Analysis of the Workforce Skills for the Factories of the Future

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***Abstract*—Industry 4.0 is promoting the digitisation of manufacturing sector towards smart and more efficient factories, seen worldwide as the fourth industrial revolution. However, its complete adoption strongly depends on the skills that existing workforce and future professionals can have in the different dimensions of this multidisciplinary vision, contributing to increase the digital maturity level of companies from the industrial sector. Additionally, new job profiles are emerging to face the implementation of these innovative approaches, which implies the need for the re-qualification and up-skilling of existing workforce, particularly focusing the digital skills. In this context, this paper analyses the gap and impact in the non-technical and technical skills required for the successful transition into digitisation, particularly across six manufacturing areas covering the collaborative robotics (cobots), additive manufacturing, mechatronics and machine automation, data analytics, cybersecurity and human-machine interface.**

***Keywords*: Industry 4.0, Digitisation, Re-qualification, Soft Skills, Technical Skills.**

I. Introduction

Industry 4.0 [1], seen worldwide as the fourth industrial revolution, is promoting the digitisation of manufacturing sector towards smart products, machines, processes and factories. This revolution is associated to the implementation of Cyber-Physical Systems (CPS), complemented with the use of several disruptive technologies, namely Internet-of-Things (IoT), Big data, Cloud Computing, Artificial Intelligence (AI), virtual and augmented reality, collaborative robotics and additive manufacturing technologies [2].

The adoption of these disruptive technologies is re-shaping the manufacturing environment and will change the processes, skills and job profiles required for executing the work [3]. In fact, according to the PwC report [4], the introduction of Industry 4.0 into the manufacturing sector will change the level of digitisation of industrial companies around the world, which will increase from 33% in 2015 to 72% in 2020. The increase of the digitisation level in companies will be translated into the introduction of more advanced technologies creating the need for more skilled workers and new job positions. The McKinsey consulting company [5] reinforces this idea by stating that Industry 4.0 will be responsible for changing 8-9% of the 2030 labour demand, requiring new types of occupations that did not existed before.

In this context, the success of implementing Industry 4.0 strongly depends on the skills and competences that the workforce can have in the different dimensions of the new vision, particularly in the enabling technologies. In particular, it is expected that the introduction of Industry 4.0 will lead to the decrease in low-skilled activities and an increase on high-skill activities, being expected to grow the complexity and number of new job profiles [6]. In fact, many jobs that are now crucial to implement this vision, such as Big Data Analyst and Cloud Services Specialist, did not exist 10 years ago [7]. Additionally, the Data Scientist job, classified by the Harvard Business Review [8] as the sexiest job of the 21th century, involves a multi-disciplinary knowledge of scientific methods, processes, algorithms, systems and businesses.

Aiming to face this challenge, a re-qualification and up-skilling of existing workforce is crucial for the companies to be immersed in the digital transformation, being crucial to identify the technical and non-technical skills that will be relevant in this digital transformation and derive the needs for training programs that will empower the re-qualification of active people (workers) in a lifelong perspective, as well as regular students during their educational programs. Note that according to [9], 73% of CEOs cite skills shortages as a threat to their business and 81% say they are looking for a wider mix of skills when hiring.

Having this in mind, the objective of this paper is to analyse the gaps, i.e. deficiencies and shortcomings, in technical and non-technical skills, knowledge and competences that the current workforce has in dealing with the introduction of digitisation, automation and emergent technologies in their industry sectors. For this purpose, the analysis of the collected feedback from a conducted survey allows to derive the identification of the skills' gaps, as well as the relevance and impact of these skills, with different granularity, namely in terms of industrial sectors. In this work, the analysis considered the collaborative robotics (cobots) (CR), additive manufacturing (AM), mechatronics/machine automation (MMA), human-machine interface (HMI), data analytics (DA) and cybersecurity (SC) industry areas.

