Bialystok University of Technology

Doctoral School

COURSE DESCRIPTION CARD

<table>
<tr><td>Course name</td><td colspan="5">Advanced Image Processing and AI/ML in Deformation Processes and Fluid-Structure Interactions</td></tr>
<tr><td>Course type</td><td>Optional</td><td>Course code</td><td>SDPB0129</td><td>ECTS credits</td><td>2</td></tr>
<tr><td>Forms and number of hours</td><td>Lecture: 20 h</td><td>Scientific discipline</td><td colspan="3">Mechanical Engineering</td></tr>
<tr><td>Course objectives</td><td colspan="5">The objective of the course is to equip students with advanced image processing, AI/ML techniques, and numerical simulations to monitor, optimize, and predict deformation and fluid-structure interaction (FSI) processes in material manufacturing.</td></tr>
<tr><td>Course content</td><td colspan="5">The course focuses on advanced image processing techniques and AI/ML methods applied to material manufacturing, with a particular emphasis on deformation processes and fluid-structure interaction (FSI). Key image processing methods include filtering (Gaussian, Median), edge detection (Canny, Sobel), segmentation (Thresholding, Watershed, Active Contours), feature extraction (HOG, SIFT, SURF), and 3D image reconstruction (Structure-from-Motion, Photogrammetry). Students will explore the application of these techniques to monitor and optimize deformation processes, such as plastic deformation, forming, and shaping, by integrating Digital Image Correlation (DIC), optical flow for strain and displacement analysis. In addition, the course addresses FSI processes, leveraging imaging data to detect structural defects, evaluate fluid-induced deformations, and improve process control. Machine learning methods, including supervised learning (e.g., Convolutional Neural Networks, Decision Trees), unsupervised learning (e.g., K-Means, DBSCAN), and reinforcement learning, will be introduced to enhance predictive modeling and process optimization. Hybrid approaches combining imaging, numerical simulations (e.g., FEM, CFD, and ALE methods), and AI-driven models will be emphasized to tackle complex challenges in deformation and FSI applications. The course incorporates practical implementation using tools such as Python (OpenCV, scikit-image, TensorFlow/PyTorch), ANSYS for FEM simulations, and high-performance computing platforms, providing students with the skills to integrate image-based diagnostics with simulation and AI-driven frameworks for innovative solutions in material manufacturing.</td></tr>
<tr><td>Teaching methods</td><td colspan="5">The multimedia presentation, information lecture, project preparation</td></tr>
<tr><td>Assessment method</td><td colspan="5">Exam and project preparation</td></tr>
<tr><td>Symbol of learning outcome</td><td colspan="3">Learning outcomes</td><td>Reference to the learning outcomes for the field of study for the 8th level of Polish</td><td>Methods of assessing the learning outcomes</td></tr>
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		Qualification Framework (PRK)	
LO1	PhD students will apply advanced image processing techniques to analyze deformation and detect defects in material manufacturing processes.	SD_W1, SD_W2	Passing the lecture and project
LO2	PhD students will integrate machine learning methods with numerical simulations to optimize and predict material behavior under deformation and FSI conditions.	SD_U1	Passing the lecture and project
LO3	PhD students will develop and implement hybrid models combining image data, FEM, and AI-driven techniques for process control and improvement.	SD_U1	Passing the lecture and project

Student workload (in hours)	
Lecture, project	10 / 10 / 0 / 0 / 0
Consultations	5
The unassisted student work	15
Implementation of project tasks and preparation for and participation in exams/tests	20
Total	60
ECTS credits	2
Basic references	1. Gonzalez, R. C., & Woods, R. E. (2018). *Digital Image Processing* (4th ed.). Pearson. ISBN: 978-0133356724. 2. Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press. ISBN: 978-0262035613. 3. Reddy, J. N. (2019). *An Introduction to the Finite Element Method* (4th ed.). McGraw-Hill Education. ISBN: 978-1259861901. 4. Versteeg, H. K., & Malalasekera, W. (2007). *An Introduction to Computational Fluid Dynamics: The Finite Volume Method* (2nd ed.). Pearson Education. ISBN: 978-0131274983. 5. Raschka, S., & Mirjalili, V. (2019). *Python Machine Learning* (3rd ed.). Packt Publishing. ISBN: 978-1789955750.
Supplementary references	1. Forsyth, D. A., & Ponce, J. (2012). Computer Vision: A Modern Approach (2nd ed.). Pearson. ISBN: 978-0136085928. 2. Szeliski, R. (2010). Computer Vision: Algorithms and Applications. Springer. ISBN: 978-1848829343.

	3. Bishop, C. M. (2006). Pattern Recognition and Machine Learning. Springer. ISBN: 978-0387310732. 4. Blondel, V. D., & Tsitsiklis, J. N. (2009). Optimal Control Theory: Deterministic and Stochastic. Springer. ISBN: 978-0691140159. 5. Itu, L. M., Sharma, P., & Esmaily, M. (2017). Computational Fluid-Structure Interaction: Methods and Applications. Academic Press. ISBN: 978-0128046018.
Author of the programme	DSc Hab. Eng. Dariusz Perkowski
Date of issuing the programme	07.03.2025