załącznik do Regulaminu programu „visiting profesor"

Osoba zgłaszająca z PW	
Tytuł i stopień naukowy	dr hab. inż.
Imię i nazwisko	Marek Wojtyra
Wydział	Mechaniczny Energetyki i Lotnictwa
Mail w domenie PW	Marek.Wojtyra@pw.edu.pl
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Propozycja osoby zgłaszanej jako visiting professor	
Tytuł i stopień naukowy	Associate Professor (Tenure Track), dr inż.
Imię i nazwisko	Grzegorz Orzechowski
Dokładna afiliacja	Laboratory of Sustainable Mechatronics Department of Mechanical Engineering School of Energy Systems Lappeenranta-Lahti University of Technology LUT Mukkulankatu 19, 15210 Lahti Finland
Mail kontaktowy	grzegorz.orzechowski@lut.fi
Opis osiągnięć (1/2-1 strony)	Grzegorz Orzechowski is an accomplished Associate Professor (Tenure Track) in Sustainable Mechatronics at the Department of Mechanical Engineering, Lappeenranta-Lahti University of Technology LUT, Lahti, Finland. With a strong academic background, Grzegorz holds a Ph.D. in Automation and Robotics from the Faculty of Power and Aeronautical Engineering, Warsaw University of Technology, Poland, and a Title of Docent in Artificial Intelligence based on Computational Dynamics from the School of Energy Systems, Lappeenranta-Lahti University of Technology LUT, Finland. Throughout his career, Grzegorz has held various significant positions, including Post-doctoral Researcher and Senior Developer at Mevea Oy. Grzegorz has also served as an Assistant Professor at the Warsaw University of Technology and has had the opportunity to work as a Visiting Researcher at the Lappeenranta University of Technology and as a Visiting Scholar at the University of Illinois at Chicago. Grzegorz's research interests lie in the fields of artificial intelligence, computational dynamics, and sustainable

	mechatronics. His work has contributed to advancements in these areas, and he has been actively involved in various research projects and collaborations. Grzegorz's achievements and contributions to the field have been recognized through his academic appointments and research positions.

Code of the course	4606-VP-ES-00024	Name of the course	Polish	**Dynamika układów wieloczłonowych z zastosowaniem parametrów Eulera i uczenia maszynowego**
			English	**Multibody Dynamics with Euler Parameters and Machine Learning**
Type of the course	Specialty subject/~~researcher's workshop~~			
Course coordinator	Grzegorz Orzechowski	Course teacher	Grzegorz Orzechowski	
Implementing unit	Faculty of Power and Aeronautical Engineering	Scientific discipline / disciplines*	Mechanical Engineering (IMECH) Automation, Electronics, Electrical Engineering and Space Technologies (AEEiTK) Information and Communication Technology (ITiT)	

Level of education	Doctoral studies	Semester	Spring		
Language of the course	English				
Type of assessment	Pass or Fail	Number of hours in a semester	60	ECTS credits	5
Minimum number of participants	10	Maximum number of participants	30	Available for students (BSc, MSc)	Yes/~~No~~

Type of classes		Lecture	Auditory classes	Project classes	Laboratory	Seminar
Number of hours	in a week					
	in a semester	24		8	28	

* does not apply to the Researcher's Workshop

1. Prerequisites

Basic knowledge of multibody dynamics, Familiarity with programming, Understanding of machine learning fundamentals

2. Course objectives

The course aims to provide students with a comprehensive understanding of spatial multibody dynamics using Euler Parameters and the application of machine learning techniques for control and prediction. By the end of the course, students will be able to:

1. Understand and apply the principles of spatial multibody dynamics using Euler Parameters.
2. Implement and integrate Lie group RK4 methods for dynamic simulations.
3. Model hydraulic actuators using lumped fluid theory.
4. Develop and code dynamic systems using the Julia Language.
5. Leverage machine learning techniques to enhance control and prediction in multibody dynamics.
6. Participate in a practical Hackathon to apply learned concepts in real-world scenarios.

3. Course content (separate for each type of classes)
Lecture

Introduction to Multibody Dynamics
Fundamental principles and equations governing multibody dynamics.
Overview of Euler Parameters and their advantages for spatial dynamics.

Euler Parameters in Dynamic Simulations
Detailed formulation and use in multibody simulations.
Numerical challenges and best practices.

