Title: "3D data structures and physics-based animation"

Course held by Prof. Jacopo Aleotti

E-mail reference professor: jacopo.aleotti@unipr.it

Duration: 20 hours

Semester: second

Short program:

Part 1) 3D collision detection algorithms (10 hours)

Algorithms for the intersection test between 3D primitives.

3D data structures for collision detection (Bounding Volumes, Bounding Volumes Hierarchies, Octree, K-d tree, BSP-tree).

Part 2) Physics-based programming (10 hours)

Rigid body dynamics. Introduction to the C++ Bullet Physics library.

Title: An introduction to power systems

Course held by Prof. Roberto Menozzi

E-mail reference professor: roberto.menozzi@unipr.it

Duration: 22 hrs

Semester: 1st

Short program:

The generation of electric energy – 4 hrs

Introduction to power systems – 4 hrs

The transmission of electric energy – 4 hrs

The utilization of electric energy – 2 hrs

Power system control – 8 hrs

Title: Quantum Computing

Course held by Prof. Michele Amoretti

E-mail reference professor: michele.amoretti@unipr.it

Duration: 18 hours

Semester: 2nd

Short program:

1. History and perspectives of quantum computing
2. Linear algebra (a refresher)
3. Postulates of Quantum Mechanics
4. Quantum bits
5. Quantum circuit model of computation
6. Quantum computers
7. Quantum algorithms
8. Protocols for quantum cryptography
9. Quantum Internet

Title: Detection over unknown channels

Course held by Prof. G. Colavolpe

E-mail reference professor: giulio.colavolpe@unipr.it

Duration: 12 hours

Semester: I (starting from September 2020)

Short program:

First part (overlapped with some lectures of the course Digital Communication, Master degree in Communication Engineering) – 14 hours

Introduction to the problem of sequence detection in the presence of unknown parameters.

Sequence detection in the presence of unknown parameters: channel models, sufficient statistics, optimal strategy in the presence of an unknown stochastic parameter, memory truncation. Examples: noncoherent sequence detection; receivers based on linear prediction.

UMP test. Generalized likelihood. Approach based on estimation. Estimators' classifications. CRB and MCRB. DA estimation. Example: Rife&Boorstyn algorithm and related MCRB. Open-loop estimation of the channel phase: analysis of the ML estimator and comparison with the CRB. Closed-loop estimation of the channel phase: 1st order PLL and its equivalent models. DD estimation. Decision-directed PLL, S-curve of a DD PLL. Per-survivor processing and tentative decisions. NDA estimation: M-th power estimator, Viterbi & Viterbi estimator. Soft-decision-directed estimation. Sufficient statistics for channels with unknown parameters.

Second part (specific for PhD students) - 6 hours (this part requires some basic knowledge on Factor graphs and the sum-product algorithm)

Detection for unknown channels based on graphical models

Title: Machine Learning for pattern recognition

Course held by Prof. A. Bononi / S. Cagnoni

E-mail reference professor: alberto.bononi@unipr.it

Duration: 56 hours (48 hours of Master course + 8 hours dedicated PhD course)

Semester: second

Short program:

Course covers

A. Bononi:

1) a review of probability and the Bayesian statistical analysis underlying ML (regression, classification)

2) extensions to generalized linear models as a basis to neural netwokrs and other kernel-based methods.

3) supervised learning for both regression and classification.

S. Cagnoni:

4) some elements of unsupervised learning .

5) some programming of ML algorithms based on Weka software.

Details can be found at: http://www.tlc.unipr.it/bononi/didattica/ML_PhD/ML_PhD.html

Title: MATLAB FOR ELECTRONICS

Course held by Prof. Valentina Bianchi

E-mail reference professor: valentina.bianchi@unipr.it

Duration: 24 hours

Semester: I – indicatively from the end of October.

Short program: The course aims to provide students with the knowledge of the main features of the MATLAB/SIMULINK software in order to use it as a support tool to the electronic design throught application examples. The students will learn how to use MATLAB and SIMULINK in typical applications of electronics, electrical engineering and signal processing. The students will learn to automatically generate C or VHDL code for Microcontrollers or FPGAs. He/she will learn how to communicate and document the choices made through a well written and documented code. Topics include: 1. Solving Equations 2. Continuous LTI Systems Analysis 3. Digital LTI Systems Analysis 4. FIR and IIR Filters Design 5. FFT 6. Automatic Code Generation 7. Hardware Connection

Title: Introduction to Model-Based Design

Course held by Prof. Alessandro Soldati

E-mail reference professor: alessandro.soldati@unipr.it

Duration: 24 hours (3 CFU)

