensalo, Quantum Computing, Springer 1998, Natural Computing Series E. Rieffel, W. Polak, Quantum Computing A Gentele Introduction, The MIT Press 2011 S.M Barnett, Quantum Information, Oxford University Press, 2012 Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2013

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Artificial Intelligence
Tantárgy típusa	Optional
Tantárgyfelelős	Dr. László Aszalós
Tematika	Symbolic and non-symbolic methods, search methods and its applications, formal logical methods for reasoning, reasoning under uncertainty, introduction into machine learning
Irodalom	• *NILSSON, Nils J.* Principles of artificial intelligence. *Morgan Kaufmann, 2014.* • *COHEN, Paul R.; FEIGENBAUM, Edward A. (ed.).* The handbook of artificial intelligence. *Butterworth-Heinemann, 2014.* • *RUSSELL, Stuart J.; NORVIG, Peter*. Artificial intelligence: a modern approach. Prentice-Hall, *2003.* • *ERTEL, Wolfgang*: Introduction to Artificial Intelligence (Undergraduate Topics in Computer Science) Springer, 2017, ISBN: 978-3319584867

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Models of parallel computing
Type of Course	Optional
Responsible Tutor	Battyányi, Péter
Syllabus	Cooperating Distributed (CD) grammar systems, controlled CD grammar systems, Parallel Communicating (PC) grammar systems, Lindenmayer systems Petri nets, membrane systems, the chemical computing paradigm, γ-calculus, parallel λ-calculus Communicating Sequential Processes (CSP), Hennessy-Milner logics, temporal properties of processes: LTL- and CTL-logics, modal μ-calculus

Bibliography

1. E. Csuhaj-Varjú, J. Dassow, J. Kelemen, Gh. Paun: Grammar Systems: A grammatical approach to distribution and cooperation. Gordon and Breach Science Publishers, Topics in Computer Mathematics 5, Yverdon, 1994.
2. G. Rozenberg, A. Salomaa (eds.): Handbook of formal languages, Springer, Berlin, Heidelberg, 1997. 3 volumes.
3. W. Reisig: Understanding Petri Nets, Springer-Verlag Berlin Heidelberg, 2013
4. J. L. Peterson: Petri Net Theory and the Modeling of Systems, Prentice Hall, 1981
5. Gh. Paun: Membrane Computing, Springer-Verlag Berlin, 2002
6. Ch. Baier and J.-P. Katoen: Principles of Model Checking, MIT Press, Cambridge, MA, 2008
7. C. Stirling: Modal and Temporal Properties of Processes, Springer Verlag, 2001

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Symbolical and numerical computations with Mathematica
Type of Course	Optional
Responsible Tutor	András Tibor Kruppa, ATOMKI
Syllabus	1. The program package *Mathematica*. user interface 2. Terms, values, lists and operations 3. Functions with one and more variables, solution of equations. 4. Graphics 5. Linear algebraic problems. 6. Solving differential equations, symbolically and numerically 7. Programming with procedures and functions.
Bibliography	Wolfram, S.: The Mathematica Book, 5th ed., Wolfram Media, Cambridge Univ. Press, 2002 Walker G.J.:Mastering Mathematica : programming methods and applications**,** Academic Press, 1998 Paul Wellin, Programming with Mathematica®: An Introduction, Cambridge University Press 2013

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Proof theory in modal logic
Type of Course	Optional
Responsible Tutor	Dr. Aszalós László
Syllabus	Relational structures, models, finite models, axioms, frames, first-order correspondence, Sahlqvist formulae, sequent method, labelled method

Bibliography

- *NEGRI, Sara. Proof theory for non-normal modal logics: The neighbourhood formalism and basic results.* IFCoLog Journal of Logic and its Applications, to appear, http://www. helsinki. fi/~ negri/negri_ifcolog. pdf, *2017.*
- *CONRADIE, Willem; PALMIGIANO, Alessandra; SOURABH, Sumit. Algebraic modal correspondence: Sahlqvist and beyond.* Journal of Logical and Algebraic Methods in Programming, *2017, 91: 60-84.*
- *BLACKBURN, Patrick; VAN BENTHEM, Johan FAK; WOLTER, Frank (ed.).* Handbook of modal logic. *Elsevier, 2006.*
- *POGGIOLESI,Francesca:* Gentzen Calculi for Modal Propositional Logic, Springer Netherlands, 2011, isbn: 978-90-481-9669-2

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Pushdown Automata
Tantárgy típusa	Optional
Tantárgyfelelős	Dr. Géza Horváth
Tematika	Definition of pushdown automata, context-free languages accepted by pushdown automata. Graphical representation of pushdown automata. Acceptance by final states, acceptance by empty stack. Equivalence of acceptance by final states and acceptance by empty stack. Equivalence of pushdown automata and context-free grammars. Deterministic pushdown automata and deterministic context-free languages. Closure properties of deterministic and nondeterministic pushdown automata.
Irodalom	1., Grzegorz Rozenberg and Arto Salomaa (Editors): Handbook of Formal Languages, 3 volumes, Springer, Heidelberg, 1997. 2., John E. Hopcroft, Rajeev Motwani and Jeffrey D. Ullman: Introduction to Automata Theory, Languages and Computation (3rd edition). Addison-Wesley, 2006. 3., Michael Sipser: Introduction to the Theory of Computation (3rd edition). Cengage Learning, 2013. 4., Géza Horváth and Benedek Nagy: Formal Languages and Automata Theory. Typotex, 2014.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Foundation of Machine Learning
Type of Course	Compulsory
Responsible Tutor	Dr. Fazekas, István
Syllabus	Schemes of neural networks, learning algorithms. The Multilayer Perceptron (MLP), the error back-propagation algorithm. Optimization methods: conjugate gradient, quasi Newton and Levenberg-Marquardt methods. Deep learning. Convolutional networks. Radial Basis Function networks (RBF), penalty functions. Support Vector Machines (SVM), the optimal hyperplane, the Kuhn-Tucker theorem. Separation by SVM, approximation by SVM. Recurrent networks, LSTM. Reinforcement learning.
Bibliography	Christianini, N., Shawe-Taylor, J.: An Introduction to Support Vector Machines and Other Kernel-based Methods. Cambridge University Press, Cambridge, 2000. Goodfellow, I., Bengio, Y., Courville, A. Deep Learning. MIT Press, 2016. Haykin, S.: Neural Networks and Learning Machines. Pearson, 2009. Devroye, L., Györfi, L., Lugosi, G.: A Probabilistic Theory of Pattern Recognition. Springer, New York, 1996. Matlab Neural Network Toolbox. The Mathworks, Inc., Natick, 2017. Titterington, D.M.: Kay, J.W.: Statistics and Neural Networks. Oxford University Press, Oxford, 1999. Vapnik, V.M. Statistical Learning Theory. Wiley, New York, 1998.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Course title	Library Management
Course type	compulsory
Course leader	Dr. Virágos, Márta
Topics	The importance of quality in library management. General system theory and the function of system theory in library activities. Methods of planning library work and services. Principles of decision making, establishing politics. Library as a system. Methods and issues of operations, monitoring, and evaluations. Main fields of quality assurance. Methods and technics of quality management.
Bibliography	[1] **Daniel N. Joudrey, Arlene G. Taylor:** The Organization of Information, 4th Edition.Libraries Unlimited. Santa Barbara. 2017. [2] **Edward Evans, Camila Alire:** Management Basics for Information Professionals, 3rd Edition. ALA Neal-Schuman. 2013. [3] **Robert D. Stueart, Claudia J. Morner, Barbara B. Moran:** Library and Information Center Management, 8th Edition. Libraries Unlimited. Santa Barbara. 2012. [4] **Rachel Applegate:** Practical Evaluation Techniques for Librarians. Libraries Unlimited. 2013.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Scientific computing

Type of Course Compulsorily eligible

Responsible Tutor Dr. Baran, Ágnes Éva

Syllabus

Accuracy of scientific computations. Computer arithmetic.

Numerical solution of system of linear equations, large, sparse matrices, iterative methods. Root finding, minimization of functions. Function approximations. Computer implementation of numerical algorithms.

Bibliography

- N. J. Higham: Accuracy and Stability of Numerical Algorithms, Siam, 2002.
- G. H. Golub, C. F. van Loan, Matrix computations, The Johns Hopkins University Press, 1996.
- O. Axelsson: Iterative Solution Methods, Cambridge Univ. Press, 1996.
- Press W.H. Numerical Recipes in C, Cambridge Univ. Press, 1999.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Topics in the theory of stochastic processes

Type of Course Compulsorily eligible

Responsible Tutor Dr. Sándor Baran

Syllabus

1. L^2 processes: covariance functions, L^2 calculus, Karhunen-Loéve expansion.
2. Spectral theory and prediction: L^2 stochastic integrals, decomposition of stationary processes, discrete and continuous parameter processes.
3. Ergodic theory: ergodicity and mixing, ergodic theorems and their applications.
4. Sample function analysis of continuous parameter processes: separability and measurability, Brownian motion, Markov processes, processes with independent increments, strong Markov property.
5. Stochastic differential equations, Ito integral: definition of the Ito integral, existence and uniqueness theorems for stochastic differential equations, chain rule.