The rest of the paper is organized as follows. Section II describes the methodology to perform the skills gap analysis, particularly the implementation of a survey that collects the feedback from experts in the area. Section III analyses the gap

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and impact in the soft skills and Section IV presents the gap and impact in the technical skills related to the six analysed industrial sectors. Finally, Section V rounds up the paper with the conclusions and points out the future work.

II. Methodology for the Skills Gap Analysis

A skill can be defined as the capability that is needed to do something well [10]. Companies need to perform activities/tasks regarding their business plan and skills define the ability to do them. Under the scope of the EU H2020 FIT4FoF project (https://www.fit4fof.eu/), one important effort is related to the identification of new skills requirements for the factories of the future (FoF), in particular across six industrial areas, namely, CR, AM, MMA, DA, CS and HMI.

A. Overall Methodology

As previously referred, the objective of this work is to identify the gaps and impact of future skills, particularly answering to the following questions: i) what kind of skills matter to employers, ii) what are the existing gaps between employer's needs and employees skills, and iii) what is the impact of each identified skill (i.e. if it affects many employees).

For this purpose, the adopted methodology, illustrated in Figure 1, comprises two distinct phases. The first phase is related to the identification of the skills gaps and impact thorough the use of an online questionnaire. For this purpose, the data collected from the respondents to the questionnaire was analysed using proper statistical techniques and more advanced data analytics techniques to characterize both the "as is" situation and the "to be situation". The performed analysis will also allow to cluster the skills by industrial sector and to present the skills ranked by gap and impact level. The output of the performed analysis was exposed to the experts and project partners, in particular to the training pilots, in order to consider their expertise feedback.

The second phase is related to the extraction of relevant skills from analysing both scientific papers and recruitment repositories by using advanced data analytics techniques. The output of this phase will be a list of relevant new skills derived from papers and recruitment repositories, which will be merged with the list of skills extracted from the first phase.

Both phases will be performed using an iterative approach, since the selection of the most relevant skills must be validated not only by the performed data analysis but also taking into account the expertise of all project partners.

B. Online Questionnaire Survey

The skills' gap and impact analysis described in this paper is centred in the first phase of the described methodology and is focused in the online questionnaire survey (see the top row of Figure 1), leveraged by the project partners and their existing networks. The survey includes an "as-is" characterization of the current skills and the "to-be in a short to medium term" characterization of the needed skills in the context of the FoF, as well as a characterization of the impact of each skill (i.e., if it will be needed by a large amount of people).

This questionnaire comprises 3 parts, namely the general information about the respondents (their education background, role and technical sector inside the company), soft and hard skills for FoF, and training programs to obtain the skills. This last part is important to support the design of actions aiming to overcome the lack of skills by FoF workers, e.g., which training typology will be more suitable to obtain the missing skills.

The development of the questionnaire was performed based on the guidelines proposed in [10], and considering some other works, namely [11], [12], [13], [14]. The classification levels used along the questions follows the 5-level Likert scale [15] (from "zero" 0 to "five" 5), where 0 is "Not Applied", 1 is "very weak", ..., and 5 is "very strong". The free open source LimeSurvey platform was chosen to deploy the questionnaire, due to its characteristics and compatibility with the survey structure. After the validation of the deployed questionnaire, this was disseminated through different channels, namely the project web page, social media as well as the partners' network connections.

C. Characterization of the Sample

The performed questionnaire focused on gathering the views of different stakeholders in regards to the workforce changes afoot in today's companies. In total, the collected data set contains 73 submitted responses by companies from a wide range of industry sectors. Additionally, the data set may be considered a diversified sample counting with 59% of the responses from large enterprises, 12% of medium enterprises, 22% of small enterprises, and the remaining 7% from companies with fewer then 10 employees. According to the surveyed companies, and considering the six technological areas that are included in the FIT4FoF project, the technologies by proportion of companies are illustrated in Figure 2.

