UNIVERSITY of DEBRECEN

FACULTY OF INFORMATICS

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Artificial Intelligence Expert postgraduate specialization programme

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Debrecen
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ARTIFICIAL INTELLIGENCE EXPERT POSTGRADUATE SPEICALIZATION PROGRAMME CURRICULUM

Program Coordinator: Dr. András Hajdu (hajdu.andras@inf.unideb.hu)

Qualification requirements

General requirements of the diploma are regulated by The Rules and Regulations of The University of Debrecen.

Diploma credit requirements:

Artificial Intelligence Specialist Knowledge:	39 credits
Informatics Specialist Knowledge:	18 credits
Thesis work:	3 credits
Total	**60 credits**

Code	Subject name	Cre-dit	Type and number			Asses-ment	Prerequisites	Period	Semes-ter
			lec.	practice					
				sem.	lab				
INSMA0101-22 INSMA0101E INSMA0101L	Machine learning	6	2		2	E S			1
INSMA0102-22 INSMA0102E	Data protection and cryptography	3	2			E			1
INSMA0103-22 INSMA0103L	Generative methods	3			2	PM			1
INSMA0104-22 INSMA0104L	Parallel computing	3			2	PM			1
INSMA0105-22 INSMA0105L	AI programming	3			2	PM			1
INSMA0106-22 INSMA0106E INSMA0106L	Autonomous vehicles	6	2		2	PM			1
INSMA0107-22 INSMA0107L	Efficient data visualization	3			2	PM			1
INSMA0108-22 INSMA0108E INSMA0108L	Cloud computing	6	2		2	PM			1
INSMA0209-22 INSMA0209E INSMA0209L	Reinforcement learning	6	2		2	E S			2
INSMA0210-22 INSMA0210E INSMA0210L	Image processing based on neural networks	6	2		2	E S			2
INSMA0211-22 INSMA0211E INSMA0211L	Natural language processing and text mining	6	2		2	E S			2
INSMA0212-22 INSMA0212L	AI frameworks	3			2	PM			2
INSMA0213-22 INSMA0213L	Big Data handling techniques	3			2	PM			2
INSMA0214-22 INSMA0214G	Thesis work	3				PM			2

Description of Subjects

MACHINE LEARNING

INSMA0101-22

Semester: 1
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Compulsory
Prerequisites: None
Assessment: Exam
Responsible: Dr. András Hajdu

Topics:

Supervised Learning, Unsupervised Learning, Linear Regression (one/multiple variables), Gradient Descent, Feature Normalization, Polynomial Regression, Logistic Regression, Binary Classification, Multiclass Classification (One-vs-all), Regularization (overfitting, underfitting), Regularized Linear Regression, Regularized Logistic Regression, Neural Networks, Backpropagation Algorithm, Train/Validation/Test Sets, Diagnosing Bias vs. Variance, Regularization and Bias/Variance, Learning Curves (training set size), Error Metrics for Skewed Classes, Support Vector Machine, Kernels in SVM, Clustering, Choosing the Number of Clusters, Dimensionality Reduction, Anomaly Detection, Recommender Systems, Content Based Recommendations, Collaborative Filtering, Stochastic Gradient Descent, Mini-Batch Gradient Descent, Map Reduce and Data Parallelism, Cloud Platforms.

Compulsory/Recommended Readings:

- John D. Kelleher, Brian Mac Namee and Aoife D'Arcy: Fundamentals of Machine Learning for Predictive Data Analytics, 2nd edition, MIT Press, 2020.
- I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016.
- D. Conway, J.M. White: Machine Learning for Hackers, O'Reilly Media, Inc., 2012.
- W. McKinney: Python for Data Analysis (2 ed.). O'Reilly Media, Inc. 2017.
- Christopher Bishop: Pattern Recognition and Machine Learning, Springer, 2006.