Bibliography

- Ash, R. B., Gardner, M. F.: *Topics in Stochastic Processes*. Academic Press, New York, 1975.
- Shiryaev, A. N.: *Probability*. Springer, New York, 1996.
- Iacus, S. M.: *Simulation and Inference for Stochastic Differential Equations. With R Examples.* Springer, New York, 2008.
- Dobrow, R. P.: *Introduction to Stochastic Processes with R.* Wiley, 2016.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Selected topics in probability

Type of Course Compulsorily eligible

Responsible Tutor Dr. Barczy, Mátyás

Syllabus Modes of convergence of random variables (uniform, almost sure, stochastic, in L_p and in distribution). Characteristic functions and their properties: inversion formulas, unicity theorem, moments and series expansion, Lévy-Cramér's continuity theorem, characteristic functions of some notable distributions. The Lindeberg's and Lyapunov's theorem, and the Lindeberg-Feller's theorem. Local central limit theorems, Berry-Esseen's theorem. Zero-and-one laws, Kolmogorov's inequality, three-series theorem, strong and weak laws of large numbers (especially, Kolmogorov's strong law of large numbers, Etemadi's and Marcinkiewicz's strong laws of large numbers). Definition and properties of conditional probability and conditional expectation with respect to a sigma algebra: convergence theorems, Jensen's inequality, general forms of law of total probability and law of total expectation.

Bibliography

1. Shiryayev, N.: *Probability-1*, *3rd edition*, Springer-Verlag, New York, 2016.
2. Shiryayev, N.: *Probability-2*, *3rd edition*, Springer-Verlag, New York, 2018.
3. Athreya, K. B., Lahiri, S. N.: *Measure Theory and Probability Theory*, Springer, 2006.
4. Bauer, H.: *Probability Theory*, Walter de Gruyter, 1995.
5. Chow, Y. S., Teicher H.: *Probability Theory*, *3rd edition*, Springer, 1978.
6. Rényi, A.: *Probability Theory*, Dover Publications Inc., 2007.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Random graphs and networks
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Fazekas, István
Syllabus	Networks and random graphs. Models of random graphs: the Erdős-Rényi random graph, the Barabási-Albert model, the Watts-Strogats model. Evolution of random graphs. Asymptotic properties. Clusters, diameter, giant component, scale-free, small word. Tools: branching processes, martingales.
Bibliography	Durrett, R.: Random graph dynamics. Cambridge University Press, Cambridge, 2010. Barabási, Albert-László: Network science. Cambridge University Press, 2018. Bollobás, B.: Random graphs. Cambridge University Press, Cambridge, 2001. Janson, S.; Łuczak, T.; Rucinski, A.: Random graphs. Wiley-Interscience, New York, 2000. R. van der Hofstad. Random Graphs and Complex Networks. Vol. 1. Cambridge Series in Statistical and Probabilistic Mathematics, 2017. R. van der Hofstad: Random Graphs and Complex Networks. Vol 2. Eindhoven University of Technology, 2017.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	HISTORY OF INFORMATION
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Miklós Bényei
Syllabus	The concept of the history of information and the development of its thinking. The elementary information and the formations of the information; the process model of the information flow. The information technology (information tool, information machine, information specialists, information factory, information industry). The branches of the history of information: information-centred analysis, history of information housekeeping, social history of information technics; history of information occurrence; preliminary history of information society. Relationship of the history of information with other disciplines, with special respect to the library and information science. The most significant tools (speach, handwriting, printed book, press, photo, telegraph, telephone, sound recording, video, radio, televison, computer and Internet etc.) and institutions (churches, schools, offices, publishers, research institutions and museums etc.) of recording and communicating the information, the place and role of the libraries in this field. Keeping the information flow under control, models of censorship.
Bibliography	Information beyond borders : International cultural and intellectual exchange in the Belle Époque / [edited] by W. Boyd Rayward. – Ashgate : 2014. The Information : A History, a Theory, a Flood / James Gleick. - New York : Pathenon Books, 2011.

History of Librarianshop, library history, or information history : A view from Russia / B. P. Volodin. In: Library Quarterley, 70)4), 2000. p.446-467.

Information Ages: Literacy, Numeracy and the Computer Revolution / Michael E. Hobart, Zachary S. Schiffman. – Baltimore : John Hopkins University Press, 1998.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course The narratives of digital reading, electronic literature

Type of Course Compulsorily eligible

Responsible Tutor Dr. Erzsébet Dani

Syllabus Narratives of reading in the Neumann galaxy. Phases of interpretative reading comprehension, the Rabinowitz stages. Intersections of information acquisition and reading. Ways in which the web impacts reading habits. Electronic literature and new trends of reading. The possibilities of making reading popular. The generational paradigm in the space of digital reading, or, is this really "the dumbest generation," and does the digital age really stupify young digital natives? The interface of 21st century indentity scenarios and reading. The cognitive aspect. The phenomenon of hyperattention and the way it influences meaningful integrative reading. The alternating phases of hyper- and deep attention.

Bibliography

Bauerlein, Mark: The Dumbest Generation: How the Digital Age Stupifies Young Americans and Jeopardizes Our Future. New York: Jeremy P. Tarcher/Penguin, 2008.

Hayles, Katherine N.: How We Think: Digital Media and Contemporary Technogenesis. Chicago and London, The University of Chicago Press, 2012.

Hayles, Katherine N.: My mother Was a Computer: Digital Subjects and Literary Texts. Chicago, The University of Chicago Press, 2005

Kamill, Michael L. – Pearson, David P. – Birr Moje, Elizabeth [et al.]: Handbook of Reading Research I-IV. New York, Routledge, 2011.

Manguel, Alberto: A History of Reading. New York, Penguin, 2014.

Page, Ruth – Thomas, Bronwen: New Narratives: Stories and Storytelling in the Digital Age. Lincoln and London, University of Nebrasca Press, 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Finite element methods

Type of Course Optional

Responsible Tutor Dr. Baran, Ágnes Éva

Syllabus

Examples and classification of partial differential equations.

Variational formulation of elliptic boundary-value problems of second order.

Basic concepts of finite element methods, conforming elements, triangular and rectangular finite elements. Nonconforming finite elements.

Finite elements for the Stokes problem. Stability.

Computer implementation of finite element methods.

Bibliography

D. Braess: Finite elements, Theory, fast solvers, and applications in solid mechanics, Cambridge University Press, 2007.

S. C. Brenner, L. R. Scott: Tha Mathematical Theory of Finite Element Methods, Springer, 2002.

P.G. Ciarlet: The finite element method for elliptic problems, Elsevier, 1978

P.I. Kattan: MATLAB guide to finite elements : an interactive approach, Springer, 2003

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Stochastic Algorithms

Type of Course Optional

Responsible Tutor Dr. Sándor Baran

Syllabus The course deals with the most important Monte Carlo methods, their applications and implementations in R language. Topics covered: random number generators, Monte-Carlo integration, stochastic optimization, Simulated Annealing, Monte Carlo approximations, EM algorithm, Metropolis-Hastings algorithms, Gibbs Sampler, variable dimension models.

Bibliography

- Christian P. Robert, George Casella: *Monte Carlo Statistical Methods. Second Edition*. Springer, New York, 2004.
- Christian P. Robert, George Casella: *Introducing Monte Carlo Methods with R*. Springer, New York, 2010.
- Emile Aarts, Jan Korst: *Simulated Annealing and Boltzmann Machines.* Wiley, New York, 1989.
- Brian D. Ripley: *Stochastic Simulation*. Wiley, New York, 1987.
- Sean Meyn, Richard Tweedie: *Markov Chains and Stochastic Stability*. Springer, New York, 1993.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Applications of virtual reality

Type of Course Optional

Responsible Tutor Dr. Rácz, Anett

Syllabus This course deals with applications of virtual- and augmented reality which topics gain even larger attention nowadays. VR and AR technology appear in several new area. We investigate efficiency and succes of the most innovative applications and learn case studies about up-to-date developements.

