Università
della
Svizzera
italiana

Faculty
of
Informatics

Master of Science in Cyber-Physical and Embedded Systems

2017/18

Cyber-Physical and Embedded Systems. This newly designed master programme is among the first in the world addressing the fast growing area of cyber-physical and embedded systems, i.e., systems and "hidden" computational devices directly interacting with the physical world. Just looking around we discover that cyber-physical and embedded systems are present at home, at work, in the environment itself, by providing the backbone technologies to design smart homes, buildings and cities, enable the internet of things, support smart energy production, management and metering, facilitate smart transportation and healthcare – and this is only a preliminary and very concise list! As an immediate consequence, the related industrial field is continuously growing with annual revenue in the order of trillion euros. If you are a student willing to actively contribute to the way embedded technology will shape our future, the Master of Science in Cyber-Physical and Embedded Systems is for you.

Awarded Degree
Master of Science in Cyber-Physical and Embedded Systems
Application Deadline
April 30th / June 30th depending on the nationality of the applicant.
Tuition fees per semester
Residents CHF 2'000.– / international CHF 4'000.–
Duration
4 semesters (2 years) - 120 ECTS
Scholarships
Fondazione per le Facoltà di Lugano
10 study grants for Faculty of Informatics, covers first year of tuition, renewable according to grade
Contacts/information
www.mcpes.usi.ch
studyadvisor@usi.ch

Goals and contents

The Master of Science in Cyber-Physical and Embedded Systems offers exclusive challenging opportunities to application designers and system developers, by integrating different areas such as microelectronics, physical modeling, computer science, machine learning, telecommunication and control, and focusing on the most advanced applications. Meeting the real need for an interdisciplinary approach, the teaching plan equips talented students with a unique body of knowledge in the area of cyber-physical and embedded systems. The educational model focuses on a system-level methodological perspective as well as on the development of interpersonal skills proven to be indispensable in today's industry, such as team work, marketing and management strategies. ALaRI research activities focus on topics of great scientific interest and industrial applicability, based on real-life design methodologies taking into account system properties such as performance, dependability, intelligence, security and energy efficiency. The programme, designed for students holding a Bachelor degree in Computer Science, Computer Engineering and, more in general, in the domain of Information and Communication Technologies is built around three major methodological pillars: the interaction with the physical world, the embedded (networked) system, and the embedded applications. Courses, integrated to provide a holistic picture of the diversified facets, are given by world renowned, award-winning professors and industrial leaders. Both modular intensive and regular, semester-long courses are offered so that technological awareness, competences and problem solving abilities are built and developed together, within the same framework. Classroom education is naturally complemented by hands-on laboratory experience so that methodological aspects are reflected in real-world environment.

Language

This programme is entirely held in English. Applicants who are not native English speaker or whose first degree was not taught in English, must supply an internationally recognised certificate to demonstrate a C1 level on the Common European Framework of Reference for language learning (CEFR).

Student profile and admission requirements

Bachelor's degree granted by a recognized university in the general domain of Information and Communication Technologies, e.g., Computer Science, Computer Engineering, Electrical Engineering and Telecommunication. Please refer to the website www.alari.ch for a complete list of recognized degrees.
Further information for applicants graduating from a University of Applied Sciences is available online:

www.mcpes.usi.ch/admission

Career opportunities

Master of Science graduates in cyber-physical and embedded systems have excellent opportunities to find exciting jobs in industry, government or academia. Since the demand for technology specialists with system-level skills in embedded and cyber-physical systems is high, our students find an appealing and rewarding job before they graduate. Many high-tech companies, some of them world leaders, offer superb job opportunities in Switzerland, Europe and worldwide.
We observe that ALaRI students careers quickly accelerate, and most of them end up in leading positions in management and engineering.
ALaRI graduates founded successful startups or joined dynamic medium-size and global companies like ABB, Google, IBM, Philips, Samsung, Siemens and Unilever. Our graduates are present across the world, in Europe, North and South America, Asia and Africa. All-in-all, it is an exciting, brave new world of cyber-physical

The two-year master programme is built around a challenging multi-disciplinary project that acts as a leitmotiv and guides students towards a friendly acquisition of both technical and soft skills, as nowadays expected for high profile positions within the industry. Each year, a main class project "guiding theme" will be assigned, e.g., centered on smart buildings, smart environments, smart medicine, smart factory. Such projects will permit students to bring life to taught methodologies and tools as well as learn from challenges that cross-disciplinary, teamwork-based, real-world problems pose.

and embedded systems where the diversity and the number of available opportunities is simply immense. Design your future and visit us at

www.alari.ch

Contacts

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Study Advisory Service
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studyadvisor@usi.ch

Study programme

The study programme of the Master of Science in Cyber-Physical and Embedded Systems consists of four full-time study semesters (120 ECTS over two years). The thesis starts during the third semester and completes by the end of the fourth. Each individual student is assisted in tailoring the teaching plan to his/her previous competences and specific interests. To broaden the student's perspective, up to 18 ECTS can be obtained with elective courses chosen from the programme.