DATA PROTECTION AND CRYPTOGRAPHY

INSMA0102-22

Semester: 1
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Compulsory
Prerequisites: None
Assessment: Exam
Responsible: Dr. Andrea Pintér-Huszti

Topics:

Basic concepts (CIA triad), Means and objectives of cybersecurity, Malware and attack technologies, Encryptions, Digital signatures, Access control, access control in distributed systems, Authentication , user authentication, authentication in distributed systems, Accountability, Security operations and incident management, Regulations, standards

Compulsory/Recommended Readings:

- Awais Rashid, Howard Chivers, George Danezis, Emil Lupu, Andrew Martin, CyBok, The Cyber Security Body of Knowledge, 2019
- William Stallings, Lawrie Brown, Computer Security, Principles and Practice, 4th Edition, 2022
- Jason Andress, Foundations of Information Security: A Straightforward Introduction, 2019.

GENERATIVE METHODS

INSMA0103-22

Semester: 1
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Compulsory
Prerequisites: None
Assessment: Practical mark
Responsible: Dr. László Kovács

Topics:

Within the framework of the subject, students learn about the theoretical and practical backgrounds of modern Generative Adversarial Networks, understanding components with the help of technology-related software and development environments. The course seeks to introduce GAN technologies in a practice-oriented form of education. The course pays special attention to more complex solutions such as data augmentation, privacy preservation, survey GANs applications, comparing generative models, and implementing StyleGAN techniques. Students work on projects that allow them to work in an application-oriented environment within the applications of GANs.

Compulsory/Recommended Readings:

- Jakub Langr and Vladimir Bok: GANs in Action, Manning, 2019.
- David Foster: Generative Deep Learning, Oreilly, 2019
- Kailash Ahirwar: Generative Adversarial Networks Projects, Packt, 2019
- I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016.
- Stuart Russell and Peter Norvig: Artificial Intelligence: A Modern Approach, 4th US ed., Pearson, 2020

PARALLEL COMPUTING

INSMA0104-22

Semester: 1
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Compulsory
Prerequisites: None
Assessment: Practical mark
Responsible: Dr. Zoltán Gál

Topics:

This introductory course on CUDA and GPU platforms shows how to get started with using modern computation methods on parallel systems. It covers the basics of cluster and distributed multiprocessor systems, explains the architecture of dedicated acceleratos, GPUs, compute sticks, etc.. Presents solutions to some of the common computational problems that are suitable for high speed processing. Accelerate AI, deep learning, and other computationally intensive analytics with CUDA and GPUs using Parallel Computing Toolbox. Use GPUs from different manufacturers directly from Python and MATLAB with built-in functions. Access multiple GPUs on desktop, compute clusters, and cloud using workers and parallel servers. Generate CUDA code directly for deployment to data centers, clouds, and embedded devices using GPU Coder. Generate Tensor code for low latency and high-throughput inference with GPU Coder. Deploy AI applications for data centers to integrate with enterprise systems.

Compulsory/Recommended Readings:

- Roman Trobec, Boštjan Slivnik, Patricio Bulić, Borut Robič: Introduction to Parallel Computing: rom Algorithms to Programming on State-of-the-Art Platforms, Springer, 2018, ISBN: 978-3-319-98833-7
- Duane Storti, Mete Yurtoglu: CUDA for Engineers: An Introduction to High-Performance Parallel Computing, 2015, ISBN-13: 978-0134177410
- Tolga Soyata: GPU Parallel Program Development Using CUDA, Chapman & Hall/CRC Computational Science, 2018, ISBN-13: 978-1498750752
- Robert Robey and Yuliana Zamora: Parallel and High Performance Computing, 2021, ISBN 9781617296468

AI PROGRAMMING

INSMA0105-22

Semester:	1
Type:	Laboratory
Number of Classes:	0+0+2
Credit:	3
Status:	Compulsory
Prerequisites:	None
Assessment:	Practical mark
Responsible:	Dr. László Szathmáry

Topics:

The aim of the course is to provide the basic knowledge required for machine learning and machine intelligence programming The course includes an introduction to the associated libraries and the kernel-level execution and compilation environments associated with the architectures also. The course covers the related Python, C/C++, scikit-learn, NumPy, SciPy, pandas, Jupiter, Matplotlib, dataflow, Keras, TensorFlow, libraries.