Bibliography

1. Jason Jerald, The VR Book: Human-Centered Design for Virtual Reality, Morgan & Claypool, Sep 1, 2015
2. Current numbers of Virtual Reality, Springer
3. Current volume of International Journal of Virtual Reality (IJVR), IPI Press
4. Tony Parisi, Learning Virtual Reality: Developing Immersive Experiences and Applications for Desktop, Web, and Mobile, O'Reilly Media, 2015

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Implementation techniques of simplex method

Type of Course Optional

Responsible Tutor Dr. Rácz, Anett

Syllabus There are several well-known version of the simplex method used in linear programming. The theoretical background is clear and well-defined, its implementation requires enormous programming knowledge. The course deals with the simplex method and its variant and their implementation. We focus on special techniques for solving large problems and the methods for improving the computational efficiency. Modelling languages like MPS and AMPL are introduced and we study the usage of standard test-problem libraries.

Bibliography

1. István Maros: Computational Techniques of the Simplex Method, Springer Science & Business Media, Dec 31, 2002
2. Koberstein A.: The Dual Simplex Method, Techniques for a fast and stable implementation, PhD dissertation, University of Paderborn
3. Fourer, R.: Notes on the dual simplex method. Draft report (1994)
4. Panos M. Pardalos and Mauricio G. C. Resende: Handbook of Applied Optimization, Oxford University Press, 2002

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Integer Programing

Type of Course Optional

Responsible Tutor Dr. Rácz, Anett

Syllabus Methods of integer and mixed integer programing and their implementational issues. Techniques to improve efficiency of solving these optimization problems.

Bibliography

5. Michele Conforti, Gérard Cornuéjols, Giacomo Zambelli: Integer Programming, Springer, 2014
6. Der-San Chen, Robert G. Batson, Yu Dang, "Applied Integer Programming: Modeling and Solution", Wiley, 2010
7. Gerard Sierksma, "Linear & Integer Programming: Theory and Practice, 2nd edition", CRC press, 2001
8. Hamdy A. Taha, Integer Programming: Theory, Applications, and Computations, Academic press, 2014

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Nonlinear optimization
Type of Course	Optional
Responsible Tutor	Dr. Pál Burai
Syllabus	Classification of nonlinear optimization problems. Unconstrained problems. First-order optimality conditions. Second-order optimality conditions. Variational principles. Constrained problems. Fritz John optimality condition. Sufficient optimality conditions. Algorithms. Basics of non-smooth optimization.
Bibliography	1. J. Nocedal – S. Wright: Numerical optimization, Springer-Verlag, New York, 1999. 2. M. Ulbrich – S. Ulbrich: Nichtlineare optimierung, Birkhäuser, 2012. 3. O. Güler: Foundation of opitmization, Springer-Verlag, New York, 2010. 4. D. Luenberger: Linear and nonlinear programming, Kluwer Academic Publishers, Boston, 2003.

UNIVERSITY OF DEBRECEN
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Name of Course	Convex analysis and optimization
Type of Course	Optional
Responsible Tutor	Dr. Burai Pál
Syllabus	Convex functions, convex sets. Conjugate, biconjugate. Quasi-convex functions. Other generalization of convexity. Convex optimization problems. Quadratic optimization. Linear programming. Duality theory. Theorems of alternative. Farkas lemma. Optimality conditions. Applications.
Bibliography	1. T. Rockafellar: Convex Analysis, Princeton University Press, 1970 2. I. Ekeland – R. Temam: Convex analysis and variational problems, North-Holland Pub. Co., 1976. 3. G. G. Magaril-Il'yaev V. M. Tikhomirov, Convex analysis, American Mathematical Society, 2003. 4. S. Boyd – L. Vanderberghe, Convex Optimization, Springer Verlag, 2004.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Convergence of Probability Measures
Type of Course	Optional
Responsible Tutor	Dr. Fazekas, István
Syllabus	Weak convergence of probability measures in metric spaces, Prohorov's theorem. Convergence in space C. Donsker's theorem. Applications, the Wiener process, the Brownian bridge. The space D, weak convergence and tightness in D. Applications in statistics, the empirical process.
Bibliography	Bhattacharya, R., Waymire, E. C.: A Basic Course in Probability Theory. Springer, 2007. Billingsley, P.: Convergence of Probability Measures. Wiley, New York, 1999. Gihman, I.I.; Skorohod, A.V.: The Theory of Stochastic Processes I. Springer-Verlag, Berlin, 1974. Jacod J., Shiryaev A.N.: Limit Theorems for Stochastic Processes. Springer, Berlin, 2003. Pollard, D.: Convergence of Stochastic Processes. Springer, New York, 1984.

UNIVERSITY OF DEBRECEN
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Name of Course	Statistical Analysis with SAS
Type of Course	Optional
Responsible Tutor	Patrícia Szokol, PhD
Syllabus	In this course you will learn the two most famous software of the SAS system. Beyond the data manipulation possibilities (queries, filters, generating of new variables, joining data tables), the SAS Enterprise Guide has a very complex statistical toolkit. Beside the base statistics, cluster analysis, regression, and several other analytic tool is available in it. The SAS Enterprise Miner provides the traditional data mining methods, i.e. the predictive modelling (regressions, decision trees, neural networks). Beside that it is possible to use more complicated data mining methods. Finally, we will get acquainted with further softwares and applying those softwares, we will present data and results in the most compelling way with advanced data visualization techniques.
Bibliography	1. Advanced Tasks & Querying Using SAS Enterprise Guide, Course Notes, SAS Institute Inc, 2006. 2. Querying and Reporting Using SAS Enterprise Guide, Course Notes, SAS Institute Inc. 2006 3. Data Mining Using SAS Enterprise Miner A Case Study Approach 4. SAS OnlineDoc 9.4 for the Web- http://support.sas.com/documentation/onlinedoc/stat/index.html 5. Everitt, B.S., Hothorn, T.: A Handbook of Statistical Analysis Using R, Chapman & Hall, 2006.

UNIVERSITY OF DEBRECEN
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Name of Course Financial mathematics

Type of Course Optional

Responsible Tutor József Gáll

Syllabus We shall study some modern financial (mathematical) models and related applications during the course. On the one hand we will turn to classical capital market models, such as the Markowitz model, the CAPM and APT, and their updated versions, on the other hand we discuss models for pricing financial derivatives both in discrete and continuous time. We shall discuss the assumptions of the models versus applications, parameter estimations, market tests, empirical studies and simulations.

Bibliography

Barucci, E. (2003): *"Financial Markets Theory"*, Springer.

Brigo, D., Mercurio, F. (2006): Interest Rate Models - Theory and Practice, Springer.

Huang, Chi-Fu and Litzenberger, R. H. (1988): *"Foundations for financial economics"*, Prentice Hall.

Hull, J. C. (2011): *„Option, Futures and Other Derivatives"*, Ed. 8, Pearson:

Musiela, M. and Rutkowski, M. (1997), *"Martingale Methods in Financial Modeling"*, Springer-Verlag, Berlin, Heidelberg.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Insurance mathematics

Type of Course Optional

Responsible Tutor József Gáll

Syllabus The main aim of the course is to discuss some basic models of modern non-life insurance and reinsurance. First we study the classical models for the total claim amount. We discuss claim number distributions and processes, claim distributions and methods for the total claim amount, in particular mixture distributions. We discuss statistical questions and applications, empirical problems. We shall also discuss reinsurance problems, risk measures and their estimations, and similar models applied in operational risk.

Bibliography

Mikosch, T. (2004): „*Non-Life Insurance Mathematics*", Springer.

Schmidli, H. (2018): *Risk Theory*, Springer.

Straub, E. (1988): „*Non-Life Insurance Mathematics*", Springer.

Klugman, S. A., Panjer, H. H. and Willmot, G. E. (2012): *„Loss Models: From Data to Decisions"*, 4th Edition, Wiley.

UNIVERSITY OF DEBRECEN
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Name of Course Computer statistics

Type of Course Optional

Responsible Tutor Dr. Kinga Sikolya-Kertész

Syllabus The aim of the course is to gain wide range of statistical analysis skills through computer programs (e.g. R, SAS, SPSS) which are required for applied research or scientific research works. Fields of practical application of a statistical software and the familiarization of the usage of the program are included in the course. Moreover the students learn how to apply the most important single and multivariable statistical methods and the interpretation of the results. The students also can learn the statistics and the chosen software's main tools through own research data.

Bibliography

Douglas C. Montgomery, George C. Runger: Applied Statistics and Probability for Engineers. John Wiley&Sons, New York, 2003.

Mardia K. V., Kent J. T., Bibby J. M.: Multivariate analysis. Academic Press, 1979.

John M. Quick: Statistical Analysis with R, Packt Publishing, 2010.

Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani: An Introduction to Statistical Learning: with Applications in R, Springer, 2013.

