Introduction to Embedded Software and Applications

Teaching: 3h lectures, 1h practical tutorials

Credits: 3.5

Target Students: This course is an elective course designed for second year (and beyond) students in the Department of Computer Science in the Faculty of Science.

Prerequisites:

- 60069 - Introduction to Computer Systems
- 61108 - Advanced Programming Workshop

Course Description:

Embedded Software Systems used at the intersection of software technologies, embedded networking, hardware, etc. This course provides a comprehensive fundamentals coverage of the system, software, and algorithms used in the development of embedded software in various environments, such as Human Machine interfaces, IoT systems, sensors, etc.

The course focuses on learning the concepts of Embedded Systems architecture from a software perspective – including practical skills in exploring, developing, and utilizing embedded software using low-level programming (including software and hardware interrupts, processing and transmitting signals, developing software interfaces for communicating with various I/O devices, etc).

Description of the technology and infrastructure for training students in the course:

This course provides both theoretical knowledge and practical skills in embedded software development domain using technological, modern, and innovative **tools** for establishing embedded systems.

By observing different platforms and microcontrollers - a common and popular platform (such as the well-known Arduino) will be selected for the "practical training" in the course.

The students will also use practical simulation tools for embedding the developed software on an embedded system in a virtual environment for solving (simulating) a given problem/task/project.

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Course Goals:

Learning the theory of Embedded Software and the dominant role it takes in Embedded Systems – characterizing the interaction of Embedded Software Systems with the environment through various interfaces.

Acquiring knowledge, skills and tools used in the field of embedded systems, including their structure and components, with a focus on embedded software using low-level programming for microcontrollers and its various applications.

The developed software programs will be embedded on the microcontroller unit to perform dedicated predefined monitoring and control operations and interactions (including polling, interrupts handling, etc) with the environment as well as other embedded systems devices or components (sensors, actuators, etc).

Final grade:

The final grade will be determined according to the following criteria

1. Practical Exercises and Homework Assignments – 50%.

2. Final Semestrial Course Project – 50%.

Course attendance – 80% required.

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Weekly schedule:

Weeks 1-2:	**Introduction to Embedded Systems and Software Development for Microcontrollers** - Embedded software and the integral part it takes in an Embedded System. - Embedded Systems overview. - Introducing the building blocks of Embedded Software. - Defining and exploring Microcontroller Units as the basis for Embedded Software. - Embedded Software for interaction with sensors and actuators (digital and analog). - Developing the first low-level programs and analyzing the process of Building, Deploying, and Debugging.
Weeks 3-4:	**The C language as a low-level programming language and Introduction to Digital I/O operations in Embedded Systems** - C Programming Refresher. - The Compilation Process & Build System understanding – getting knowledge of the translation process from High-Level software languages to our architecture specific implementations. - General introduction to I/O principles and operations with Microcontrollers and utilization using Embedded Software. - Analyzing various units used as Input/Output in Embedded Domain. - Developing Embedded Software for communication with I/O devices and simulation on development board.
Weeks 5-6:	**Interrupts, Timers, and Counters** - Introduction to Interrupts and their usage in Embedded Systems. - Software and Hardware Interrupts. - Polling VS Interrupts. - ISR (Interrupt Service Routine). - Implementing and Developing Embedded Software using Interrupts and simulating on the development board. - Introduction to Timers and Counters Units. - Developing Embedded Software based on the principles and attributes of Timers, Counters, and Interrupts.
Weeks 7-8:	**Communication Protocols and their Implementation in Embedded Software** - Introduction to Serial Communication Protocols and the part it takes in Embedded Software systems. - Serial VS Parallel Protocols. - Principles and attributes of Communication Protocols (Synchronous, Asynchronous, baud, bps, etc). - Overview of UART, SPI, I2C Protocols. - Developing Embedded Software using Communication Protocols for interaction in Embedded Systems and Sensors Environment.
Week 9:	**Data Acquisition – Analyzing Analog Signals** - Introduction to the Analog World of sensors, signals, and their principles of working. - Analog and Digital Comparison. - The process of taking an Analog signal into a Digital data representation. - Developing an Embedded Software for reading the Environmental Analog Data (Temperature/Microphone/etc) and converting it into Digital Data.
Weeks 10-11:	**Embedded Systems – End to End Configuration and modern Version Control Tools for Embedded Software Development** - Communication (Wired/Wireless) and Networks: Cellular, Wi-Fi, Bluetooth, etc.

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	- Cloud Programming: Embedded Software for Data Collection and Post-Processing using Cloud Resources.
Weeks 12-13:	**Course Project Development & Presentation**

Course site:

Visiting hours:

Bibliography:

- Embedded Software Development: The Open-Source Approach (Embedded Systems) 1st Edition by by Ivan Cibrario Bertolotti (Author), Tingting Hu (Author).
- Introduction to Embedded Systems: Using ANSI C and the Arduino Development Environment (Synthesis Lectures on Digital Circuits and Systems) by David Russell (Author), Mitchell Thornton (Series Editor).
- Better Embedded System Software by Philip Koopman.
- Introduction to Embedded Systems Using Microcontrollers and the MSP430 – Manuel Jiménez, Rogelio Palomera, Isidoro Couvertier.
- Hands-On Embedded Programming with C++17: Create versatile and robust embedded solutions for MCUs and RTOSes with modern C++ by Maya Posch.

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