USER GUIDE

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SKILLS MATRIX

In the Field of

Computers, Cognition and Communication in control (Co4)

Reading Guidelines for Academics and Industrials

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This user guide can be read at any moment to clarify the use of the documents composing the skills matrix.

INDEX

1. OBJECTIVE

The purpose of this document is to provide a guide presenting the concept and how to use the skills matrix developed in the field of Computers, Cognition and Communication in Control (Co4) during the project "Co4AIR - Computers, Cognition and Communication in Control: A strategIc paRtnership", an Erasmus+ Key Action 203 Strategic Partnerships for Higher Education.

A key point of this project is to propose an approach that allows reducing the gaps that exist today between education, research and industry in the Co4 field. Our proposal, called "Competence Matrix", which address this issue consists in a set of documents generically named “Matrix_*name*.pdf”, “Matrix_Application_X.pdf” and “Job_Titles_Co4AIR.pdf”. The content of those documents and how to use them are described in the following.

Finally, the skill matrix has been designed to be an open-source document that can be freely used by its recipients.

1.1 WHAT IS THE SCOPE OF THE CO4 DOMAIN?

The domain covered by Co4 refers to problems of control, command or decision making in a real time environment that involves:

- ✓ hardware supports (microprocessor, microcontroller, PLC, computer, among others) to embed the algorithms
- ✓ conventional control methods but also computationally based ones which can be issued from recent research work
- ✓ consideration of communications and telematics aspects

1.2 WHY DEVELOPING A SKILLS MATRIX IN THIS FIELD?

The digital revolution, driven by artificial intelligence [1], and combined with cheaper hardware components (actuators, sensors, embedded processors, etc.) [2], leads to a generalisation of the systems controlled by computer in many domains (e.g. Transport, Robotics, Industry, Health, Building, Energy, etc.). Nowadays and in the future, with the ongoing development of increasingly affordable and efficient IT tools and hardware in the industrial context, the need for skills and competences in the Co4 domains will become more and more essential.

It must be noted that there is no reference framework specifically dedicated to this field of expertise that covers all the skills and competences required in this area. Currently, in the universities around the world, Co4 topics generally overlap between several academic domains (e.g. Automation and control, Computer science, Electrical engineering, Mechanical engineering) which moreover could be different depending on the country. As a result, this subject is never considered as a whole and in its own right, whereas the demand for staff with those qualifications exists and will continue to grow [3].

In this context, the skills matrix is intended to help develop new curricula, define job descriptions, and more, as you may read in the following.

1.3 WHO IS THE TARGET AUDIENCE?

This document is primarily aimed at academic professionals and managers in the industrial sector in the Co4 domain. To be more precise, the main target audience are the people in charge of designing teaching programs or industrial managers who define job profiles. For each of those groups, some specific reading guidelines are given based on the following questions:

- ✓ What is the content of the matrices?
- ✓ How to use the matrices?

1.4 HOW TO MIX ACADEMIC SKILLS / INDUSTRY-SECTOR TECHNICAL COMPETENCIES?

Skill expectations and their applications are not necessarily the same in the academic world and in the industrial sector. Indeed, the needs of industry are coming from the labour market (defined through job positions) whereas the objective of academia is to develop vocational education (through training programmes).

A common example is that the academic world approaches skills more from a cognitive point of view, whereas the industrial world is more interested in technical abilities of their new recruit and staff. In response to this problem, the Co4AiR project provides a common reference framework to ensure consistency. This is achieved by adopting two taxonomies:

1. For defining a specific skill, a recent modification of the Bloom’s taxonomy is adopted, which was originally developed by Benjamin Bloom in 1956 (cf. Figure 1).

   Using the given verbs from this taxonomy, skills can easily be expressed in a natural way. For example: “Understand the fundamentals of …” or “Apply the method …”.

