COURSE DESCRIPTION CARD - SYLLABUS

Course name
Designing advanced HMI and M2M interfaces [S2AiR2-ISA>PO2-PZI]

Course

Field of study
Automatic Control and Robotics

Year/Semester
1/2

Area of study (specialization)
Intelligent Control Systems

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture
15

Laboratory classes
30

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

3,00

Coordinators

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Lecturers

Prerequisites

Knowledge: Students starting this subject should have knowledge of automation and robotics corresponding to level 6 of the Polish Qualifications Framework, in particular knowledge of programming, data structures, microprocessor systems and the basics of network communication. Skills: The student should have the ability to solve and implement programming problems in the field of automation and robotics, as well as the ability to obtain information from specified sources. He should also understand the need to expand his competences and be ready to cooperate in a team. Social competences: In addition, in the area of social competences, the student must exhibit such qualities as honesty, responsibility, perseverance, cognitive curiosity, creativity, personal culture, respect for other people.

Course objective

1. Providing students with knowledge of the construction and exchange of information in real time for human-machine and machine-machine interfaces. 2. Developing students' skills to develop human-machine and machine-machine data exchange interfaces for the control and measurement system as well as their implementation and launch in a programming environment. 3. Developing in students the importance of knowledge of technology and recommendations related to the construction and programming of data exchange interfaces.

Course-related learning outcomes

Knowledge:
1. The student has ordered and in-depth knowledge related to control systems and control and measurement systems; [K2_W11]
2. has basic knowledge about the life cycle of automation and robotics systems as well as control and measurement systems; [K2_W13]

Skills:
1. Student is able to select and integrate elements of a specialized measurement and control system including: control unit, executive system, measurement system as well as peripheral and communication modules; [K2_U13]
2. is able to make a critical analysis of how control and robotics systems work; also has the ability to select automation systems using microprocessor controllers; [K2_U19]
3. can design improvements (improvements) in existing design solutions for automation and robotics components and systems; [K2_U20]
4. is able to design and implement a complex device, object or system taking into account non-technical aspects; [K2_U23]

Social competences:
1. The student is aware of the need for a professional approach to technical issues, meticulous familiarization with the documentation and environmental conditions in which devices and their components can function; [K2_K4]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

The learning outcomes presented above are verified in the following way:
Formative assessment:
a) in terms of lectures:
based on homework assignments and answers to questions about the material covered in previous lectures,
b) within the scope of the laboratory:
based on the assessment of knowledge and understanding of current issues presented in the course.
c) In both forms of classes, it is possible to use Problem-Based Learning (PBL) tasks that support the current research and technical needs of the course coordinator and are supervised by the instructor, taking into account the iterative and cyclical nature of task implementation, provided that they are consistent with the course content.

Summary rating:
a) in the field of lectures, verification of the assumed learning outcomes is carried out by:
i. assessment of knowledge and skills demonstrated using a multiple-choice test,
ii. discussion of the test results.
b) in the laboratory, verification of the assumed learning outcomes is carried out by:
i. assessment of the student's preparation for individual classes,
ii. continuous assessment in each class (oral answers) - rewarding the increase in the ability to use the learned principles and methods,
iii. assessment of tasks prepared partly during classes, as well as after their completion.
c) The summative assessment may include the results of Problem-Based Learning (PBL) assignments developed for the research and technical needs of the course coordinator and supervised by the instructor, provided they are consistent with the course curriculum.
d) Obtaining additional points for activity during classes, in particular for:
i. independent construction of a distributed control and measurement system consisting of several electronic modules with microprocessors communicating in real time and preparation of documentation,
ii. effectiveness of applying acquired knowledge when solving a given problem
iii. comments related to the improvement of teaching materials.

Programme content

The subject covers a wide range of issues related to the design of advanced human-machine interfaces (HMI) and machine-machine communication (M2M). Students become familiar with modern technologies supporting human-computer communication (voice commands, gestures), wearable sensors, HMI interfaces (including RESTful web interfaces), M2M solutions (MQTT protocol), voice and gesture interfaces, as well as research and development work in the field.

During the lectures, students will learn to determine the functional requirements of interfaces and prepare metadata, design graphical interfaces for microprocessor systems (e.g. STM32 TouchGFX), use wearable sensors in human-machine interfaces, analyze signals from wearable sensors, design HMI and web interfaces with RESTful, implement M2M solutions with the MQTT protocol, create voice and gesture interfaces, and learn about the latest developments in the field of HMI and M2M.

Laboratory classes will allow students to practically apply the acquired knowledge. These include interface prototyping, designing graphical interfaces for microprocessor systems (STM32 TouchGFX), working with selected M2M protocols (e.g. HTTP, MQTT, CoAP), event handling and presentation of measurement data in real time (e.g. STM32 TouchGFX), creating RESTful interfaces and responsive websites, processing voice commands, analyzing signals from wearable sensors and measurement systems, speech and gesture recognition, as well as assessing the performance and responsiveness of HMI and M2M interfaces.

The course program provides comprehensive preparation for the design and implementation of advanced HMI and M2M interfaces, which is increasingly important in today's technology-dominated world. Students will acquire theoretical knowledge and practical skills necessary to work in various fields, such as automation, robotics, automotive, computer science and many others.