Everitt, B.S., Hothorn, T.: A Handbook of Statistical Analysis Using R, Chapman & Hall, 2006.

Marques de Sá J. P.: Applied Statistics Using SPSS, STATISTICA, MATLAB and R, Springer, 2003.

Salcedo J., McCormick K.: SPSS Statistics for Data Analysis and Visualization, Wiley, 2017.

SAS OnlineDoc 9.4 for the Web - http://support.sas.com/documentation/onlinedoc/stat/index.html

SAS Enterprise Guide: ANOVA, Regression and Logistic regression – online training

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Name of Course Numerical Analysis for Engineers

Type of Course Optional

Responsible Tutor Tamas Vertse

Syllabus Approximations for real and complex functions, spline interpolations (differentiation, integration), quadrature rules, solutions of ordinary and partial differential equations.

Bibliography

William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery: Numerical Recipes The Art of Scientific Computing, Third Edition, Cambridge University Press 2007.
L. Gr. Ixaru: Numerical Methods for Differential Equations and Applications, D. Reider Publ. Comp., Dordrecht/Boston/Lancaster 1984.
S. D. Conte, C. de Boor: Elementary Numerical Analysis, McGraw-Hill Book Comp. New York etc 1980.
Gisbert Stoyan, Agnes Baran: Elementary Numerical Mathematics for Programmers and Engineers, Birkhauser, 2016.

UNIVERSITY OF DEBRECEN
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Name of Course Cognitive Science

Type of Course Optional

Responsible Tutor Dr. habil. István Boda

Syllabus

The basic aim of the course is to give a comprehensive overview of the main topics of cognitive science and its various relationships with other fields and disciplines. Successful completion of the course will allow the students to apply contemporary cognitive science paradigms as well as to follow new research results and ideas.

Selected topics:

Problems and main concepts of cognitive science and related disciplines. Types and taxonomies of human knowledge. The emergence and development of cognitive science. The classic view of cognitive science. The organization of human memory and the mental representations. The symbolic and connectionist processing approach. The evolutional thought. The concept of representation in cognitive science. Donald's view about the origin of human mind and cognition. Cognitive science and artificial intelligence. The development of human knowledge. The body-mind problem, Karl Popper's „three worlds" theory.

Bibliography

[1] Bly, Benjamin Martin; Rumelhart, David E. (eds).: Cognitive Science. Academic Press, 1999.
[2] Donald, Merlin: Origins of the Modern Mind. Three Stages in the Evolution of the Culture and Cognition. Cambridge, Massachusetts–London: Harvard Univ. Press.
[3] Fodor, Jerry; Massimo Piatelli-Palmarini: What Darwin Got Wrong. London: Profile Books, 2011.
[4] Stillings, Neil A. [et al.]: Cognitive Science. An Introduction. The MIT Press, 1995.
[5] Tegmark, Max: Life 3.0. Being Human in the Age of Artificial Intelligence. New York: Alfred A. Knopf, 2017.
[6] Thagard, Paul: Mind. Introduction to Cognitive Science. The MIT Press, 2005.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Software quality
Type of Course	Optional
Responsible Tutor	Eszenyiné dr. Borbély Mária
Syllabus	The quality of software products and software processes. International standards of the software product quality. The definition of the quality in use of the software products. Metrics and case studies to measure software product quality in use. Measurement of user satisfaction in software environment.
Bibliography	[1] ISO/IEC 25010:2011: Systems and software engineering -Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models [2] ISO/IEC TR 9126-4:2004: Software engineering -- Product quality -- Part 4: Quality in use metrics [3] Maria Borbely, (2011) "Measuring user satisfaction with a library system according to ISO/IEC TR 9126-4", Performance Measurement and Metrics, Vol. 12 Iss: 3, pp.157 – 171. [4] ISO/IEC 25022:2016: Systems and software engineering -- Systems and software quality requirements and evaluation (SQuaRE) -- Measurement of quality in use

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Name of Course	Metadata of digital collections
Type of Course	Optional
Responsible Tutor	Dr. Némethi-Takács Margit
Syllabus	Metadata and types of metadata. Metadata standards. Metadata schemas (Dublin Core, Metadata Objects Description Schema, Visual Resources Association Core Categories). XML encoded metadata. Metadata interoperability. Metadata and the semantic web. Linked data. A Linked Open Data (LOD) and the bibliographic data of public collections.
Bibliography	Miller, S. J.: Metadata for digital collections. New York: Neal-Schuman, cop.2011 Willer, M. - Dunsire, G.: Bibliographic information organization in the semantic web. Oxford: Chandos, 2013 Horváth Z.: A hálózat vonzásában: a „linked data" szétfeszíti a könyvtári katalógusok kereteit. Könyvtári Figyelő, 61. évf. (2015), 4. sz., p. 463-481. Caplan, P.: Metadata fundamentals for all librarians. American Library Association, 2003.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Web information retrieval

Type of Course Optional

Responsible Tutor Erzsébet Tóth, Ph.D

Syllabus The main types of web search services (search engines, subject directories, meta search engines, intelligent agents) and their characteristics. The related research fields of the search engine subject (e.g. semantic web, network theory, hidden web, text mining and web data mining etc.). The semantic analysis and retrieval of multimedia content in two- and three-dimensional spaces. The structure and operation of the search engines. The principles of ranking the web pages, the PageRank algorithm. Measuring the retrieval effectiveness of web search engines. The overview of the applicable metrics in evaluations. The most significant statistical analyses conducted on the search engines. The methodology of the relevance analyses. Various definitions of the relevance in technical literature.

Bibliography

Baeza-Yates, R. and Ribeiro-Neto, B.: Modern Information Retrieval. The Concepts and Technology Behind Search. 2nd ed. Harlow [etc.]: Pearson, 2011.

Representation of Knowledge and Search Engines in the Internet. Textbook. Chapters 1-3 are by E. Tóth, Chapter 4 is by E. Dani. Debrecen: University of Debrecen, 2015. URL:

http://szaknyelvtudas.unideb.hu/images/tananyagok/Representation_of_Knowledge_and_Search_Engines_in_the_Internet1.pdf (2018-12-30)

Wiza, W.: Interactive 3D Visualization of Search Results pp. 253-291. In: Interactive 3D Multimedia Content. Cellary W., Walczak K. (eds). London: Springer, 2012.

Langville, A. N. and Meyer, C. D.: Google's PageRank and

Beyond. The Science of Search Engine Rankings. Princeton - Oxford: Princeton University Press, 2006.

Harter, S. P. and Hert, C. A.: Evaluation of Information Retrieval Systems. Approaches, Issues and Methods. Annual Review of Information Science and Technology, vol. 32. 1997. pp. 3-79.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Tantárgy megnevezése	Basic Questions of the Copyright in the Digital Age
Tantárgy típusa	optional
Tantárgyfelelős	Dr. Virágos, Márta
Tematika	The concept and the place of copyright in the legal system. The evaluation of intellectual property law (short historical survey). The intellectual property law and related rights. General terms of contracts of intellectual property for fair use. Copyright law for publications (concerning the question of plagiarism also). Copyright issues of software use (including data bases). Important questions of digital right management. Questions of public copyright and open access. Academic institutions' Open Access policies. Open Access publishing.
Bibliography	[1] **Li, Yuan and Meghan Banach**: Institutional Repositories and Digital Preservation: Assessing Current Practicies and Research Libraries. D-Lib Magazine 17. no. 5/6 (2011) [2] **Charles W. Bailey, Jr**.: Author's Rights, Tout de Suite. Digital Scholarship. www.digital-scholarship.org/Houston, Texas [3] **Copyright Information Management and the University Library:** Staffing, Organizational Placement and Authority. The Journal of Academic Librarianship 39, no. 5 (2013) [4] **Christian Meier zu Verl and Wofram Horstmann**: Studies on Subject-Specific Requirements for Open Access Infrastructure. Universitatsbibliothek Bielefeld. 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Course title	Questions of knowledge transfer
Course type	Optional
Course leader	Dr. Márta Virágos
Topics	New definition of knowledge management in the field of research and innovation. The definition of technology transfer, innovation paradigms. New ways of scholarly communication: Open Access, Open Data. Measuring scholarly work: qualitative and quantitative indeces (IP, Hirch Index, Altmetrics, Webometrics). Process and steps of digitization, international standards. Accessing digital content: open systems. Question of long term presevation. Licences and consortiums and copy right questions The technics of research data management. EU research infrastructure (ERA), COAR. EU programs: Driver, OpenAir, OpenAirPlus, DARIAH, Horizon 2020. Content and infrastructure issues of repositories.
Bibliography	[1] **Hans-Christoph Hobohm**: Knowledge management. IFLA Publications 108. KG. Saur. Munchen. 2004. [2] **Davenport, Thomas H.; Leibold, S.; Voelpel** (2006). Strategic management in the innovation economy. Strategy approaches and tools for dynamic innovation capabilities. Wiley. ISBN 3-8957-8263-7. [3] **Tedd, Lucy A**.: Digital libraries:principles and practice in a global environment Large. - München: Saur, K. G., Verlag. 2005 [4] **Christian Meier zu Verl**: Studies on Subject-Specific Requirements for Open Access Infrastructure. Bielefeld. 2011. [4] **Richard Jones, Theo Andrew and John MacColl**: The Institutional Repository. Chandos Publishing. Oxford. 2007.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Routing and Switching
Type of Course	Compulsory
Responsible Tutor	Dr. Gál, Zoltán
Syllabus	The course works on the routing and switching mechanisms of the next generation computer networks. Dynamic interior and exterior routing protocols. Ad-hoc networking. Switching mechanisms in Layer 2 and in upper Layers, MPLS, QoS, VoIP switching requirements. Multipath and multilink communication technologies int he different Layers. The course studies the effects of the next generation IP technology (IPv6) on the routing and switching mechanisms.
Bibliography	A. S. Tanenbaum: Computer Networks, 5th ed. Prentice-Hall 2010. RFC Documents and drafts: www.rfc-editor.org