Please be aware that slight changes in the study programme may occur.

First semester		Digital Signal Processing	3.0
		Embedded Systems Architectures	3.0
		Introduction to CPS	3.0
		Microelectronics	6.0
		Mobile Computing	6.0
		Physical Modelling	6.0
		Project Management and Leadership	3.0
Second semester		Cyber-Communication	6.0
		Digital Automation	6.0
		CPS-Intelligence	6.0
		Nanosystems: Devices and Design	6.0
		Real-Time Systems	6.0
Third semester		Cyber-Security	3.0
		Multicore Embedded Application Design	3.0
		Optimizing Embedded Applications	3.0
		Specification Languages	6.0
		Master Thesis	6.0
	Electives 9.0	Heterogeneous Multicore Architectures	3.0
		Machine Learning	6.0
		Mobile Computing	6.0
		Reprogrammable Systems	3.0
		Validation and Verification	3.0
Fourth semester		Physical Computing	6.0
		Master Thesis	24.0

First semester

Digital Signal Processing

This course is aimed at illustrating the relevance and need for signal processing techniques in present-day multimedia and communications systems, and giving an overview of a few major DSP subdomains. First, a DSP basics refresh is given (linear systems and transforms, filter design and realisation). Then an introduction is given to multi-rate systems and filter banks, illustrated by applications such as subband coding and transmultiplexers, as well as optimal and adaptive filtering, illustrated by such applications as line echo cancellation and channel equalisation. Finally, two DSP case studies are given, one on highspeed telephone line modems (ADS/VDSL) and one on wireless communications, with emphasis on DSP aspects of so-called ‘smart antennas’.

Embedded Systems Architectures

The course deals with the high-level structure of modern digital systems, with a particular focus on low-power systems-on-chip and on massively parallel computing platforms. The lectures illustrate concepts and techniques leveraging the opportunities offered by instruction-, data-, thread- and request- level parallelism, in order to increase the run-time performance and the efficiency of processors. Real-world case studies are provided, detailing the characteristics of the ARM family of systems-on-chip and that of the OpenCL framework, among others. The course showcases how application domains shape the hardware features of computing ICs, which in turn demand dedicated execution and programming models.

Introduction to CPS

Cyber-physical and embedded systems increasingly pervade all walks of our lives where applications range from agriculture and healthcare to energy, manufacturing and social networks. The course will provide a course overview of the Master programme on cyber-physical and embedded systems. Basic concepts and forms of computing in CPS and embedded systems will be discussed and properties such as real time, dependability, cyber-intelligence, safety and security will be covered. Basic scheduling techniques will be introduced as well as overview of key protocols for wireless communication will be presented. Then main operating systems and processor architectures used in the CPS and embedded systems will be reviewed followed by applications case studies and trends.

Microelectronics

This course describes electronic and microelectronic technologies and design techniques used to implement CPS technologies. The first part of course introduces basics of electronics as well as layout design. The second part describes the design of simple CMOS circuits. Basic cells libraries will be introduced. Finally, aspects related to lowpower design will be given. Evolution of microelectronic technologies for the next 15 years will be presented.

Mobile Computing

Mobile devices such as mobile phones, smart watches, and other wearable devices can interact seamlessly by relying on available communication infrastructures. This course focuses on challenges and opportunities arising from the use of systems of mobile devices or “mobile sensing systems”. Following an overview of applications enabled by mobile sensing systems the focus will be devoted to the most significant technologies, including hardware platforms, programming environments and tools. Relevant aspects related to the design and development of a mobile sensing system, including the handling of sensors, the design of user interfaces, the management of local and remote sensor data storage, privacy and security issues will be investigated and addressed. In order to gain practical hands-on experience, students will learn in the lab sessions how to design, implement, and demonstrate Android-based mobile sensing applications.

Physical Modelling

The goal of the course is to provide the student a working knowledge in basic mathematical concepts and show how these tools are used in applied problems. It is divided in two main parts. Part I is devoted to the study of ordinary differential equations (ODEs). Initially, the Cauchy problem and the study of its stability is introduced. Then, the main focus is on classical and modern discretisation methods for the simulation of ODEs and system of ODEs: one-step methods, multistep methods, Runge-Kutta, and spectral deferred correction methods. In part II, after a brief recap about basic linear algebra concepts (vector spaces, scalar product, norm, orthogonal projection), the focus will be on the theory of transforms: Fourier series and integrals, Discrete and Fast Fourier Transform, Laplace, Zeta and Wavelet transforms.

