SKILLS MATRIX

IN THE FIELD OF

COMPUTERS, COGNITION AND COMMUNICATION IN CONTROL (CO4)

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TOPIC 1 : EMBEDDED COMPUTERS	
1.1	Basic computer knowledge
1.2	Embedded systems
1.3	Hardware programming

		LEVEL				
	1.1 BASIC COMPUTER KNOWLEDGE	**A**	**B**	**C**	**D**	**E**
SKILLS	● Implement program solution in one of the programming languages			x		
	● Convert a pseudocode or an algorithm into the program code			x	x	
	● Advanced use of programming tools			x	x	
KNOWLEDGE	● Know the functioning and role of the basic components of a computer system		x			
	● Apply program development life cycle	x				
	● Understand and use advanced principles of modern programming languages		x	x		
	● Identify basic data structures and classify computational performance	x	x			

Example of content:

1. Introduction
2. Main components of the general-purpose computer systems
    a. Hardware: processor, memory, input/output devices
    b. System software: operating systems, scheduling, synchronization
    c. Computer networks: components, protocols, services
    d. Advanced computer architectures
3. Computer programming
    a. Program development life cycle
    b. General strategies for solving problems with the computers
    c. Debugging, testing and validation
    d. Programming tools
4. Basics of data structures and computational performance
    a. Static and dynamic data structures
    b. Time and space complexity

	1.2 EMBEDDED SYSTEMS	LEVEL A	B	C	D	E
SKILLS	• Implement a (distributed) embedded platform		x	x	x	
	• Interfacing with the physical environment		x	x		
	• Programming of an embedded application		x	x		
KNOW LEDGE	• Interpret the real-time constraints of embedded application		x	x		
	• Consider the particularities of programming of embedded systems		x	x	x	
	• Analyze the dependability, safety and security of embedded systems	x	x	x		
	• Understand concepts of advanced solutions (ubiquitous, IoT, cyber-physical...)	x	x	x		

Example of content:

1. Introduction
2. Architecture of embedded systems
    a. Microprocessors and systems
    b. Advanced architectures
3. Real-time concepts
    a. Soft and hard real-time and temporal predictability
    b. Multitasking under time constrains
    c. Time-triggered communication
4. Safety, security and dependability of embedded systems
    a. Risk assessment
    b. Fault management: avoidance, detection, tolerance
    c. Functional safety
    d. Security of networked embedded systems
5. Ubiquitous and Cyber-Physical systems
    a. Internet of things
    b. Edge computing
    c. Industry 4.0
    d. Cobots
6. Programming of embedded systems
    a. Particularities of programming of embedded systems
    b. Exceptions and interrupt handling
    c. Programming of distributed embedded systems

	1.3 HARDWARE PROGRAMMING	LEVEL A	B	C	D	E
SKILLS	• Use one of the hardware programming languages			x		
	• Implement typical parallel algorithm in hardware		x	x		
	• Analyze and prepare sequential algorithm for parallelization in hardware			x	x	
KNOW LEDGE	• Different techniques for hardware implementation of algorithms			x		
	• Advantages and limitations of parallel algorithms for hardware implementation		x	x		
	• Typical parallel algorithms for hardware implementation			x		

Example of content:

1. Introduction
2. Hardware implementation of algorithms
    a. Combinatorial and sequential logic
    b. Data flow computing
    c. Systolic arrays
    d. State machines
    e. Fixed-point arithmetic
3. Programable devices
    a. PLA
    b. FPGA
    c. ASIC
    d. PSoC
4. Programming languages for hardware programming
    a. Verilog
    b. VHDL
    c. Schematic
5. Conventional parallel algorithms
    a. Parallel map and reduce
    b. Parallel matrix multiplication
    c. Signal processing
    d. Bitonic sort

TOPIC 2 : COGNITION and MACHINE LEARNING	
2.1	Machine learning
2.2	Human-Machine System