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Reconfigurable Embedded Systems based Cyber-Physical systems

Type of Course Compulsory

Responsible Tutor Dr. Oniga István

Syllabus Definition of the embedded systems and cyber-physical systems, their connection and applications. Specifications and modeling. Cyber-physical systems hardware issues. High complexity programmable logic devices (FPGA) characteristics'. Advanced and efficient design methods. Hardware-software codesign. IP (Intellectual Property) based design. Cyber-physical systems software issues. Case studies within sensor networks, e-health and smart environment topics.

Bibliography

1. E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, Second Edition, MIT Press, 2017. ISBN: 978-0-262-53381-2
2. Peter Marwedel, Embedded Systems Foundations of Cyber-Physical Systems, and the Internet of Things, Third Edition, Springer 2017, 448 oldal, ISBN 978-3-319-56043-4
3. Dennis Silage, Trends in Embedded Design Using Programmable Gate Arrays, Bookstand Publishing 2013, 320 oldal, ISBN 978-1-61863-541-9
4. Vahid, Frank; Givargis, Tony: Embedded System Design – A Unified Hardware/Software Introduction, John Wiley & Sons, 2002, 352 oldal, ISBN 0-471-38678-2
5. Tammy Noergaard, Embedded Systems Architecture, 2nd Edition, Elsevier, 2012, 768 oldal, ISBN: 9780123821966

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Queueing Theory

Type of Course Compulsory

Responsible Tutor Dr. Sztrik, János

Syllabus Basic queueing systems: concepts, notations, Little-law, Poisson-process and its properties. Birth-death processes, existence of steady-state distribution, derivation of transient and stationary distribution. Queueing systems based on birth-death processes. M/M/1 queueing systems and its properties, Erlang-loss formulas, Markov-type arrival and service processes, phase-type distributions for arrival and service. Queueing systems with generally distributed arrival and/or service processes, M/G/1, G/M/m, G/G/1 systems, their properties, calculation of the main performance measures.

Bibliography

D. Gross, C. Harris: Fundamentals of Queueing Theory, John Wiley, New York, 1985.

L. Lakatos, L. Szeidl, M. Telek: Introduction to Queueing Systems with Telecommunication Applications, Springer, New York, 2013.

W.J. Stewart: Probability, Markov chains, Queues, and simulation, Princeton University Press, Princeton and Oxford, 2009

J. Sztrik: Basic Queueing Systems, Univesity of Debrecen, Debrecen, 2012
http://irh.inf.unideb.hu/user/jsztrik/education/16/SOR_Main_Angol.pdf

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Network science

Type of Course Compulsory

Responsible Tutor Dr. Varga, Imre

Syllabus Basic concepts of networks, basics of graph theory (node, link, directed/undirected graph, weighted/unweighted graph, loop, path, cluster, etc.). Quantities describing networks (average degree, degree distribution, average clustering coefficient, diameter, betweenness centrality, assortativity, etc.). The small-world property. Scale-free networks. Networks models (Erdős-Rényi model, Watts-Strogatz model, Barabási-Albert model, etc.) and their implementation by computer. Properties of networks in our natural-, social- and technological environment. Processes on networks and their simulation.

Bibliography

- Albert-László Barabási: *Network science*, Cambridge University Press, 2016.
- Mark Newman: *Networks: An Introduction*, Oxford University Press, 2010.
- Mark Newman, Albert-László Barabási, D. J. Watts: *The structure and dynamics of networks*, Princeton University Press, 2006.
- Guido Caldarelli: *Scale-Free Networks: Complex Webs in Nature and Technology*, Oxford University Press, 2008.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Stochastic Modeling of Informatics Systems
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Sztrik, János
Syllabus	Queueing networks, reversibility and Burke-theorem, Open and closed networks. Existence of product-form solution, Numerical methods for product-form solutions, convolution algorithm, mean value analysis, Decomposition and approximation methods. Fields of application: computer systems, performance modeling of communication protocols and info-communication networks,
Bibliography	**K. Begain, G. Bolch G., H. Herold:** Practical Performance Modeling, Kluwer Academic Publisher, 2001 **J.N. Daigle:** Queueing Theory for Telecommunications, Addison-Wesley, 1992 **F. Gebaldi:** Analysis of Computer and Communication Networks, Springer Science and Business Media, New York, 2009 **J.F. Hayes, T.V.J. Babu:** Modeling and Analysis of Telecommunication Networks, Wiley-Interscience, Hoboken, 2004 **L. Lakatos, L. Szeidl, M. Telek**: Introduction to Queueing Systems with Telecommunication Applications, Springer, New York, 2013.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Analytic methods in stochastic modeling
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Bérczes Tamás
Syllabus	Renewal and Markovian Renewal processes. Phase Type Distributions. Birth and Death Processes. Quasi Birth and Death Processes. Spectral expansion, calculation of eigenvalues and eigenvectors. Complex Markovian queueing systems. Finite source systems, examples, applications.
Bibliography	**Kleinrock**: Queueing systems I-II, Wiley-Interscience, 1975-1976 **G. Latouche, V. Ramaswami:** Introduction to Matrix Analytic Methods in Stochastic Modeling, Society for Industrial and Applied Mathematics, 1987 **Marcel F. Neuts**: Matrix-Geometric Solutions in Stochastic Models An Algorithmic Approach, Johns Hopkins University Press, 1981 **Bolch De Meer, Greiner, Trivedi**: Queueing networks and Markov chains, Wiley-Interscience, 2006 **J. R. Artalejo, A. Gómez-Corral**: Retrial Queueing Systems, Springer 2008

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Communication in the Internet of Things

Type of Course Compulsorily eligible

Responsible Tutor Dr. Buchman, Attila

Syllabus IoT in smart cities, smart homes and industry. Relationship of IoT and M2M (Machine-to-Machine). Wired synchronous and asynchronous communication: UART, SPI, I2C, CAN protocols. Wireless, low data rate, low range, energy efficient communication: IEEE 802.15.4, 6LoWPAN, ZigBee, Bluetooth LE protocols. Transferring sensor data on the internet. Server/client and publish/ subscribe model-based communication in the IoT. CoAP (Constrained Application Protocol) and MQTT (Message Queuing Telemetry Transport) protocols. IoT and the cloud. Connecting sensors to the cloud. HTTP REST (Representational State Transfer) based communication. Connecting to various IoT platforms: ThingSpeak, DeviceHubNet. Inter-platform communication.

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Bibliography

1. Ian F. Akyildiz, Mehmet Can Vuran, *Wireless sensor networks*, *(Ian F. Akyildiz series in communications and networking)* Wiley, 2010.
2. Jelena Misic, Vojislav B. Misic, *Wireless personal area networks* : *performance, interconnections and security with IEEE 802.15.4*, *(Wiley series on wireless communications and mobile computing)* Wiley, 2008
3. Holger Karl, Andreas Willig, *Protocols and Architectures for Wireless Sensor Networks*, Wiley, 2005.
4. Robert Faludi, *Building wireless sensor networks: a practical guide to the ZigBee Mesh networking protocol*, O'Reilly, 2011.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Agent-based models and simulation methods

Type of Course Compulsorily eligible

Responsible Tutor Dr. Kocsis, Gergely

Syllabus As a beginning we study the basics of agent-based modeling and then we turn to exact modeling methods. Between these we put special focus on cellular automata models. After these we study models that are used in practice and learn how they are implemented (disease spreading models: SI, SIS, SIR, SIRS; fiber bundle models ELS, LLS; models of information diffusion: Rogers' model, Sznajd model). In order to be able to test these models we learn the basics about complex networks. We implement the models in simulation programs.