Semester: Second

Short program:

- Abstraction levels, system partitioning and the V-model (3h)
- Unit testing, static code analysis and automatic test-benches and documentation (3h)
- Version Control Systems (3h)
- Numerical analysis for real-time computation (3h)
- Benchmarking of processing units and algorithms (3h)
- Data processing in MATLAB for embedded programming (3h)
- Optimizers and solvers (3h)
- Model-based design and system validation with MIL/SIL/PIL/HIL (3h)

Title: "Embedded System"

Course held by Prof. Guido Matrella and Prof. Carlo Concari

E-mail reference professor: guido.matrella@unipr.it – carlo.concari@unipr.it

Duration: 24 hours

Semester: 2nd

Short program: The aim of the course is to provide to SDIA students, coming from all three different areas of Information (Electronic, Informatics, Telecommunication), an overview of the main high performance Embedded Systems design methodologies.

The crucial issue of the Hw/Sw partition of an Embedded System will be illustrated and how an Embedded System can be implemented using different approaches: 1. Completely by SW, 2. By SW but using specific DSP processors, 3. By SW but using HW circuits "ad hoc" developed on FPGA.

"Programming standards" and "functional safety techniques" will be mentioned.

Examples of HW/SW design activities will be carried out, also using HDL languages and automatic code generation techniques.

Title: Optimization using Graphical Models

Course held by Prof. M. Locatelli, G. Colavolpe, A. Vannucci, L. Consolini

E-mail reference professor: giulio.colavolpe@unipr.it

Duration: 12 hours

Semester: II

Short program:

Topic 1: Basics on convex optimization (Locatelli) – 2 hours

Definitions of convex functions and sets. Brief sketches about complexity and algorithms. Constraint qualifications. Optimality conditions (KKT). Lagrangian duality.

Topic 2: Bayesian inference and graphical models (Colavolpe) – 4 hours

Bayesian Networks and Markov Random Fields: Inference in general Graphs.

Variational Inference techniques in Machine Learning and Artificial Intelligence: Belief Propagation (BP) and Loopy Belief Propagation

Factor graphs and sum product algorithm: general framework and applications to communications.

Topic 3: Variational Inference and the Free Energies methods of Physics (Vannucci) – 4 hours

Approximate Inference and factorized distributions. Variational mixtures of Gaussians. Exponential Family distributions. Variational message passing. Expectation Propagation and its implementation om graphs.

Energy functions and their minimization schemes. Variational average energy and variational entropy; Gibbs and Helmholtz free energies. Stationary conditions for the Bethe free energy and its connections with Loopy belief Propagation. The Mean Field approximation.

Topic 4: Graphical models for optimization - Trajectory planning and power control (Consolini) – 2 hours

Speed and trajectory planning problems, dynamic programming. Power control in radio systems. Reduction of previous problems to a standard form and definition of the associated graph. Graph-based solution algorithms.

Title: Electronics (and laboratory) for Internet of Things

Course held by Prof. Mora Niccolò

E-mail reference professor: niccolo.mora@unipr.it

Duration: Sept-Dec

Semester: 1

Short program:

Power supply and power profiling of IoT devices

Good practices in the design and manufacturing of IoT devices: analysis of specifications, components and PCB production

Signal acquisition and conditioning: the analog domain (circuits and architecture review)

The digital domain: filtering, signal enhancement, data exploration and analysis

Review of main communication and cloud infrastructure for IoT sensors applications

Title: ICT for Health and Wellbeing

Course held by Prof. Paolo Ciampolini

E-mail reference professor: paolo.ciampolini@unipr.it

Duration: 48 h (recommended part: 24 h)

Semester: I

Short program:

Introduction and motivation (2 h)
Telemedicine, e-health and m-health (2h)
Biosignals: classification and main features (4h)
Signal acquisition: sensors and acquisition architectures (2h)
Activity and behavioral monitoring (2h)
Data analytics: classification, statistical techniques, machine learning techniques (4 h)
Data protection and interoperability: concepts and main standards.(2h)
Healthcare systems organization (2h)
Topical seminars (research, industry). (4h)
Laboratory: teamwork, aimed at multidisciplinary, user-centered design in health and Active and Healthy Ageing use-cases (supported by IBM Research). (24 h)

(Ph.D. Students may also decide to attend the laboratory part only [boldface], jointly managed by UNIPR and IBM Research, if interested)

Title: Methods of Probabilistic Robotics

Course held by Prof. Dario Lodi Rizzini

E-mail reference professor: dario.lodirizzini@unipr.it

Duration: 12 h

Semester: Second (March-June)

Short program:

The goal of this course is to provide an overview of the the concepts of probabilistic robotics and of the main localization and mapping methods. Practical demonstrations with software tools used by research community will support the exposition. The main program is organized as follows: definitions and estimation methods, localization and mapping problems, data association, and sensor registration.

