

DOCTORAL STUDIES COURSE DESCRIPTION

Course title	Research field, code	Faculty	Institute, department
Model-Based Systems Engineering	Informatics Engineering (T 007)	MIF	Institute of Data Science and Digital Technologies

Mode of study	Number of credits ECTS	Mode of study	Number of credits
lectures	1	consultations	1
individual study	4	seminars	1
Semester: spring			

Course annotation
Prerequisites. The module requires knowledge of master's-level informatics and mathematics courses offered to students of informatics study programs. Course objective – to deepen knowledge of model-based systems engineering. Main topics. System development life cycles from RUP to Agile/DevOps. The Zachman taxonomy (Zachman Framework) and TOGAF 10 (2022). The OMG MDA approach. MDE, MDD and MBSE methodologies. MDA/MDE layers: CIM, PIM, PSM. Development of the CIM level, formalization of fuzzy (vague, uncertainty) requirements, and LLM-based transformation of natural-language requirements. Transformations: CIM-to-PIM and PIM-to-PSM transformation rules (fuzzy-logic-based rules); application of BPMN/UML 2.5/SysML v2+KerML, and QVT, ATL, and LLM-based model generation and transformation. Mathematical foundations of MBSE: application of fuzzy set theory and machine learning (ML) to uncertainty modeling. Implementation of MBSE within the UAF architecture framework (successor to MODAF/DoDAF). Software tools: Eclipse Capella, Cameo Systems Modeler, IBM ELM (Rhapsody, DOORS Next), and use of AI agents for requirements quality analysis and model element generation. Domain knowledge layer: modified MDA scheme, development of a domain causal model, Fuzzy Cognitive Maps (FCM), relationship to the CIM level. Practical assignments (Assignment 1 is mandatory; two assignments are to be selected from Assignments 2–6): Analytical part. A report on model-based systems engineering methods, software tools and the latest scientific literature (2024-2026), aligned with the dissertation topic. Practical part. Development of a CIM-PIM-PSM model for a selected fragment of the dissertation domain using one of the tools (Eclipse Capella, Cameo Systems Modeler, or an experimental SysML v2 environment), applying documented transformation rules. Formalization of transformations. Development of a set of QVT or ATL transformation rules for a specific CIM-to-PIM or PIM-to-PSM transformation, based on the dissertation topic. Comparison with an alternative fuzzy-logic-based approach to the same transformation. Domain knowledge modeling. Development of a domain causal model based on the dissertation using Fuzzy Cognitive Maps, justifying the relationship between the model and the CIM level. AI/LLM assignment. Transformation of natural-language requirements (CIM-level text) into initial PIM model elements using LLMs (e.g., via the Claude/GPT API or IBM Engineering AI Hub). Architecture framework application. Description of the architecture of a selected complex system (based on the dissertation) within the UAF framework, justifying the mapping of the UAF "view" types used to the CIM/PIM levels.

Main literature
Josey, A. (2023). The TOGAF Enterprise Architecture Foundation Study Guide. Van Haren Publishing. ISBN: 9789401810159; 940181015X.
Brambilla, M., Cabot, J., & Wimmer, M. (2017). Model-driven software engineering in practice. p. 208, Morgan & Claypool Publishers. ISBN: 1627057080; 9781627057080.
Douglass, B. P. (2022). Agile Model-Based Systems Engineering Cookbook: Improve system development by applying proven recipes for effective agile systems engineering. Packt Publishing Ltd. ISBN: 1803235829; 9781803235820
Wu, H. C. (2023). Mathematical foundations of fuzzy sets. John Wiley & Sons.
Mendel, J. M. (2024). Explainable Uncertain Rule-Based Fuzzy Systems. Cham: Springer.
OMG. MDA Specifications. (2014) https://www.omg.org/mda/
Ross, T. J. (2005). Fuzzy logic with engineering applications. John Wiley & Sons.
László T. Kóczy (2023). Fuzzy Cognitive Maps: A Tool for the Modeling and Simulation of Processes and Systems. Springer. ISBN: 9783031379581; 3031379586; 9783031379598.
Gudas, S.; Valatavičius, A. Extending model-driven development process with causal modeling approach // Data science: new issues, challenges and applications / Dzemyda, Gintautas, Bernatavičienė, Jolita, Kacprzyk, Janusz (Eds.). Cham: Springer, 2020. ISBN 9783030392499. eISBN 9783030392505. p. 111-143. (Studies in Computational Intelligence, ISSN 1860-949X, eISSN 1860-9503 ; vol. 869). DOI: 10.1007/978-3-030-39250-5_7.
Johns, B., Carroll, K., Medina, C., Lewark, R., & Walliser, J. (2024, July). AI Systems Modeling Enhancer (AI-SME): initial investigations into a ChatGPT-enabled MBSE modeling assistant. In INCOSE International Symposium (Vol. 34, No. 1, pp. 1149-1168). https://incose.onlinelibrary.wiley.com/doi/pdfdirect/10.1002/iis2.13201
Cámara, J., Troya, J., Burgueño, L., & Vallecillo, A. (2023). On the assessment of generative AI in modeling tasks: an experience report with ChatGPT and UML: JJ. Cámara et al. Software and Systems Modeling, 22(3), 781-793.
Calamo, M., Mecella, M., & Snoeck, M. (2025, June). Assessing the suitability of large language models in generating uml class diagrams as conceptual models. In International Conference on Business Process Modeling, Development and Support (pp. 211-226). Cham: Springer Nature Switzerland.
Tagliaferro, Alberto, Simone Corbo, and Bruno Guindani. "Leveraging llms to automate software architecture design from informal specifications." In 2025 IEEE 22nd International Conference on Software Architecture Companion (ICSA-C), pp. 291-299. IEEE, 2025.
Rhazali, Y., Hadi, Y., & Mouloudi, A. (2016). Model Transformation with ATL into MDA from CIM to PIM Structured through MVC. Procedia Computer Science, 83, 1096-1101.
A. Solberg, D. Simmonds, R. Reddy, S. Ghosh, R. France, "Using Aspect Oriented Technologies to Support Separation of Concerns in Model Driven Development", Accepted in the 29th Annual International Computer Software and Applications Conference (COMPSAC 2005), Edinburgh, Scotland, July, 2005

Consulting lecturers (name, surname)	Academic degree	Major publications in the research field over the last 5 years
Jolanta Miliauskaitė	Assoc. Prof. Dr.	https://elaba.mb.vu.lt/dmsti/?aut=Jolanta+Miliauskait%C4%97
Asta Slotkienė	Assoc. Prof. Dr.	https://elaba.mb.vu.lt/dmsti/?aut=Asta+Slotkien%C4%97