Project Management and Leadership

The course is organized as a series of seminars by speakers from academia and industry who share first-hand experience on the following topics: Project management, product management, service catalogues, manufacturing embedded systems for missioncritical applications, basics of entrepreneurship, turning technology into business, business models, business plan, experiences in innovative high-tech spinoffs and startups - basic rules and guidelines, transforming industrial giants into IT-based organizations, software quality management by visualization, software process organization and approaches in the main software companies, leadership and qualities of successful manager.

Second semester

Cyber-Communication

The goal of this course is to convey the fundamentals of communication in Cyber-Physical Systems. Both wired and wireless communication technologies will be considered. The course will be accompanied by hands-on tutorials.

- Communication in Cyber-Physical Systems: Requirements and challenges;
- Basic communication technologies for wired networks (e.g., CAN bus, Ethernet, USB, optical communication);
- Basic communication technologies for wireless networks (e.g., ZigBee, NFC, Bluetooth, Wi-Fi);
- Networking protocols for Cyber-Physical Systems;
- Performance evaluation of communication protocols for Cyber-Physical Systems;
- Hands on tutorials (e.g., CAN bus and Zigbee).

Digital Automation

A CPS interacts with the environment and other CPSs in order to accomplish higher goals. Such goals may require a suitable real-time behavior with the acquisition and processing of signals and the real-time computation and transmission of information and/or the application of the necessary actuation mechanisms. The objective of the course is to educate CPS and embedded engineers to work in interdisciplinary teams in which they are faced with control engineering and automation issues. The students will learn aspects related to sensing, actuation, communication and control as well as master the tools and methods necessary to implement a CPS.

CPS-Intelligence

With ever-growing proliferation of cyber-physical systems in all walks of life, their properties like adaptation ability, dependability, security and timeliness are of utmost importance. The built-in intelligence in cyber-physical systems will have to face these challenges to ensure problem-free, continuous operation of such systems, maximum security, effectiveness and real time operability. The course will propose intelligent mechanisms to guarantee appropriate performance within an evolving, time invariant environment, optimal harvesting and management of the residual energy, to identify faults within a model-free framework as well as solve the compromise between output accuracy and computational complexity.

Nanosystems: Devices and Design

This course introduces students to design methods and tools for integrated circuits and systems. It focuses on modeling and on circuit and systems synthesis by stepwise refinement. It presents optimisation problems and algorithms that are common in embedded circuit/system design and it shows a simple design flow for designing integrated circuits and systems. The course is reinforced by exercises and a mini-project using state of-the-art commercial tools.

Real-Time Systems

Real-time systems play a crucial role in our society since an increasing number of complex systems rely, in part or completely, on dependable and timely operation. This course will first give an introduction into the basic concepts of real-time computing and then treat two major issues, namely real-time scheduling and real-time kernels. Real-time scheduling will concentrate on predictable scheduling algorithms and provide the scientific methodology for the design of real-time systems. Real-time kernels will address the challenges and issues in the design and implementation of real-time operating systems.

Third semester

Cyber-Security

The course provides an introduction to modern applied cryptography. Students will develop an understanding of the different types of cryptographic algorithms and the security services that can be realized with them. Representatives of widely used cryptographic algorithms will be introduced, and their implementation behavior will be discussed.

Multicore Embedded Application Design

Embedded Multiprocessor System-on-Chip (SoC) architecture design:

- Introduction to present and future heterogeneous multicore SoC's;
- Early HW/SW power estimation and optimization

System Modeling and Virtual Prototyping:

- Full system modeling;
- Fast instruction set simulation;
- Parallel SoC simulation;

Examples of real-world applications.

Optimizing Embedded Applications

The course aims at providing the basics for designing optimal embedded applications starting from a given problem.
The course, configured to stimulate the interaction with the students, will address the following methodological aspects

- Problem complexity and complexity reduction (deterministic vs probabilistic approaches for problem solving; Randomized algorithms);
- Approximate computing (sources of approximation, Probably approximately correct computation);- Optimization methods for
- embedded applications (gradient-based optimization, evolutionary-based optimization, learning mechanisms);
- Application porting to low precision hardware platforms (robustness analysis in the small; robustness analysis in the large; accuracy loss estimation);
- Performance and quality assessment of the solution (Crossvalidation, bootstrap, bags of little.