Bibliography

] E.M. Rogers, Diffusion of Innovations 5th edition, Free Press Simon and Schuster, New York, 2003.

M.E.J. Newman, Networks - An introduction, Oxford University Press, Oxford, 2010.

D. Easley, J. Kleinberg, Networks, Crowds, and Markets, Cambridge University Press, 2010.

W. Christian, H. Gould, J. Tobochnik, An Introduction To Computer Simulation Methods Examples 3rd edition, Addison-Wesley, 2006.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Tools for Network Modeling

Type of Course Compulsorily eligible

Responsible Tutor Dr. Kuki, Attila

Syllabus Basic concepts of Markov-type queueing systems, methods for determining the system characteristics (Utilization, Throughput, Response Time, Waiting Time, Queue Length): analytical, approximation, simulation. Investigating Non-Markov systems. Using Discrete Event Simulation. Computer tools for determining the performance characteristics. Using PEPSY tools, MOSEL-2 tool, and Riverbed Modeler© (former OPNet IT Guru) for analyzing queueing and infocommunication systems.

Bibliography

Bolch G., Greiner S., de Meer H., Trivedi K.S. *Queueing Networks and Markov Chains* John Wiley & Sons Inc. New York, 2nd edition, 2006.

Gross, D., Shortie, J. F., Thompson, J. M., and Harris, C. M., *Fundamentals of Queueing Theory, Fourth Edition* John Wiley & Sons, Inc., 2008.

Begain K., Bolch G., and Herold H., *Practical Performance Modeling, Application of the MOSEL Language*, Kluwer Academic Publisher, Boston, 2001.

Sethi, A., S., Hnatyshin, V., Y., *The Practical OPNET® User Guide for Computer Networks*, CRC Press, (2013).

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Imaging by informatics systems

Type of Course Compulsorily eligible

Responsible Tutor Dr. Tóth, László

Syllabus In the framework of the course the students become familiar with the main characteristics and theoretical descriptions of different types of imaging systems in the cases of different energy range electromagnetic radiations, particles as well as particle- and mechanical waves. Following the acquisition of this knowledge an optical system can be built in which the individual components can be replaced with computer algorithms. These algorithms are then able to be used for the correction of optical aberrations and creation of new types of instruments. Such an instrument i.e. the Software Based Imaging Energy Analyzer (SBIEA) that opens new direction in its field.

Bibliography

1. Grant R. Fowles, *Introduction to modern optics* (Dover Publications, 1975)
2. R. D. Guenther, Modern Optics (John Wiley & Sons, Inc., 1990)
3. J. M. Cowley, Diffraction Physics (Elsevier, 1995)
4. Jon Orloff (ed.). Handbook of Charged Particle Optics (CRC Press, 2009)
5. Ray F. Egerton, Physical Principles of Electron Microscopy (Springer, 2005)
6. *Fazekas Á, Tóth L, Filtering Chromatic Aberration for Wide Acceptance Angle Electrostatic Lenses, IEEE TRANSACTIONS ON IMAGE PROCESSING 23:(7) pp. 2834-2841. (2014)*

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Performance analysis of multipath infocommunication technologies
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Szilágyi Szabolcs
Syllabus	The course discusses the solutions of multipath communication technologies that can be used in different layers in new generation IP networks: Second and higher layer multipath infocommunication technologies, Multi-Link PPP, EtherChannel, MPT-GRE, MLP, MPTCP, MultiTCP. The course will pay special attention to the investigation of efficiency of multipath technologies over IPv4 and next generation IP network technologies (IPv6).
Bibliography	• W. Stallings: Data and Computer Communications, 10th Edition, Pearson, 2013. • M. Li, A. Lukyanenko, Z. Ou, A. Ylä-Jääski, S. Tarkoma, M. Coudron and S. Secci. *Multipath transmission for the internet: A survey*, IEEE Communications Surveys Tutorials, vol. 18, no. 4, pp. 2887-2925, 2016. • W. Song, D. Zhou: Multipath TCP for User Cooperation in Wireless Networks, Springer, 2015. • B. Almási, G. Lencse, S. Szilágyi, *Investigating the Multipath Extension of the GRE in UDP Technology*, Computer Communications, Vol. 103, pp. 29-38, ISSN 0140-3664, DOI: 10.1016/j.comcom.2017.02.002, 2017. • RFC documents: http://www.rfc-editor.org/

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Communication Mechanisms of the Wireless Sensor Networks
Type of Course	Compulsorily eligible
Responsible Tutor	Zoltán Gál
Syllabus	The low energy usage of the WSN systems requires special IoT architecture and running modes. One of the main energy consumer subsystem of the WNS node is the communication interface. This course covers main communication mechanisms of the WSN systems. Short range technologies: IEEE 802.15.4, Z-Wave, insteon, EnOcean, ONE-NET, KNX, IEEE 802.11, NFC, DASH7, IEEE 1902.1, Bluetooth, ANT/ANT+. Long range technologies: LoRa, Sigfox, LPWAN, 6LoWPAN. Communication mechanisms of the swarm intelligence are discussed, too.
Bibliography	[1] Ovidiu Vermesan, Joel Backuet, Cognitive Hyperconnected Digital Transformation Internet of Things Intelligence Evolution, River Publishers, 2017. (pages 17-82) [2] Nell Munro, Darre M. Dawson, Chaouki T. Abdallah: Robot Manipulator Control: Theory and Practice, 2003. [3] R. Kelly, V. Santabanez, A. Loria: Control of Robot Manipulators in Joint Space, Springer, 2014. [4] Yuhui Shi: Critical Developments and Applications of Swarm Intelligence, 2018.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Classification and Regression with Machine Learning
Type of Course	Compulsorily eligible
Responsible Tutor	Dr. Sütő, József
Syllabus	One of the aims of the course is to allow PhD students to become familiar with the most popular machine learning methods such as shallow and deep neural networks, Gaussian processes, decision trees, decision forests, and k-nearest neighbors. The other aim of the course is to give an insight into the application possibilities of the above mentioned algorithms in the classification and regression problems. Within the subject, students must work on real databases on their own, according to the supervisor's instructions.
Bibliography	[1.] M. Nielsen, Neural Networks and Deep Learning, 2015, eBook. Link.: http://neuralnetworksanddeeplearning.com/ (2018.12.20) [2.] M.T. Hagan, H.W. Demuth, M.H. Beale, O.D. Jesus, Neural Network Design, 2.nd ed., eBook. Link.: http://hagan.okstate.edu/NNDesign.pdf (2018.12.20) [3.] C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. [4.] K. P. Murphy, Machine Learning a Probabilistic Perspective, MIT Press, 2012. [5.] G. James, D. Witten, T. Hastie, R. Tibshirani, An Introduction to Statistical Learning with Applications in R, Springer, 2013.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	IT applications in the development of business processes
Type of Course	Compulsory
Responsible Tutor	Dr. Budai István
Syllabus	Comparison of quality improvement techniques, developer awareness, testing their applicability. The computer-based imaging techniques, modeling process. Improved processes and basic modeling, simulation. Streamlined the business processes, in which we find the technique using various quality processes errors and to specify corrective actions. Examine the grant of the effectiveness of corrective action - simulation and statistical methods.
Bibliography	J. Závadsky, L. TurCok, *Simulation and its purpose in implementing of Business Process Management*, Advances in Management, Vol. 3 No. 3, 2010, pp. 9-12 J. Mendling, H. A. Reijers, W. M. P. van der Aalst, *Seven process modeling guidelines (7PMG).* Information and Software Technology, Vol. 52, No. 2. pp. 127-136. 2010 Fred R. David, *Strategic Management A Competitive Advantage Approach, Concepts and Cases*, Prentice Hall, 16th edition, 2016, Michael L. George John Maxey David Rowlands Mark Price, *The Lean Six Sigma Pocket Toolbook*, McGraw-Hill; 1 edition, 2004 Lorenz T. Biegler, *Nonlinear Programming: Concepts, Algorithms, and Applicationsto Chemical Processes,* Society for Industrial and Applied Mathematics, 2010