Compulsory/Recommended Readings:

- John V. Guttag: Introduction to Computation and Programming Using Python, 2nd ed., The MIT Press, 2016
- Jake VanderPlas: Python Data Science Handbook: Essential Tools for Working with Data, O'Reilly, 2016
- Allen B. Downey: Think Python (How to Think Like a Computer Scientist), 2nd ed., O'Reilly, 2016.

AUTONOMOUS VEHICLES

INSMA0106-22

Semester: 1
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Compulsory
Prerequisites: None
Assessment: Practical mark
Responsible: Dr. László Kovács

Topics:

Within the framework of the subject, students learn about the theoretical and practical backgrounds of modern image processing methods, machine learning methods, and neural networks related to self-driving cars with the help of technology-related software and development environments. The course seeks to introduce advanced simulation technologies in a practice-oriented form of education. The course pays special attention to more complex solutions such as sensor integration, sensor fusion, advanced localization technologies, optimization, system integration, and complex traffic situation analysis. Students work on projects that allow them to work in an application-oriented environment within the deployment process.

Compulsory/Recommended Readings:

- Abdelaziz Bensrhair, Thierry Bapin: From AI to Autonomous and Connected Vehicles: Advanced Driver-Assistance Systems (ADAS), Wiley, 2021
- Shaoshan Liu: Engineering Autonomous Vehicles and Robots: The DragonFly Modular-based Approach, Wiley, 2020
- Francois Chollet: Deep Learning with Python, Manning Publications, 2017
- I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016
- Thor I. FossenKristin, Y. Pettersen, Henk Nijmeijer: Sensing and Control for Autonomous Vehicles - Applications to Land, Water and Air Vehicles, SPRINGER, 2017.

EFFICIENT DATA VISUALIZATION

INSMA0107-22

Semester: 1
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Compulsory
Prerequisites: None
Assessment: Practical mark
Responsible: Dr. Roland Imre Kunkli

Topics:

The basic concepts and the goals of Data Visualization. Data abstraction, different data types, preparing data for visualization. Task abstraction. Scalar, vector, and tensor visualization. Volume visualization. Visualizing large trees, networks, temporal, geographical, and multi-dimensional data. Efficient techniques for dealing with massive sensor data. Interaction. Scalability. Colors. Modern libraries and software for Big Data Visualization. Visualizations supported by GPU-accelerated solutions and parallel computing techniques.

Compulsory/Recommended Readings:

- Andy Kirk: Data Visualisation: A Handbook for Data Driven Design, SAGE Publications Ltd; 2019
- Alexandru Telea: Data Visualization: Principles and Practice, Second Edition, A K Peters/CRC Press, 2014, ISBN: 978-1466585263
- Tamara Munzner: Visualization Analysis and Design, A K Peters/CRC Press, 2014, ISBN: 978-1466508910
- Katy Börner, David E. Polley: Visual Insights: The Practical Guide to Making Sense of Data, The MIT Press, 2014, ISBN: 978-0262526197
- Gerald Farin, Dianne Hansford: Mathematical Principles for Scientific Computing and Visualization, First Edition, A K Peters/CRC Press, 2008, ISBN: 978-1568813219

CLOUD COMPUTING

INSMA0108-22

Semester: 1
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Compulsory
Prerequisites: None
Assessment: Practical mark
Responsible: Dr. Tamás Bérczes

Topics:

Introduction to the different cloud infrastructures. Case studies to distinguish between IaaS, PaaS and SaaS.