Course topics

The lecture program covers the following topics:
1. Defining the functional requirements of the interface and preparing metadata. Introduction to the graphical interface for a microprocessor system (STM32 TouchGFX). Modern technologies in supporting human-computer communication (voice commands, gestures). Wearable sensors in human-machine communication interfaces. Analysis of signals from wearable sensors.
2. Processing and visualizing data from a 6DoF (Inertial Measurement Unit – 6 Degrees of Freedom) IMU and a photoplethysmographic signal (PPG).
3. RESTful web interfaces. HTTP client and server for embedded systems using the STM32 as an example. Using the WebSocket protocol.
4. MQTT protocol for embedded systems using the STM32 as an example.
5. Speech-to-Text (STT), Text-to-Speech (TTS), and Large Language Model (LLM) voice interfaces.
6. Gesture-based interfaces (wearable IMU 6DoF, optical and visual MediaPipe).
7. Research and development work undertaken in the areas of HMI and M2M.

The laboratory curriculum includes:
1. Prototyping an interface for specific functional constraints for drive systems in the research laboratory.
2. Graphical interface template for a microprocessor system for drive systems in the research laboratory.
3. Real-time presentation of measurement data (STM32 TouchGFX, IMU 6DoF, and PPG signal).
4. Real-time processing and presentation of measurement data (CMSIS-DSP and STM32 TouchGFX).
5. RESTful interface for the microprocessor system (STM32, LwIP, FreeRTOS, HTTP server).
6. Responsive web interface for the microprocessor system (STM32, LwIP, FreeRTOS, HTTP client and server).
7. MQTT for microprocessor systems (STM32, LwIP, FreeRTOS, MQTT)
8. Voice interface for microprocessor systems - STT (Speech-to-Text) and TTS (Text-to-Speech).
9. Voice interface for microprocessor systems - LLM (Large Language Model)
10. Gesture support for microprocessor systems (using a 6DoF IMU and PPG signal)
11. HMI and M2M for drive systems in a research laboratory for research and development purposes.

Teaching methods

1. Lecture: presentation of creating HMI and M2M interfaces for control and measurement system, multimedia presentation illustrated with literature data and sample projects
2. Laboratory classes: the use of a microprocessor system with a touch screen and an Ethernet interface, environment for HMI design and M2M implementation
3. Both forms of instruction offer the opportunity to incorporate elements of Problem-Based Learning (PBL), in which students work on problems and projects defined for the research and technical needs of the

course coordinator and supervised by the instructor. This approach places particular emphasis on the iterative nature of work, encompassing problem analysis, solution design, practical verification, and systematic refinement.

Bibliography

Basic
1. STM32F7 documentation (online)
2. TouchGFX documentation (online)
3. Interfejs API : strategia programisty, Daniel Jacobson, Greg Brail, Dan Woods, Helion, 2015.
4. Łuczak, D. Data-Driven Machine Fault Diagnosis of Multisensor Vibration Data Using Synchrosqueezed Transform and Time-Frequency Image Recognition with Convolutional Neural Network. Electronics 2024, 13, 2411, doi:10.3390/electronics13122411.
5. Łuczak, D. Machine Fault Diagnosis through Vibration Analysis: Time Series Conversion to Grayscale and RGB Images for Recognition via Convolutional Neural Networks. Energies 2024, 17, 1998, doi:10.3390/en17091998.
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7. Łuczak, D.; Brock, S.; Siembab, K. Cloud Based Fault Diagnosis by Convolutional Neural Network as Time–Frequency RGB Image Recognition of Industrial Machine Vibration with Internet of Things Connectivity. Sensors 2023, 23, 3755, doi:10.3390/s23073755.

Additional
1. Mikrokontrolery STM32 w systemach sterowania i regulacji, Maciej Szumski, BTC, 2018
2. A Model-Driven Mobile HMI Framework (MMHF) for Industrial Control Systems, 2020, https://doi.org/10.1109/ACCESS.2020.2965259
3. Designing an Adaptive Interface: Using Eye Tracking to Classify How Information Usage Changes Over Time in Partially Automated Vehicles, 2020, https://doi.org/10.1109/ACCESS.2020.2966928
4. Łuczak D., „Remote laboratory with WEB interface”, Computer Applications in Electrical Engineering, Vol. 9, str. 257-268, Poznań, 2011, ISSN 1508-4248
5. Łuczak D., „DSP implementation of electric drive control system”, Proc. of 8th IEEE, IET Int. Symposium on Communication Systems, Networks and Digital Signal Processing, Poznan, Poland, 18-20 July 2012, pp. 6, ISBN: 978-1-4577-1472-6.
6. Łuczak D. i inni : „Microprocessor temperature measurement system”, Proc. of the 5th International Interdisciplinary Technical Conference of Young Scientists, InterTech 2012, Polska, Poznań, 16-18 maj 2012, str. 261-264, ISBN 978-83-926896-4-5.

Breakdown of average student's workload

	Hours	ECTS
Total workload	75	3,00
Classes requiring direct contact with the teacher	45	2,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	30	1,00