1. Representation of Uncertainty [2 h]
- Motivation and examples
- Probability density functions, function of random variables, normal distribution
- Propagation of uncertainty
2. Bayesian filters [4 h]
- State estimation for localization and mapping
- ML and MAP criteria
- Parametric filters: Kalman filters, EKF, UKF (hints)
- Derivation of KF
- EKF for localization and SLAM
3. Graphical models [4 h + 2h]
- Full SLAM problem: derivation
- Least-square SLAM
- Models for graphical formulation: landmark-based, pose graph, perturbation operator
- Practical: graphical SLAM backend g2o
4. Localization and Mapping Issues [2 h + 2 h]
- Map models: landmarks, occupancy grid maps
- Data association methods: NN, JCBB, correspondence graphs
- Practical: data association

Title: Applied Security

Course held by Prof. Luca Veltri

E-mail reference professor: luca.veltri@unipr.it

Duration: 20h

Semester: Second

Short program:

This is a laboratory course that has the objective of providing practical knowledge on the use of security algorithms and protocols for protecting data and communications.

The course is formed by a series of laboratory activities and assignments, consists in both programming and security tool exercises, that will allow the student to learn and improve his/her knowledge on how to use standard security mechanisms.

The following topics will be considered: symmetric cryptography (stream and block ciphers); secure hash functions; password hashing and message authentication code; brute force attacks, asymmetric cryptography (public-key encryption and digital signature); digital certificates; protection of network communications through TLS and VPNs; vulnerability scanning; firewalls.

For the programming exercises, Java with its standard security library will be used as reference programming language; however other languages like C/C++, Python, Go, etc, can be used by the students for their exercises and assignments.

Basic knowledge of cryptography and communication protocols (TCP/IP) is required.

Title: Digital Design of Embedded Systems in the IoT Era

Course held by Prof. Davide Zoni
E-mail reference professor: davide.zoni@polimi.it
Duration: 24 hours – once per week.
Time frame December 2019 – January 2020 organized in 5 or 6 classes
Semester: First semester

Short program:
Course abstract and goals: We are active members of the Internet-of-Things (IoT) revolution, and we are living in a tightly cooperative world where each interconnected device is constantly sensing and processing multiple data streams. As part of such revolution, novel applications emerged to support a broad variety of target domains, e.g., robotics, virtual reality, autonomous driving, thus delivering scenarios that were seen as futuristic even only a decade ago. Regardless each specific task, the commonalities of such applications are a high-bandwidth interface for data acquisition and a near real-time Hw/Sw processing platform thus imposing a two-fold change in the design for IoT.

First, the ultra low power requirements of IoT gadgets impose the adoption of a true hardwaresoftware co-design approach where the software engineer is required to increase his/her understanding of the architectural and microarchitectural details of the computing platforms. At the very extreme end of the stick, the separation between hardware and software engineers is vanishing, thus imposing to each computer science engineer to understand both hardware and software. We note that a software architecture can require to implement part of the computation in hardware to meet the performance and/or the energy requirements.
Second, IoT devices employing traditional 16/32-bit microcontrollers can not easily sustain the imposed high bandwidth and performance requirements due to their fixed architecture. We note that such devices were initially meant to manage simple computing tasks without critical performance constrains while offering a wide connectivity in terms of sensors and actuators to the real world. However, such connectivity was limited to low-bandwidth signals, thus their adoption in the IoT is a stretch. To this extent we are witnessing to the spurring of a fresh view on the design methodologies for the embedded platforms employed in the IoT domain.
The price drop and the increase in logic gates density per chip make current FPGAs products good candidates to host such innovative embedded platforms also enabling a solid substrate to assess novel hardware-software design methodologies. In particular, FPGA architectures easily support parallel computation and data acquisition and permit to tailor the design to the specific task at hand. This latter fact allows to dramatically increase their energy efficiency that, otherwise, in general would be easily overcame by ASIC-based microcontrollers.
We note that, the use of high level synthesis methodologies to develop ad-hoc accelerators is not sufficient to deliver competitive IoT platforms, since software architects are also expecting a certain degree of software programmability for the nodes. Moreover, high level synthesis methodologies are conceived for fast prototyping, without ensuring low power or high performance solutions compared to hand made hardware designs.