Introduction to public, private, hybrid cloud infrastructures. Positive and negative aspects of different cloud infrastructures and On premisses systems. Describe the reliability, availability and scalability of the cloud environment; Cost factors; Cost analysis and monitoring options. Presentation of the different BigData and AI solutions available in the cloud environment. Creating virtual machines; Managing virtual networks; Different data storage methods. Identifying security risks of systems deployed in the cloud, creating disaster scenarios.

Developing a backup strategy; Introduction to cloud DevOps systems.

Compulsory/Recommended Readings:

- Erl Thomas, Puttini Ricardo, Mahmood Zaigham : Cloud Computing: Concepts, Technology & Architecture, Pearson, 2013
- Kris Jamsa: Cloud Computing: SaaS, PaaS, IaaS, Virtualization, Business Models, Mobile, Security and More, Jones & Bartlett Learning, 2012
- George Prestonship: Amazon Web Services and Microsoft Azure Bundle: AWS and Azure Explained for Beginners: API, Cloud Computing for Data Storage, Machine Learning, Security, Networking and More!, George Prestonship, 2020.

REINFORCEMENT LEARNING

INSMA0209-22

Semester: 2
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Compulsory
Prerequisites: None
Assessment: Exam
Responsible: Dr. Balázs Harangi

Topics:

Introduction to Reinforcement Learning; Formalize problems as Markov Decision Processes; Key Concepts and Terminology; States and Observations; Dynamic Programming; Action Spaces; Policies; Deterministic Policies; Stochastic Policies; Trajectories; Reward and Return; The RL Problem; Value Functions; The Optimal Q-Function and the Optimal Action; Model-Free vs Model-Based RL; Policy Optimization; Q-Learning; RL Algorithms.

Compulsory/Recommended Readings:

- Richard S. Sutton and Andrew G. Barto: Reinforcement Learning: An Introduction, MIT Press, 2020.
- Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning, MIT Press, 2016.
- Stuart Russell and Peter Norvig, Editors: Artificial Intelligence: A Modern Approach, Pearson, 2020.

IMAGE PROCESSING BASED ON NEURAL NETWORKS

INSMA0210-22

Semester: 2
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Compulsory
Prerequisites: None
Assessment: Exam
Responsible: Dr. Balázs Harangi

Topics:

Neural networks (Activation functions, Backpropagation, Stochastic gradient descent, Momentum, Optimizers), Embeddings, Dropout Regularization, Recommender Systems, Convolutions, CNNs for Image Classification, CNN Architectures, Simple Localisation as regression, Detection Algorithms, Fully convolutional Networks, Semantic & Instance Segmentation, Learning with Deep Networks (Expressivity, Optimization, Generalization), Multi-labeling and Sampling strategies, Metric Learning and siamese networks, Triplet Loss and advanced techniques, Unsupervised learning, Autoencoders, Generative Adversarial Networks.

Compulsory/Recommended Readings:

- François Chollet: Deep Learning with Python, Manning, 2017.
- Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning, MIT Press, 2016.
- D. Conway, J.M. White: Machine Learning for Hackers, O'Reilly Media, Inc., 2012.
- W. McKinney: Python for Data Analysis (2 ed.). O'Reilly Media, Inc. 2017.

NATURAL LANGUAGE PROCESSING AND TEXT MINING

INSMA0211-22

Semester: 2
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Compulsory
Prerequisites: None
Assessment: Exam
Responsible: Dr. András Hajdu

Topics:

Text Mining, Text Embeddings, Recurrent Neural Networks for NLP, Transformer-Based Architectures (e.g., ELMo, BERT, ALBERT, DistilBERT, Transformer XL, XL-Net, RoBERTa, GPT, DALL-E), Self-Attention, Self-Supervision, Domain-Specific Models, Pre-Trained Models, Text Clustering, Conversational AI, Named-Entity Recognition, Question Answering, Sentiment Analysis, Machine Translation, Summarization, Text and Zero-Shot Classification, Inference and Deployment, Cloud-based NLP Services.