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Model Investigation of Technical Systems
Type of Course	compulsory
Responsible Tutor	Dr. Husi Géza, Dr. Szemes Péter
Syllabus	Theory of Bond graph: (is an explicit graphical tool for capturing the common energy structure of systems) Power variables of Bond Graphs, Bond Graph Standard Elements, Basic 2-Port elements, The 3-Port junction elements. Theory of Bond graph: Power directions on the bonds, Assigning numbers to bonds, Causality, Generation of system equations, algebraic loops, Causal loops, Power loops, and Differential Causalities Bond graph modeling: mechanical system, two degrees of freedom mechanical system, electrical system, hydraulic system, thermal system, magnetic system, Method of Flow Map, Method of Effort Map, Method of Mixed Map. Bond graphs of electrical circuits: Method of Gradual Uncover, Point Potential Method, Mixed Network Method. Gyrator and transformer combinations: Combination of gyrators and sources, Combination of a gyrators and transformers with storage and resistive elements, Combination of gyrators and junction elements, Dual Models, Multi and vector bond graphs. Technical System Modeling Process: Bond Graph, Block Diagram, - Computer Based Model (LabView, MatLab).
Bibliography	1. Arun Kumar Samantaray, Belkacem Ould Bouamama : Model-based process supervision: a bond graph approach, 2008/3/14, Publisher, Springer Science & Business Media 2. Jan F. Broenink : Introduction to Physical Systems Modelling with Bond Graphs Jan F. Broenink University of Twente, Dept EE, Control Laboratory PO Box 217, NL-7500 AE Enschede Netherlands 3. Borutzky, W: Bond Graph metolodogy Spinger 2010, ISBN 979-1-84882-881-0 *4.* W Borutzky : Bond graph modelling of engineering systems - 2011 - Springer

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Advanced signal processing methods in technical diagnostics

Type of Course compulsory

Responsible Tutor Dr. Kocsis Imre

Syllabus

Goals and tools of condition monitoring and process monitoring (measuring systems, data processing software, algorithms). Role of diagnostic data in digital manufacturing systems. Determination of parameters for diagnosis of technical systems: detection of failures caused by manufacturing process or and deterioration. IT tools of proactive maintenance. Data acquisition methods. Application of vibration measurement systems in technical diagnostics. Vibration signal processing, special purpose investigations, transformations and filters. Pattern recognition, learning systems. Application of infrared imaging and image processing in technical diagnostics.

Methods of engineering system optimization.

Bibliography

Kadry. S., (ed.), *Diagnostics and Prognostics of Engineering Systems: Methods and Techniques,* IGI Global, 2013

Boashash, B. (ed.), *Time Frequency Signal Analysis and Processing*, Elsevier, 2003

Misiti, M., Misiti, Y., Oppenheim, G., Poggi, J.M., *Wavelets and their Applications*, ISTE Ltd and John Wiley & Sons Inc., 2007

Gao, R. X., Yan, R., *Wavelets - Theory and Applications for Manufacturing*, Sringer, 2011

Vollmer, M., Möllmann, K-P., *Infrared Thermal Imaging: Fundamentals, Research and Applications,* Wiley-VCH 2010

Gonzalez, R.C., *Digital Image Processing*, Prentice Hall, 2002

Marwala, T., *Condition Monitoring Using Computational Intelligence Methods*, Applications in Mechanical and Electrical Systems, Springer, 2012

Marwala, T., *Condition Monitoring Using Computational Intelligence Methods*, Applications in Mechanical and Electrical Systems, Springer, 2012

Iqbal, K., *Fundamental Engineering Optimization Methods*, Bookboon.com, 2013

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UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Automated technical systems

Type of Course compulsory

Responsible Tutor Dr. Tóth János

Syllabus

Solving of computerized control problems connected with industrial technological operations. Informatics implementation of technical automation based on the new industrial guidelines. Selection and programming of the typical hardware components of automated technical systems. Get to know different standard industrial control devices and protocols, having regard to the needs of process control and technical support systems. Computer-supported intelligent data acquisition and signal processing.

Researching fast and efficient signal processing techniques related to computer technology, especially for industrial applications.

Bibliography

1. Steven Smith: Digital Signal Processing: A Practical Guide for Engineers and Scientists, Newnes in as imprint of Elsevir Science, 2003;
2. Behzad Ehsani: Data Acquisition Using LabVIEW, Birmigham, Packt Publishing Ltd. 2016;
3. Maurizio Di Paolo Emilio: Data Acquisition Systems: From Fundamentals to Applied Design, Springer Science+Business Media, New York, 2013;
4. Simon S. Young: Computerized Data Acquisition and Analysis for the Life Sciences: A Hands-on Guide, Cambridge University Press, 2001.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course Computer Process Control

Type of Course compulsorily eligible

Responsible Tutor Dr. Husi Géza

Syllabus Concepts, mathematical description of physical phenomena: Definition of the real physical system, Definition of signal, The inputs and outputs, The definition of the system and process, linear and non-linear systems, parameter and variable. Theory of distributed and concentrated parametric description, deterministic and stochastic systems, Concept of causality, Deterministic description with lumped parameters, The concept of static systems, The concept of dynamic systems, Concept of time invariant and autonomous systems General principles of dynamical systems: Linear, quantized, single in and output system, ARMA System, Linear, quantized, one input-output system, Generalized derivative. Types of drives in process: features and principles, Drive Control Methods and Feedback Devices, control of process: P, I, D, PID, sliding mode. Model investigation of Systems and Processes in Industry 4.0: ICT technologies converting to the IoT, The impact of information and communication technology, digital enterprise, integrated cyber physical systems, elements of I4.0, vision of manufacturing, RAMI 4.0. In the subject, diagnostic applications of signal and image processing methods are related to the health check of technical (especially mechatronic) systems.

Bibliography

1. Alasdair Gilchrist : Industry 4.0: The Industrial Internet of Things Apress, 2016
2. Korondi P: Basic concepts, mathematical description of physical phenomena
3. Alp Ustundag, Emre Cevikcan : Industry 4.0: Managing The Digital Transformation (Springer Series in Advanced Manufacturing) 1st ed. 2018 Edition
4. Husi Géza: Mechatronic System in the CyberPhysical Space course material/work/publication is supported by the EFOP-3.4.3-16-2016-00021 "Development of the University of Debrecen for the Simultaneous Improvement of Higher Education and its Accessibility" project.

5. Husi Géza: Cyber-Physical Systems (Industry 4.0) course material/work/publication is supported by the EFOP-3.4.3-16-2016-00021 "Development of the University of Debrecen for the Simultaneous Improvement of Higher Education and its Accessibility" project.

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Decision Models and Applications
Type of Course	compulsorily eligible
Responsible Tutor	Dr. Budai István
Syllabus	Decision Models and Applications course covers comprehensive overview of various methods and applications in decision engineering. It presents conceptual aspects of decision support applications in various areas including finance, vendor selection, construction, process management, production scheduling and control. This course provides a valuable resource for students of decision analysis, multi-criteria decision analysis and Kesselring, AHP, PROMETHEE and Monte Carlo methods.
Bibliography	Guarnieri, Patricia (Ed.): *Decision Models in Engineering and Management*, Springer, 2015 Ashok D. Belegundu, Tirupathi R. Chandrupatla: *Optimization Concepts and Applications in Engineering*, 2nd Edition, Cambridge University Press, 2011

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Computer aided modelling, finite element analysis and simulation of gear pairs
Type of Course	compulsorily eligible
Responsible Tutor	Dr. Bodzás Sándor
Syllabus	Geometrical and technological analysis of planar and spatial gears (cylindrical toothed gear, bevel gear and worm gear drive). Geometrical analysis of toothed manufacturing tools, tool designing by utilization of informatics devices. Computer aided modelling of gear drives, optimization of the tool and workpiece profiles in the function of the geometrical and technological parameters. Finite element analysis of tooth connections and connection's simulations by computer software. Construction and technological analysis of noncircular gears.
Bibliography	[1] D. W. Dudley, *„Gear Handbook"*, MC Graw Hill Book Co. New York-Toronto-London, 1962. [2] F. L. Litvin, A. Fuentes, *"Gear Geometry and Applied Theory"*, Cambridge University Press, 2004., ISBN 978 0 521 81517 8 [3] F. L. Litvin, A. Fuentes, I. Gonzalez, K. Hayasaka, "*Noncircular gears, Design and Generation",* Cambridge University Press, 2009, ISBN 978-0-521-76170-3 [4] V. Goldfarb, E. Trubachev, N. Barmina, *"Advanced Gear Engineering",* Springer, 2018, ISBN 978-3-319-60399-5 [5] V. Goldfarb, N. Barmina, *"Theory and Practice of Gearing and Transmissions",* Springer, 2016, ISBN 978-3-319-19739-5 [6] J. Klingelnberg, *"Bevel Gear, Fundamentals and Applications",* Springer, 2016, ISBN 978-3-662-43892-3

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Computer aided manufacturing and analysis of manufacturing processes
Type of Course	compulsorily eligible
Responsible Tutor	Dr. Bodzás Sándor
Syllabus	Supported structure of technological processes by informatics background. Analysis of complex manufacturing technologies, computer aided manufacturing planning for unique and complex workpieces. Application of LEAN methods during the manufacturing planning. Designing of complex cutting tools by informatics supports. Finite element analysis of technological processes. Practice orientated analysis of manufacturing technologies by informatics equipment (heat camera, noise and vibration measuring machine, cutting force measuring device, etc.) and software applications. Workpiece manufacturing by CNC working machines. Rapid prototyping. Manufacturing planning of Hybrid technologies.