Specification Languages

The course is composed of two parts. Part 1 reviews at first the functional and non-functional properties of modern cyber-physical and embedded systems that have to be specified. Next, an overview of system level specification models is presented, with links to the specification languages. Considered models cover control dominated, data processing dominated and data storage dominated applications. They also focus on the different phases in the design flow, from functionality oriented to implementation oriented. In a hands-on section, an advanced video recorder is modeled that features dynamic task graph modification. Part 2 of the course focuses on using the specification models given in Part 1 for the architectural design of digital embedded systems. Relevant application examples will be provided.

Master Thesis

The Master thesis is an academic piece of work, an original contribution to the body of knowledge in cyber-physical and embedded systems. Such a contribution can be theoretical or experimental, but always builds on a solid research effort, and on the use of appropriate concepts, methods, and tools acquired during the Master. Faculty members advise students during their Master's thesis work.

Electives

Heterogeneous Multicore Architectures

The course focuses on Heterogeneous Multicore architectures, with the goal of giving an in-depth understanding of application requirements, architectural templates, hardware-software solutions and design tradeoffs. Several case studies on state-of-the-art solutions from various application domains will be covered.

Machine Learning

Introductory Master's Course to Intelligent Systems (IS) or Artificial Intelligence (AI), taught by award-winning experts of the Swiss AI Lab IDSIA, and USI. The focus is on Machine Learning (ML). According to Computer World (2009), expertise in ML is the top skill sought by IT employers. Today ML is everywhere: search engines use it to improve answers to queries, email programmes use it to filter spam, banks use it to predict exchange rates and stock markets, doctors use it to recognize tumors, robots use it to localize themselves and obstacles, video games use it to enhance the player's experience, smartphones use it to recognize objects / faces / gestures / voices / music, etc. After the first few lectures of the basic IS course on ML, IS master students will already know how to train self-learning artificial neural networks to recognize images and handwriting better than any other known method. They will rapidly gain familiarity with state-of-the-art algorithms developed at IDSIA and other AI labs.

Mobile Computing

Mobile devices such as mobile phones, smart watches, and other wearable devices can interact seamlessly by relying on available communication infrastructures. This course focuses on challenges and opportunities arising from the use of systems of mobile devices or “mobile sensing systems”. Following an overview of applications enabled by mobile sensing systems the focus will be devoted to the most significant technologies, including hardware platforms, programming environments and tools. Relevant aspects related to the design and development of a mobile sensing system, including the handling of sensors, the design of user interfaces, the management of local and remote sensor data storage, privacy and security issues will be investigated and addressed. In order to gain practical hands-on experience, students will learn in the lab sessions how to design, implement, and demonstrate Android-based mobile sensing applications.

Reprogrammable Systems

The course provides an introduction to reconfigurable design technologies (FPGAs). Students will get familiar with advanced VHDL programming and will develop a deep understanding of the of FPGAs architectures and the complex systems that can be realized with them. Representatives of widely used basic blocks for interacting with physical components will be introduced and implemented during the laboratory.

Validation and Verification

This course introduces the students to an approach to validation of hardware and software based on formal analysis of system behaviors. Among the formal methods, model checking enjoys considerable popularity because of its relatively high degree of automation. This approach has been highly effective in the analysis of CPS. The course presents the foundations of model checking starting from the modelling of systems and properties, and then proceeding with the basic algorithms for model checking. Among other things, the distinction between branching time and linear time is discussed, safety and liveness properties are defined, and the use of logics and automata as specifications is discussed. Various logics are introduced, including CTL*, CTL, and LTL. It is shown that model checking for CTL can be reduced to the computation of fixed points of appropriate monotonic functions, and that LTL model checking is based on the translation of the given formula into a Buechi automaton.

Fourth semester

Physical Computing

Physical Computing is about integrating the real world with sensing, communication, and computation. It is about rapidly prototyping devices that can react and interact directly with their environment, rather than being accessed through a keyboard and monitor. The class introduces students to the idea of using small, programmable microcomputers to build self-contained, physical systems that help automate everyday tasks. The course exposes students to basic electronics, microcontroller programming, wireless networking (WiFi and Bluetooth), mobile interfaces (smartphones), and embedded sensing. The class centers on Arduino and ESP development boards that allow one to rapidly build reactive and/or interactive everyday items, without the need for attaching a Mac or PC to them.

Master Thesis

The Master thesis is an academic piece of work, an original contribution to the body of knowledge in cyber-physical and embedded systems. Such a contribution can be theoretical or experimental, but always builds on a solid research effort, and on the use of appropriate concepts, methods, and tools acquired during the Master. Faculty members advise students during their Master's thesis work.

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