Compulsory/Recommended Readings:

- D. Rothman: Transformers for Natural Language Processing, Packt Publishing, 2021.
- S. Vajjala, B. Majumder, A. Gupta, H. Surana: Practical Natural Language Processing: A Comprehensive Guide to Building Real-World NLP Systems. O'Reilly Media, 2020.
- H. Lane, H. Hapke, C. Howard: Natural Language Processing in Action: Understanding, analyzing, and generating text with Python, Manning, 2019.
- L. Deng, Y. Liu: Deep Learning in Natural Language Processing, Springer, 2018.
- Y. Goldberg, G. Hirst: Neural Network Methods in Natural Language Processing, Morgan & Claypool Publishers, 2017.

AI FRAMEWORKS

INSMA0212-22

Semester: 2
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Compulsory
Prerequisites: None
Assessment: Practical mark
Responsible: Dr. Bernadett Aradi

Topics:

Learn about how to use the most popular frameworks for artificial intelligence. The course will also cover the underlying software and hardware infrastructure for these frameworks. The course material covers C/C++ and Python languages to learn about Intel Nervana Deep Learning, TensorFlow, Keras, Microsoft CNTK, Caffe, Theano, Torch frameworks to implement machine learning methods and neural networks.

Compulsory/Recommended Readings:

- A. Géron: Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 2nd Edition. O'Reilly Media, 2019. ISBN: 978-1-492-03264-9.
- I. Pointer: Programming PyTorch for Deep Learning: Creating and Deploying Deep Learning Applications. O'Reilly Media, 2019. ISBN: 978-1-492-04535-9.
- W. Meints: Deep Learning with Microsoft Cognitive Toolkit Quick Start Guide, 2019, Packt Publishing
- C. Bourez: Deep Learning with Theano, Pakt, 2017
- J. Patterson, A. Gibson: Deep Learning: A Practitioner's Approach. O'Reilly Media, 2017. ISBN: 978-1-491-91425-0.
- S. Pattanayak: Pro Deep Learning with TensorFlow: A Mathematical Approach to Advanced Artificial Intelligence in Python. Apress, 2017. ISBN: 978-1-484-23095-4

BIG DATA HANDLING TECHNIQUES

INSMA0213-22

Semester: 2
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Compulsory
Prerequisites: None
Assessment: Practical mark
Responsible: Dr. Henrietta Tomán

Topics:

To get familiar with the most important tasks, tools and techniques regarding Big Data (e.g. IoT sensor data) processing, artificial intelligence-based data analysis and data mining via solving realistic problems. Basic concepts. Data Representation Techniques. Big Data Processing and Storing Architectures. Distributed Data Processing. Hadoop, Spark, MongoDB. Data Pre-processing. Real-time Visualization. Artificial Intelligence-based Data Analysis. Linear and Logistic Regression, Decision Trees, Clustering, Naive Bayes, Neural Networks. Dimensionality Reduction. Analysis of Data Flows. Big Data Processing on Cloud Platform (for example MS Azure). Case Studies.

Compulsory/Recommended Readings:

- J. Leskovec, A. Rajaraman, J. D. Ullman: Mining of Massive Datasets, Cambridge University Press, 3rd edition, 2020.
- A. Deshpande, M. Kumar: Artificial intelligence for Big Data: complete guide to automating Big Data solutions using artificial intelligence techniques, Packt Publishing Ltd, 1st edition, 2018.
- V. K. Solanki, V. G. Díaz, J. P. Davim: Handbook of IoT and Big Data, CRC Press, 1st edition, 2019.
- T. White: Hadoop: The Definitive Guide, Yahoo Press, 2012.
- Y. Bengio: Learning Deep Architectures for AI, Foundations & Trends in Machine Learning, Now Publishers Inc., 2009.