2. For defining the required technical level of a skill in a certain topic or for specific job position, a taxonomy related to a systems engineering framework from the International Council on Systems Engineering (INCOSE) is used. Five levels are considered from "A" to "E" as:

   - ✓ A: Entry (Understands, but cannot contribute)
   - ✓ B: Intermediate (Implements under supervision)
   - ✓ C: Solid (Implements without supervision)
   - ✓ D: Advanced (Improves and implements)
   - ✓ E: Expert (Subject Matter Expert)

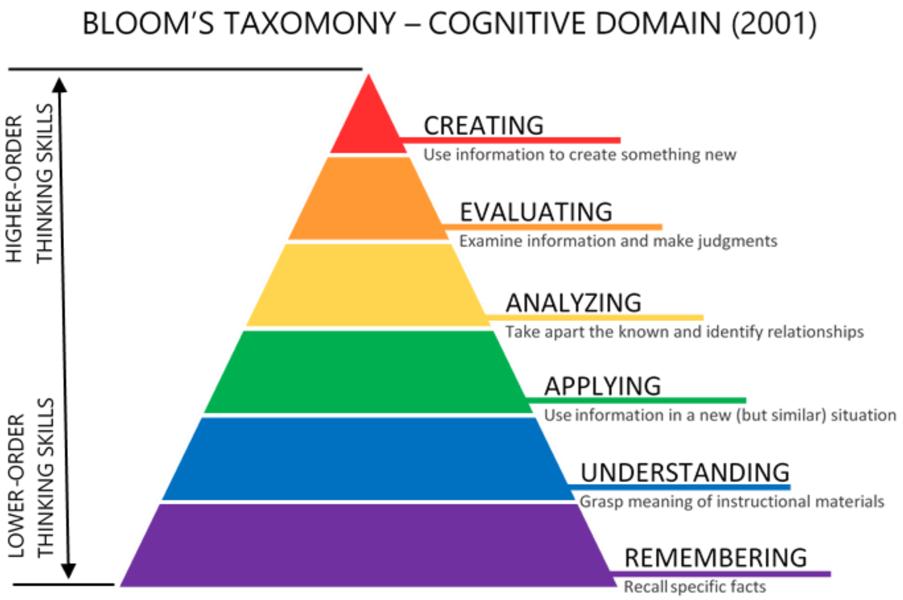

Figure 1: Bloom's Taxonomy

Both taxonomies are used for the creation of several matrices targeted for academic as well as industrial professionals. Specific matrices suited for each target group are described in more detail in the next section.

2. READING GUIDELINES FOR ACADEMIC STAFF

2.1 WHAT IS THE CONTENT OF THE MATRICES?

2.1.1 Choice of the topics

From the vast Co4 domain, five main topics have been identified which are deemed to give a relatively large coverage: Embedded Computers, Cognition and Machine Learning, Communication, Automatic Control and Automation Systems.

For each main topic, several sub-topics, summarized in Table 1, have been specified which are considered most relevant in the respective main topic.

TOPICS	EMBEDDED COMPUTERS	COGNITION and ML	COMMUNICATION	AUTOMATIC CONTROL	AUTOMATION SYSTEM
REQUIREMENTS	Basic computer knowledge	Machine learning	Communication Technologies	Modelling	Automation System Analysis & Design
	Embedded systems	Human-machine interaction	Industrial Communications	Control design	Supervision and Monitoring
	Hardware programming			Diagnosis and Observer	Production Management & Scheduling
					Digital Transformation Technologies

Table 1: Main Topics and their Sub-Topics

Note that the list of topics that was compiled by a panel of specialists in the associated fields is not exhaustive. It merely contains the essential topics. However, if required the matrices can be easily extended to other topics as well.

2.1.2 Contents of the matrices

The matrices for a main topic "*name*" are combined into single file with the naming convention "Topic x : *name*" with direct links from Index.

In such a file, the individual skills matrices for each identified sub-topic can be found. Additionally, the required knowledge related to the skills of the sub-topic is also given. As described in Section 1.4, both taxonomies were used for a matrix. The row of a matrix consists of the skills expressed according to Bloom's taxonomy or of the knowledge. The columns are the technical levels from the INCOSE taxonomy. A cross ("X") in a matrix element marks the technical level of the skill or knowledge which is required for the given topic. Multiple crosses may appear in adjacent columns in order to specify a range of technical levels.

Figure 2 and Figure 3 detail two example matrices with explanations. In the first example, given Figure 2, the direct link between the chosen taxonomies and the skills and knowledge are illustrated. In the second example, Figure 3, two concepts are pointed out. The first is the possibility of having several levels associated with the same skill or knowledge, which makes it possible to envisage the introduction of more or less complex tools for the same skill or knowledge. The second one shows how to create a link with research by introducing tools coming from research community through the use of higher levels from the taxonomies.