Lie Group RK4 Methods
Basics of Lie groups in mechanics.
Implementation of Lie group RK4 methods for multibody simulations.

Hydraulic Actuator Modeling
Introduction to hydraulic systems in multibody dynamics.
Lumped fluid theory for actuator modeling and its integration with dynamic systems.

Machine Learning in Multibody Dynamics
Machine learning fundamentals relevant to dynamics.
Applications in control systems, prediction, and optimization of multibody systems.

Julia Language for Dynamics
Overview of the Julia Language and its benefits in computational mechanics.
Development of efficient and reusable code for multibody dynamic simulations.

Hackathon Preparation
Introduction to real-world challenges to be addressed in the Hackathon.
Guidance on combining theoretical knowledge with practical skills.

Project classes

1st Session: Workshop on Multibody System Modeling
Excavator Simulation – Friction, Particles, and Hydraulics

Students will build a simple excavator model and explore:
- Using multibody software to solve practical problems.
- Friction effects in joints and ground contact.
- Basic particle modeling for soil interaction.
- Hydraulic actuators for controlling movement.

This session focuses on hands-on practice in multibody modeling, with applications in machine simulations.

2nd Session: Hackathon on AI for Multibody Systems
Machine Learning for Simulation and Control

Students will use AI methods to improve multibody simulations by:
- Building a fast model to predict system behavior (surrogate modeling).
- Using reinforcement learning to control a robotic arm or pendulum.
- Comparing AI results with traditional methods.

This session helps students understand how machine learning can make simulations faster and smarter.

Laboratory

Implementation of Multibody Code with Euler Parameters
Hands-on implementation of Euler Parameters in simulation software using Julia.
Analyzing the stability and accuracy of Euler Parameter-based methods.

Lie Group RK4 Simulations
Practical coding of Lie group RK4 methods.
Testing and validation of algorithms with provided dynamic models.

Hydraulic Actuator Design and Simulation
Development of hydraulic actuator models based on lumped fluid theory.
Simulation of hydraulic systems in multibody environments.

Machine Learning Applications
Building and training machine learning models for control and prediction.
Integration of ML-based solutions with multibody simulations.

Dynamic Systems in Julia
Coding dynamic systems from scratch in Julia.
Optimizing performance and debugging for complex systems.

Hackathon
A practical team-based challenge where students apply their skills to solve a real-world multibody dynamics problem.
Presentation and evaluation of solutions based on innovation, accuracy, and implementation quality.

Type of learning outcomes	Learning outcomes description	Reference to the learning outcomes of the WUT DS	Learning outcomes verification methods*
Knowledge			
K01	Understanding the principles of spatial multibody dynamics using Euler Parameters	SD_W2 SD_W3	homework test
K02	Gained knowledge regarding the Lie group RK4 integration methods for dynamic simulations	SD_W2 SD_W3	homework test
Skills			
S01	Capability to model hydraulic actuators using lumped fluid theory	SD_U1	homework
S02	Ability to develop and code dynamic systems using the Julia Language	SD_U1	homework
S03	Capacity to leverage machine learning techniques to enhance control and prediction in multibody dynamics	SD_U1 SD_U2	homework project evaluation
Social competences			
SC01	Team work competences — participation in a practical Hackathon to apply learned concepts in real-world scenarios	SD_K2 SD_K4	presentation evaluation

*Allowed learning outcomes verification methods: exam; oral exam; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

4. Assessment criteria
Individual homework assignments (3), team assignment (1) in a form of hackathon.

5. Literature

Primary references:

[1] Lecture Notes

[2] "Multibody System Dynamics" by Ahmed A. Shabana

[3] "Deep Learning with Python" by François Chollet

Secondary references:

[1] Stable Baselines3 documentation

[2] The Julia Programming Language documentation

6. PhD student's workload necessary to achieve the learning outcomes**

No.	Description	Number of hours
1	Hours of scheduled instruction given by the academic teacher in the classroom	60
2	Hours of consultations with the academic teacher, exams, tests, etc.	20
3	Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework	25
4	Amount of time devoted to the preparation for exams, test, assessments	20
	Total number of hours	**125**

ECTS credits	**5**

** 1 ECTS = 25-30 hours of the PhD students work (2 ECTS = 60 hours; 4 ECTS = 110 hours, etc.)

7. Additional information	
Number of ECTS credits for classes requiring direct participation of academic teachers	3
Number of ECTS credits earned by a student in a practical course	3