	2.1 MACHINE LEARNING	LEVEL A	B	C	D	E
SKILLS	• Understand key concepts in machine learning: data; algorithm; paradigm: supervised, unsupervised, or reinforcement learning	X				
	• Represent a given problem in the right paradigm and choose a set of candidate algorithms to apply		X	X		
			X	X		
	• Configure existing frameworks for machine learning and apply them to standard problems			X	X	
	• Adapt and extend existing frameworks to apply them to nonstandard problems					
KNOWLEDGE	• Supervised learning problems and algorithms	X	X	X		
	• Unsupervised learning problems and algorithms		X	X		
	• Reinforcement learning problems and algorithms			X	X	
	• Deep learning algorithms			X	X	
	• Complexity of algorithms			X	X	

Example of content:

1. Introduction to Machine Learning
2. Supervised learning:
    a. Types of supervised learning: regression, classification, and forecasting
    b. multi-layer perceptrons, radial base function networks
    c. supervised training and adaptation
3. Unsupervised learning:
    a. data clustering
    b. unsupervised training methods, based on Hebbian rules and on competition;
4. Reinforcement learning
    a. basics of dynamic programming for optimal control
    b. Q-learning and actor-critic
    c. applications to control
5. Deep learning:
    a. deep belief and convolutional networks

b. application to deep Q-learning

	2.2 HUMAN MACHINE SYSTEMS	LEVEL A	B	C	D	E
SKILLS	• Know and use human Operator models: structural (sensor-motor, sensor-actuators, properties and limits), functional (cognitive activities and problem solving); human activity regulation model.	X				
	• Know some principles related to ergonomics, principles, methods and criteria.	X				
	• Master the concepts of human reliability, human error, and some methods of human-machine system evaluation.	X				
	• Analyze an automation problem involving one or more human operators		X			
	• Integrate from the design stage a human-centred approach taking into account the characteristics of users (operator capacities, pmr...).		X	X		
	• Propose a control architecture and a level of automation by defining the distribution of tasks, authority and information between operators and automatic systems.			X	X	
	• Develop and evaluate monitoring, diagnostic and problem-solving tools for operators, as well as support (multimodal or not) for the activity allowing interaction or cooperation with operators.			X	X	
KNOWLEDGE	• Human Operator models	X				
	• Human reliability and human factors concepts		X			
	• Level of automation		X	X		
	• Human-Machine cooperation methodology			X	X	

Example of content:

- Human Operator models, structural (sensor-motor, sensor-actuators, properties and limits) functional (cognitive activities and problem solving) human activity regulation model, prioritization of activities according to time constraints
- Ergonomics, principles and methods: ergonomic criteria related to HMI and activity (Workload, Situation Awareness) and evaluation methods
- Definition of the concepts of human reliability and human error, human factors and accidents
- Human-centred design approach
- Level of automation, Authority and responsibility
- Impact of support systems on activity
- Human-machine cooperation, assistance, dynamic distribution and delegation of tasks for control and supervision systems like ATM
- Support for cooperative activities for ADAS: HMI, common work space, System transparency
- Practical work in the form of a project: implementation of an advanced assistance tool for the supervision of a manufacturing system

TOPIC 3 : COMMUNICATIONS	
3.1	Communication Technologies
3.2	Industrial Communications

	3.1 COMMUNICATION TECHNOLOGIES	LEVEL A	B	C	D	E
SKILLS	• Understand the basics in communication systems and their application in control and automation systems.	X	X			
	• Evaluate and analyze communication network architectures suitable for the automation domain.			X		
	• Apply communication protocols in automation applications.			X		
KNOW LEDGE	• Fundamentals on communication technologies	X				
	• Communication networks/Reference models	X	X			
	• Basic communication protocols			X		
	• Internet protocols			X		

Example of content:

- Communication basics:
  - Analog and digital transmission
  - Topologies
  - Transmission media
  - Wired and wireless technologies
  - Signal encoding techniques
  - Asynchronous and synchronous transmission
  - Communication devices
- Data Communications, networking and communication paradigms.
- OSI Reference Model vs. TCP/IP Protocol Architecture.
- Ethernet basics.
- Wireless communications.
- TCP/UDP Protocols, IP Stack.
- Internet Application Protocols.
- Service Oriented Applications.