One can notice that across the surveyed industries, DA, MMA, and CR were referred as technological areas adopted by 63%, 53%, 51%, respectively. Also 48% of the companies are adopting HMI technology and, in contrast, only 26% of the companies refer the adoption of AM and CS. In the following sections, a descriptive analysis with an emphasis on the skills gaps and impact for both soft and hard skills will be presented and described.

III. Analysis of Soft Skills

The term "soft skills" can be defined as *"desirable qualities for certain forms of employment that do not depend on acquired knowledge: they include common sense, the ability to deal with people, and a positive flexible attitude"* (see the Collins English Dictionary at www.collinsdictionary.com).

In this work, the gap for a specific skill was calculated by considering the difference of scores (Likert scale) between the "future relevance" and the "present level". For example, if a skill has a "present level" classification score of "3" and a "future relevance" classification score of "5", it will lead to an existing gap of size "2", which means that the respondent consider that in the future it will be necessary to improve that

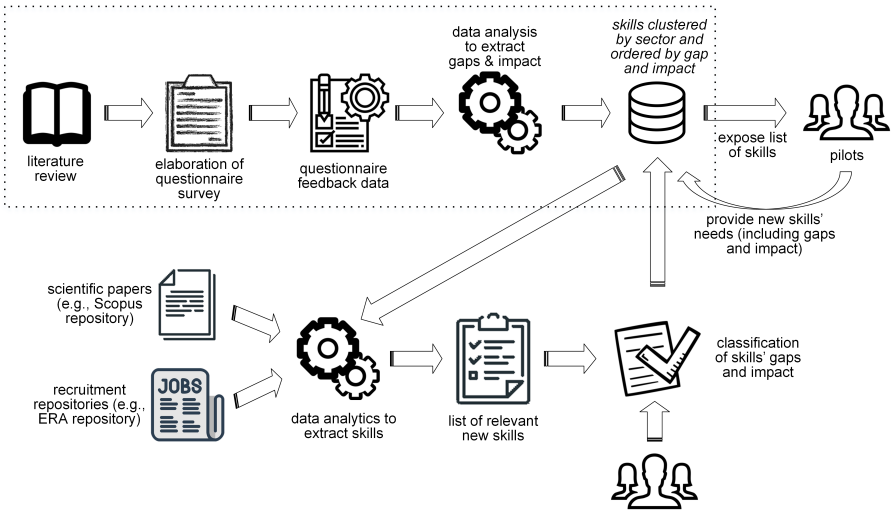

Figure 1: Methodology for the Analysis of the Skills Gap and Impact.

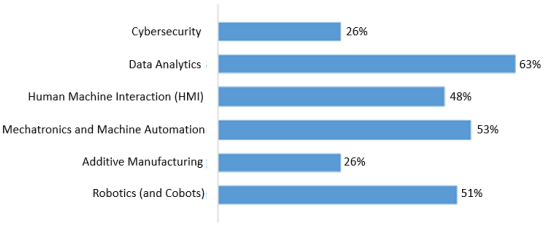

Figure 2: Technological areas by proportion of companies.

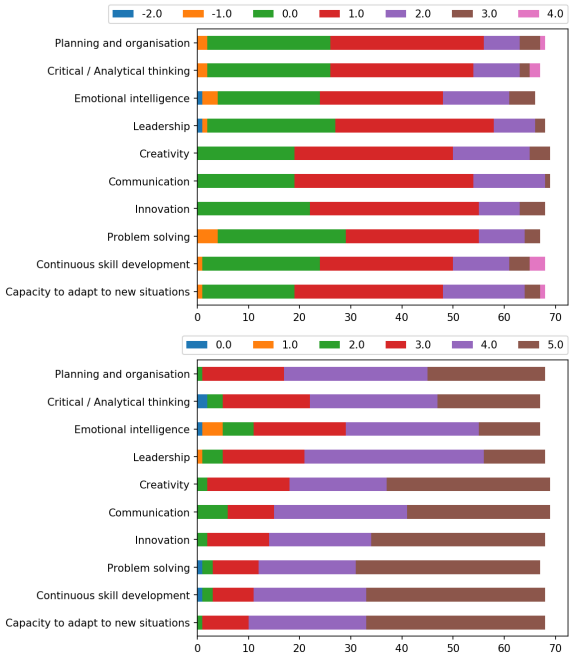

Figure 3: Gap (top) and impact (down) in soft skills.