Bibliography

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[8] J. G. Bralla, *"Handbook of Manufacturing Processes",* First Edition, Industrial Press Inc., New York, 2007, ISBN 0-831 1-3179-9

[9] H. A. Youssef, H. El – Hofy, *"Machining Technology, Machine tools and operations",* CRC Press, United States of Amerika, p. 672, ISBN 978-1-4200-4339-6

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[11] I. Gibson, D. Rosen, B. Stucker, *"Additive Manufacturing Technologies, 3D Printing, Rapid Prototyping and Direct Digital Manufacturing",* Second Edition, Springer, 2015, ISBN 978-1-4939-4455-2

[12] L. Wilson, „*How to implement Lean Manufacturing",* Second Edition, MCGraw-Hill Education, p. 419, ISBN 978-0-07-183573-3

UNIVERSITY OF DEBRECEN
Doctoral School of Informatics

Name of Course	Finite element modelling of metal forming processes
Type of Course	compulsorily eligible
Responsible Tutor	Dr. Pálinkás Sándor
Syllabus	History of metal forming. Definitions, advantages of metal forming. Bulk deformation processes. Sheet metal forming processes. Properties of materials. Industrial materials. The uniaxial tensile test. Upsetting test. Classification of different forming processes. Planning and finite element simulation of different metal forming technology (Applying software: SolidWorks and Simufact Forming).
Bibliography	1. Prakash M. Dixit, Uday S. Dixit: Modelling of Metal Forming and Machining Processes, Springer-Verlag, 2008, ISBN 978-1-84996-749-5 2. J. Beddoes, M. J. Bibby: Principles of Metal Manufacturing Processes, 1999, ISBN 978-0340-731621 3. Mikell P. Groover: Fundamentals of Modern Manufacturing Materials, Processes and Systems, John Wiley & Sons, 2010, ISBN 978-0470-467008 4. O. C. Zienkiewicz, Robert Leroy Taylor, R. L. Taylor: The Finite Element Method: Solid mechanics, Butterworth-Heinemann, 2000, ISBN 978-0750-650557

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Name of Course	Modeling of Sound Propagation
Type of Course	compulsorily eligible
Responsible Tutor	Dr. Kocsis Dénes
Syllabus	Fundamentals of noise propagation. Outdoor sound propagation. Indoor propagation. Frequency spectrum. Factors affecting sound propagation. Reflection. Absorption. Deflection. Room acoustic parameters. Speech intelligibility. Methods for calculating sound propagation. Computer modeling possibilities. Environmental noise maps. Noise mapping in practice. Modeling possibilities for workplace Noise propagation.
Bibliography	Keyel, A.C., Reed, S.E., McKenna, M.F., Wittemyer, G., Modeling anthropogenic noise propagation using the Sound Mapping Tools ArcGIS toolbox (2017) Environmental Modelling and Software, 97, pp. 56-60. Reed, S.E., Boggs, J.L., Mann, J.P., A GIS tool for modeling anthropogenic noise propagation in natural ecosystems (2012) Environmental Modelling and Software, 37, pp. 1-5. Akieh, Y., Jaafari, S., Ahmadi, M., Danekar, A., Green and calm: Modeling the relationships between noise pollution propagation and spatial patterns of urban structures and green covers (2017) Urban Forestry and Urban Greening, 24, pp. 195-211. Di, H., Liu, X., Zhang, J., Tong, Z., Ji, M., Li, F., Feng, T., Ma, Q., Estimation of the quality of an urban acoustic environment based on traffic noise evaluation models (2018) Applied Acoustics, 141, pp. 115-124. Zhao, W.-J., Liu, E.-X., Poh, H.J., Wang, B., Gao, S.-P., Png, C.E., Li, K.W., Chong, S.H., 3D traffic noise mapping using unstructured surface mesh representation of buildings and roads (2017) Applied Acoustics, 127, pp. 297-304.

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Name of Course	Engineering modelling, simulation of dynamic systems
Type of Course	compulsorily eligible
Responsible Tutor	Rita Nagy-Kondor, Gusztáv Áron Szíki
Syllabus	Presenting the main characteristics of MATLAB which is applicable for performing scientific and engineering calculations and simulations, and for the visualization of data. Describing MATLAB/SIMULINK which has been developed for the simulation of dynamic systems and applying it for the studying of phenomena and systems belonging to different engineering fields. Extending the observation capability of real experiments. To fulfil the subject requirements students have to perform the simulation of a freely chosen technical process.
Bibliography	1. Agam Kumar Tyagi (2012). MATLAB and Simulink for Engineers, Oxford University Press 2. Harold Klee, Randal Allen (2018). Simulation of Dynamic Systems with MATLAB and Simulink, CRC Press, Inc. 3. Mohammad Nuruzzaman (2004). Modeling and Simulation in Simulink for Engineers and Scientists, AuthorHouse 4. Bill Messner, Dawn Tilbury. Control Tutorials for MATLAB and Simulink: http://ctms.engin.umich.edu/CTMS/index.php?aux=Home

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Name of Course	Modeling IT systems to support enterprise processes
Type of Course	compulsorily eligible
Responsible Tutor	Dr. Krauszné Dr. Princz Mária
Syllabus	The student learns and applies the most important questions, tools and techniques of software system development: specification, design, implementation and management.
Bibliography	Dennis, Wixom, Roth: Systems Analysis and Design, Wiley & Sons, 2012 Jacqueline Pike, Lauren Kenyo, Sarah Pels Raymond D. Frost: Business Information Systems: Design an App for That, Flat World Knowledge, 2011 Scott Tilley, Harry J. Rosenblatt: Systems Analysis and Design, Kindle Edition Paige Baltzan, Amy Phillips: Business Driven Information Systems, Kindle Edition

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Name of Course Imaging light- and electron-optical systems

Type of Course compulsorily eligible

Responsible Tutor Dr. Tóth László

Syllabus

The purpose of this course is to introduce concepts of light- and electron optics and to explain how the principles of electrodynamics, modern physics and informatics have been used to develop instruments that have wide application in science.

In the framework of the course the students become familiar with the main characteristics and theoretical descriptions of different types of imaging systems in the cases of different energy range electromagnetic radiations, particles as well as particle- and mechanical waves.

Following the acquisition of this knowledge optical systems can be built in which the individual components can be replaced with computer algorithms that are able e.g. for the correction of optical aberrations and creation new types of instruments.

Bibliography

1. Grant R. Fowles, *Introduction to modern optics* (Dover Publications, 1975)
2. R. D. Guenther, *Modern Optics* (John Wiley & Sons, Inc., 1990)
3. J. M. Cowley, *Diffraction Physics* (Elsevier, 1995)
4. Jon Orloff (ed.). *Handbook of Charged Particle Optics* (CRC Press, 2009)
5. Ray F. Egerton, *Physical Principles of Electron Microscopy* (Springer, 2005)
6. P. W. Hawkes, E. Kasper, *Principles of Electron Optics*, vol. 1-3, (Academic Press, 1996)

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Name of Course	Embedded systems and wireless sensors networks
Type of Course	compulsorily eligible
Responsible Tutor	Dr. Buchman Attila
Syllabus	The sensor network paradigm: motivations, applications and challenges. Energy efficiency related issues: energy harvesting. Embedded systems and sensor node platforms: processors, radio transceivers and sensors. Media access control techniques. IEEE 802.15.4 physical layer and MAC. Routing strategies. ZigBee standard. Time synchronization in sensor networks. Localization, tracking and mobility. Sensor network and embedded systems: software and programming related issues.
Bibliography	5. Ian F. Akyildiz, Mehmet Can Vuran, *Wireless sensor networks, (Ian F. Akyildiz series in communications and networking)* Wiley, 2010. 6. Jelena Misic, Vojislav B. Misic, *Wireless personal area networks* : *performance, interconnections and security with IEEE 802.15.4, (Wiley series on wireless communications and mobile computing)* Wiley, 2008 7. Holger Karl, Andreas Willig, *Protocols and Architectures for Wireless Sensor Networks*, Wiley, 2005. 8. Robert Faludi, *Building wireless sensor networks: a practical guide to the ZigBee Mesh networking protocol*, O'Reilly, 2011.