	3.2 INDUSTRIAL COMMUNICATIONS	LEVEL A	B	C	D	E
SKILLS	• Analyze the networking issues of automation systems.			X		
	• Select and apply the appropriate industrial communication protocols in automation applications.		X	X		
	• Design and implement distributed automation systems.			X		
	• Keep up-to-date in communication technologies evolution.		X	X		
KNOWLEDGE	• Temporal features for industrial systems		X			
	• Hierarchical architecture in industrial communications	X				
	• Standard industrial protocols: Fieldbuses		X	X	X	
	• Ethernet based industrial communications		X	X	X	
	• Information and Communication Technologies (ICT) for Industrial Communications		X	X		
	• Middleware for industrial communications		X	X		

Example of content:

- Basics in industrial communications
  - Hierarchical models
  - Real-time techniques in industrial communications
- Fieldbuses
  - Architecture and features
  - Standard fieldbuses: Modbus Serial, Profibus, CAN, DeviceNet, etc.
- Industrial Ethernet
  - IP based industrial communications
  - Industrial Ethernet fieldbuses: Modbus TCP, Profinet, Ethernet/IP, etc.
  - Real-time in Industrial Ethernet communications
- Safety in industrial communications
- Industrial distributed systems
  - Middleware for industrial communications
  - OPC: Classic OPC and OPC UA
  - Web Services for industrial communications
  - Industrial IoT Protocols
  - Cybersecurity techniques applied to industrial communications

TOPIC 4 : AUTOMATIC CONTROL	
4.1	Modelling
4.2	Control design
4.3	Diagnosis and Observer

	4.1 MODELING	LEVEL A	B	C	D	E
SKILLS	• Understand the fundamentals of the mathematical models and their applications in systems design, control and simulation	X				
	• Use the most convenient methods to obtain the required models		X	X		
	• Use symbolic and numerical software packages (Matlab, Simulink,…)		X	X		
KNOWLEDGE	• Identification of linear models	X				
	• Identification of LPV models		X			
	• Identification of nonlinear models			X		
	• Validation of models and design of experiments	X	X	X		

Example of content:

- Introduction
  - General concepts
  - Black/grey/white box identification
- Recall of the classical tools for linear system and linear parameter estimations
- Nonlinear parametric estimation (different methodology, how to use them with…)

	4.2 CONTROL DESIGN	LEVEL A	B	C	D	E
SKILLS	• Formulate a control problem according to the chosen specifications		X	X		
	• Analyze the stability of a non-linear system on simple cases			X		
	• Apply methods of analysis and control of systems with non-linear behaviour			X	X	
KNOW LEDGE	• Basic control of linear systems	X	X			
	• Robust linear control		X			
	• Stability and stabilization of non-linear systems			X		
	• Fuzzy Takagi-Sugeno's case			X	X	

Example of content:

- Important recall about control of linear systems
  - Continuous/discrete,
  - Transfer function, state space, etc…
- Consideration of model uncertainties: robust control
  - Illustration, sensitivity functions,
  - Hinf. criterion, th. of small gain,
  - Synthesis of control laws by LMI)
- Control of non-linear systems
  - Theory of stability of non-linear systems (Lyapunov, Linearisation,…)
  - Fuzzy Takagi-Sugeno systems (definition, LMI approach to control)

	4.3 DIAGNOSIS AND OBSERVER	LEVEL A	B	C	D	E
SKILLS	• Understand the fundamentals of fault detection and isolation		X			
	• Use the linear techniques for the design of observers and fault diagnosis,		X	X		
	• Use symbolic and numerical software packages (Matlab, Simulink,…) to implement diagnosis schemes,		X	X	X	
	• Extension to the diagnosis of some nonlinear systems (Lyapunov, Linearisation, quasi-LPV/Takagi-Sugeno systems...)			X		
KNOWLEDGE	• Modelling systems with faults	X				
	• Model-based fault monitoring approaches		X			
	• Residual generation			X		
	• Residual evaluation and threshold selection	X	X	X		

Example of content:

- Introduction: Context of the diagnosis
  - Diagnosis: What? Why? How? monitoring and supervision,
  - Remote operation, remote diagnosis,
  - Diagnosis and quality, Diagnosis and maintenance policy,
- Modelling system with faults
  - Description of system with disturbances
  - Description of systems with parametric uncertainties
  - Description of systems with sensor, actuator and process faults
  - Modelling faults in closed-loop systems
  - Fault detectability & isolability
- Methods and tools for residual generation
  - Observer-based techniques for residual generation,
  - Decoupling techniques (unknown input observers, ...),
  - Parity space approach for residual generation,
  - Introduction to fault isolation schemes,
- Statistical methods for residual evaluation and threshold selection
  - Basic statistical methods (hypothesis test, likelihood Ratio, ...),
  - Criteria for threshold computation (Neyman-Pearson, Bayes, …).