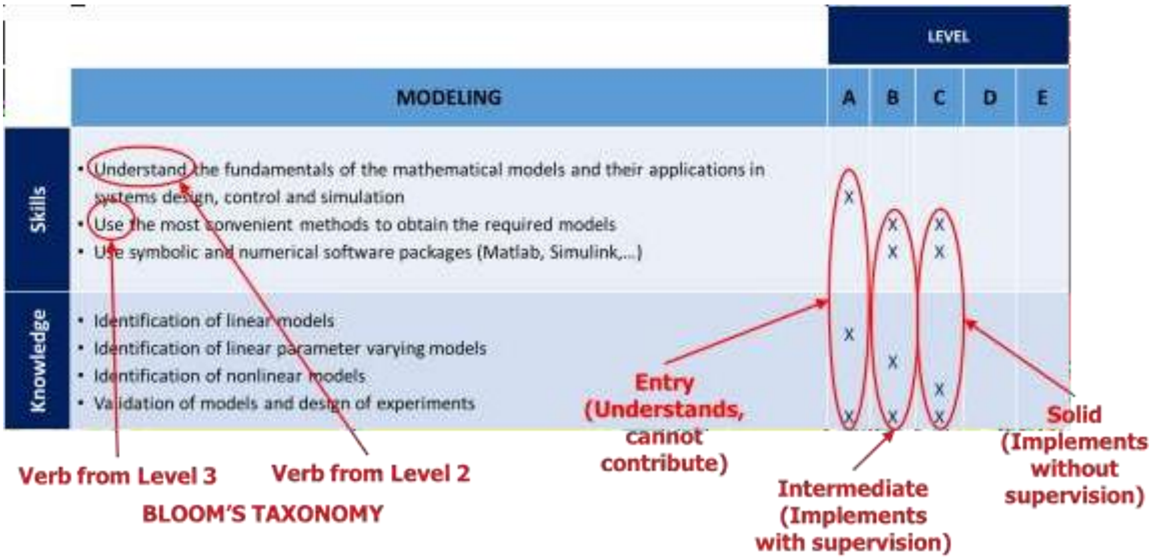

Figure 2: Skills Matrix Example 1

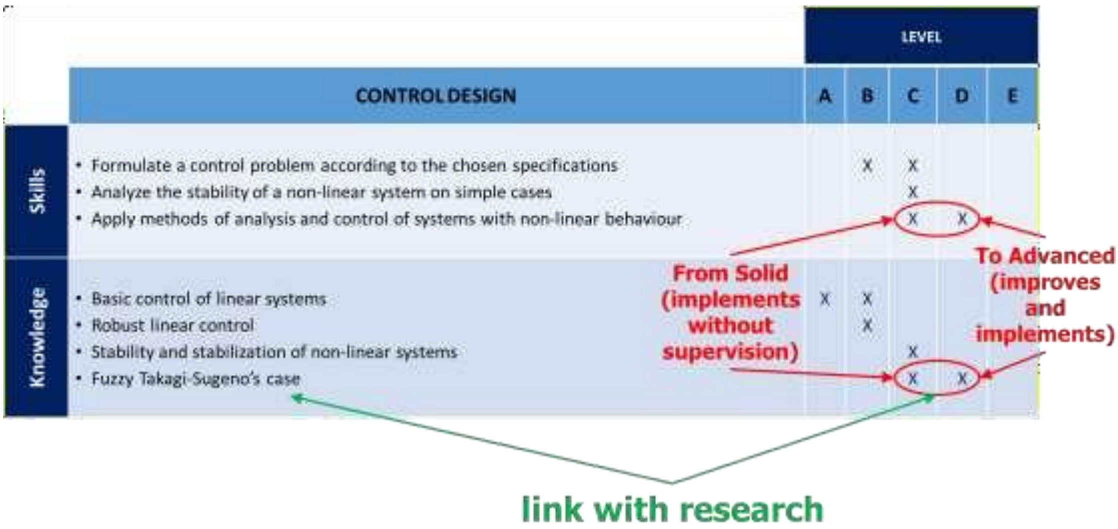

Figure 3: Skills Matrix Example 2

Below each matrix for a sub-topic, an example of content is also given (not shown in the examples). This serves as possible concretisation of several aspects from which course content can be created.

Note that the list of skills and knowledge is not exhaustive and the reader can develop her or his own and integrate it into the matrix.