Goals: The course addresses the hardware design methodologies for embedded systems in the IoT era with emphasis on two different aspects. First, the synthesis and implementation problem of medium-complex finite-state-machine (FSM) component is addressed. Such objective is meant to cope with the gap between the teaching of traditional digital design courses and the need for a computer engineer to actually provide a working prototype of the design. Second, the problem of interfacing, i.e., sensing and actuating, the hardware design with the real world is addressed. Such objective is meant to favor the adoption of the design methodologies introduced in the course for real-life designs. During the course, the Xilinx Vivado Design Suite commercial hardware flow is employed coupled with SystemVerilog 2012 hardware description and verification language.
Examination: project assignment and oral presentation. The idea is to focus on a subset of the presented methodologies, trying to apply them in practice using existing tool flow. During the final oral presentation it will be also checked the capability of the candidate to move from the small scale examples towards a wider view of the problem and available technologies. Specific cut-off dates will be given for the discussion of the project.

Teaching approach: the course is made of standard face-to-face classes and hands-on sessions. A macro topic is introduced for each day of the course. In the morning, the theoretical aspects and useful tools for the analysis are discussed (3 hours) while the hands-on session in the afternoon (2 hours) is meant to foster the student to apply the presented theory to an assigned task. The final project, that is required to complete the course, has the goal to consolidate several of the presented analysis and design methodologies to realize embedded systems in the IoT era.

Profile of the lecturer
Davide Zoni, Ph.D., is Post-doc Researcher at the Politecnico di Milano, Italy. His research is focused on low power design of embedded systems ranging from single to multi-core architectures. A specific research emphasis is on the on-chip interconnect and the cache hierarchy for single and multi-cores as well as the power-related side-channel hardware analysis and design of the related countermeasures. He authored more that 40 papers in peer-reviewed, international journals and conferences and received 2 HiPEAC collaboration grants in 2013 and 2014 and 2 HiPEAC industrial collaboration grants to visit ARM LTD in 2015 and 2017, respectively. He also participated 4 EU projects (CONTREX, MANGO, HARPA and RECIPE) between 2013 and 2018 in the role of either work-package and task leader. He is the principal investigator of the Lightweight Application-specific Modular Processor (LAMP) platform, that introduces a complete and openhardware
FPGA-based design framework to investigate fully synthesizable embedded platforms.
The LAMP-platform is flexible enough to integrate High Level Synthesis (HLS) hardware accelerators and RISC CPUs. All in all it comes with its own in-order RISC-V CPU. The complete system is synthesizable and tailored to the Xilinx Artix 7 FPGA family while it can be easily ported to any FPGA chip.

Title: Edge Computing & Microservices for the Next Generation of Internet of Things Architectures

Course held by Prof. Marco Picone

E-mail reference professor: marco.picone@unipr.it

Duration: 16h

Semester: First (November - December)

Short program:

1. [2h] - Internet of Things Overview and (Re)View
   - Introduction
   - Internet of Things Definition & Vision
   - From WSN and M2M to IoT
   - IoT Characteristics
   - IoT Protocol Stack
   - IoT Applications
2. [2h] - Do not reinvent the wheel ... Design and Make it Standard !
   - Pub/Sub
   - RESTful

- CoAP
- MQTT

3. [2h] - IoT Heterogeneity, Interoperability and Web of Things
    - Service and Resource Discovery
    - Protocol Translation and Standardization Solutions
    - Web of Things
    - Digital Twin
    - People & Things Challenges and Opportunity
4. [2h] - Edge/Fog Computing: A new Architectural approach for the IoT
    - Edge Computing principles
    - IoT & Edge Computing
    - Cloud, Edge and Hybrid Architectures
    - The IoT Hub
5. [2h] - Monolithic vs Microservice oriented Architectures for the IoT
    - Microservices and Service Mesh
    - IoT and Microservices
    - Microservices composition and orchestration in Distributed Environments
6. [2h] - Make it real ! Tools, Projects and Resources to join the IoT Community
    - Hardware Platform & Operating System
    - Software Libraries
    - IoT Eclipse Foundation Projects
    - Open Source Projects
7. [4h] Projects & Evaluation

Title: Subspace-based identification methods

Course held by Prof. Luca Consolini

E-mail reference professor: luca.consolini@unipr.it

Duration: 12 hours

Semester: second

Short program:

1) Singular value decomposition.

2) Elements of realization theory.

3) Elements of model reduction.

4) Identification of deterministic systems.

5) Identification of systems affected by noise.