TOPIC 5 : AUTOMATION SYSTEMS	
5.1	Automation System Analysis & Design
5.2	Supervision and Monitoring
5.3	Digital Transformation Technologies

	5.1 AUTOMATION SYSTEM ANALYSIS & DESIGN	LEVEL A	B	C	D	E
SKILLS	• Identify the requirements the automation must meet.		X	X		
	• Use methodologies and standards to design automation systems.		X	X		
	• Use programming standards and I/O devices to implement the system.			X		
	• Validate the automation systems against requirements.			X		
	• Integrate analysis, design and implementation methods along the development cycle			X	X	
	• Apply development techniques to achieve reusability by means of modularity			X	X	
KNOWLEDGE	• Classify industrial processes.	X				
	• Classify different automation problems and understand the corresponding automation technology.	X	X	X		
	• Understand design methods and standards for automation systems.	X				
	• Understand programming standards for automation systems.	X	X			
	• Understand the different types of sensors and actuators.					

Example of content:

- Introduction:
  - Context. Locate the subject within the automation pyramid
  - Why automation is needed?
  - Examples of processes: continuous, batch, discrete
  - Types of automation devices: CNC, DCS, PLC based, etc.

- Methodologies and standards:
  - Design and development phases: Requirement Analysis, Analysis, Design, Coding, commissioning
  - Related standards: GEMMA, GRAFCET, IEC 61131-3
- Programming using IEC61131-3:
  - Software model
  - Combinational Logic (Timers, Counters, etc.)
  - Sequential systems
  - Data Variables
  - Execution control
  - Programming blocks
  - Input/output
- Case studies.

		LEVEL				
	5.2 SUPERVISION AND MONITORING	**A**	**B**	**C**	**D**	**E**
SKILLS	● Identify the monitoring and supervision requirements		X	X		
	● Evaluate and select the appropriated technologies to be applied		X	X		
	● Use Supervisory Control & Data Acquisition systems (SCADA) tools		X	X		
KNOW LEDGE	● Understand the base technologies involved in monitoring and supervision		X			

Example of content:

- Introduction:
  - Supervision types: centralized, distributed, information registering, long-term data storage, etc.
  - Human Machine Interface types: operator panel, PC, etc.
  - Data acquisition technologies, data bases, etc.
- Requirements analysis:
  - Identification of monitoring functional requirements (user interface, templates, process variables, etc.)
  - Selection of process variables to be acquired/manipulated

- Technology selection:
  - SCADA systems
  - Web services
  - OPC / OPC UA architectures
  - Other protocols
  - Data base
  - Tools

		LEVEL				
	5.3 DIGITAL TRANSFORMATION TECHNOLOGIES	**A**	**B**	**C**	**D**	**E**
SKILLS	● Keep up-to-date on cutting-edge IT technologies and apply them to industrial systems.			X		
	● Analyze and evaluate the right technology for the specific industrial problem.		X	X		
	● Apply industrial reference architectures to achieve factory flexibility				X	
KNOW LEDGE	● Understand current manufacturing demands: smart factory.		X	X		
	● Identify and classify enabling technologies.		X	X		
	● Understand current industrial reference architectures.		X	X		
	● Understand distributed intelligence patterns that enable advanced manufacturing systems.				X	

Example of content:

- Introduction:
  - Industrial revolutions
  - Smart factory: lines of approach
- Enabling technologies:
  - Big data in automation
  - Distributed databases
  - Vertical and horizontal integration
  - Cyber-security for industry
  - Digital Twin for Virtual Commissioning (Software in the Loop, Hardware in the Loop)

  - Virtual and augmented reality
- Industrial references architectures:
  - RAMI4.0 – Industry 4.0
  - IIRA Industrial Internet Reference Architecture
- Industrial Case Studies.