2.2 WHY THIS MATRIX

The interest is that our common proposal remains open enough to adapt to the diversity of academic needs, which are a function of the countries and pedagogical practices. In the university context, the skills matrix finally obtained can be used for several purposes:

- ✓ to develop all or part of a new curricula according to the needs in terms of skills
- ✓ to serve as a skill benchmark for defining the skills to be acquired in the Co4 domain
- ✓ to introduce research-based tools into a curriculum
- ✓ to have a language understandable by the industrial sector and to facilitate skills/knowledge development

3. READINGS GUIDELINES FOR INDUSTRIAL STAFF

3.1 WHAT IS THE CONTENT OF THE MATRICES?

3.1.1 Choice of the application areas and job titles

The matrices for the industrial sector are arranged in terms of several application areas. These areas were chosen from a very large set of possibilities in which control is essential and which are currently very active areas in research. The considered application areas are: Autonomous Vehicles, Industrial Robotics, Industry 4.0, Aerial Vehicles, Mobile Robotics and Vehicle Powertrain and Dynamics.

The basic premise is that a staff member is defined above all by the skills she or he possesses and which the company needs. These skills may come from the person's education or may have been acquired through experience in various positions in the industry. Hence, the industrial needs are translated into job descriptions, which in turn describe the skills and technical competencies expected to perform a given job.

Therefore, for each selected application area, several relevant job titles were identified. The list of job titles is partially different for the application areas, but includes common job titles such as Control Engineer, Automation Engineer, Software / Embedded software Engineer, Application Engineer, Process Engineer, Systems Engineer, Systems Architect, Test and Validation Engineer and Research Engineer.

3.1.2 Contents of the matrices

Two kinds of document are proposed. In the first one, named "Matrix_Application_X.pdf" for each application area "X", a table summarizes the connection between academic sub-topic (from Section 2.1.1) and job titles through the use of the technical level letters (A to E) coming from the INCOSE system engineering framework. Thus, this matrix shows the required technical level of a specific sub-topic for a given job. An example for the application area "Autonomous Vehicles" is given in Figure 4.

			JOB TITLE				
	AUTONOMOUS VEHICLES (on ground)		Autonomous and ADAS Control Systems Engineer	Embedded Control Systems Engineer	Autonomous Driving SW Engineer	Autonomous Driving Systems Integration and Test Engineers	Autonomous Driving Research Engineer
Tech. Comp.	EMBEDDED COMPUTERS	✓ Basic computer knowledge	B	C	C/D	C	C/D
		✓ Embedded systems	B/C	D	C/D	B/C	B/C
		✓ Hardware programming	C	C/D	C	B	C
	COGNITION AND MACHINE LEARNING	✓ Machine learning	B/C	A	C	B	C/D
		✓ Human-machine interaction	C/D	A	A/B	B/C	B/C
	COMMUNICATION	✓ Communication Technologies	A	B/C	B/C	B/C	A
		✓ Industrial Communications	A	B	B/C	A	A
	AUTOMATIC CONTROL	✓ Modelling	B/C	A/B	B	A	B/C
		✓ Control design	C/D	B/C	B/C	B/C	C/D
		✓ Diagnosis and observer	C/D	B/C	A/B	A/B	B/C
	AUTOMATION SYSTEMS	✓ Automation System Analysis & Design	A	A	A	A	A
		✓ Supervision and Monitoring	A	A	A	A	A
		✓ Digital Transformation Technologies	A	A	A	A	A

From Solid (implements without supervision) to Advanced (improves and implements)

Figure 4: Job Titles and Sub-Topics

In the second document "Job_Titles_Co4AIR.pdf", the selected job titles are roughly described from a general context and then the specific skills and qualifications for each are presented in a more conventional manner.

Finally, the whole proposal allows connecting skills/competences of industrial applications with potential job titles and required entry level.

3.2 HOW TO USE IT?

Based on the previous description, in the industrial context, the proposed solution can be used:

- As a skill benchmark, matching and comparing abilities, job positions and required competence level
- As a baseline to define the skills to be acquired in a proposed field
- As a tool to assess the skills/competences of employees along their career

4. CONCLUSION

This user guide has described the key concept of the skills matrix as well as the associated documents and the way to consider and use them.

5. GLOSSARY

Skills

Skills are the specific learned abilities that you need to perform well a given task or a set of tasks which could correspond to a job profile.

Hard skill

A hard skill is a technical and quantifiable skill that a professional may demonstrate through their specific qualifications and professional experiences.

Soft skill

A soft skill is a non-technical skill that is less rooted in specific vocations.

Competencies

Competencies are the person’s knowledge and behaviours that lead them to be successful in a performing some tasks.

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