specific skill. Summarizing, a positive gap value means that in the future the skill will be more relevant, and a negative gap value means that the skill will lose relevance in the future.

Figure 3 summarizes the frequencies for the gaps and impact of the 10 most relevant surveyed soft skills. The first observation is that the "Integrity/Ethics" skill does not appear in the 10 most relevant skills, which means that is seen as a relevant skill at the moment without any gap for the future. On the other hand, the listed skills have a median gap of "1", which means that respondents consider that in the future it will be necessary to empower these skills. On the other hand, the median for the impact has a range from "4" to "5", which denotes that these skills have a strong impact in a large amount of workforce in the future.

Analysing deeper the results, it is possible to observe that "Capacity to adapt to new situations", "Continuous development" and "Problem solving" skills have an impact median of "5", indicating a strong impact in the future. Additionally, "Innovation" and "Creativity" are being point out as important soft skill to support the development of innovative technological solutions. This implies the need to reinforce the profile of the workers with these new skills, which can be achieved with the incorporation of up-skilling in the training programs.

IV. Analysis of Hard Skills

The second step in the gap skills' analysis considers the analysis of the hard skills for each industrial sector considered in the questionnaire. Hard skills, also called technical skills, are skills relating to a specific task or situation, comprising both understanding and proficiency in such specific activity that involves methods, processes, procedures, or techniques.

A. Collaborative Robotics Sector

Collaborative Robotics are designed to interact with operators in a shared work-space, assisting them during the execution of a specific task. This approach contrasts with

the traditional industrial robots, which are designed to work independently, requiring barriers to protect people from the mechanical impacts caused by robots that normally move at high speed.

Figure 4 summarizes the results for the hard skills gap and impact considering the CR sector.

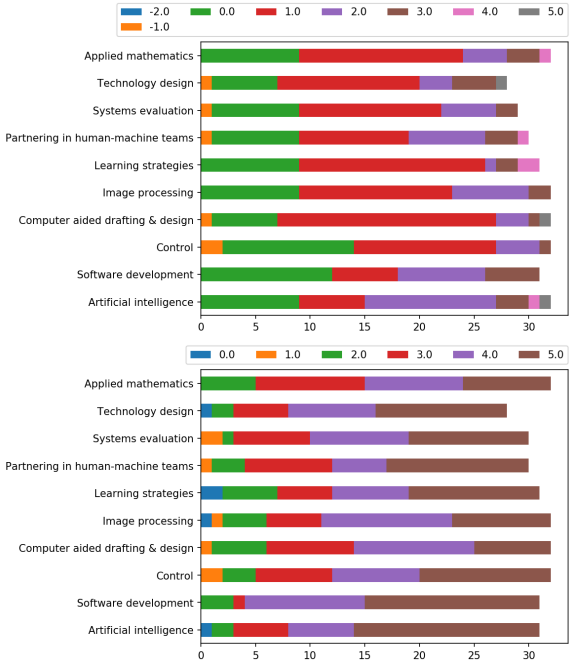

Figure 4: Gap (top) and impact (down) in hard skills for CR.

From the 10-most relevant skills, "Artificial Intelligence" and "Software development" show an impact median of "5", being the first with a gap median of "2" and the second a gap median of "1". All the other listed skills present a gap median of "1" and an impact median of "4", which means that they are also relevant but not as much as the previous ones. This indicate the need to reinforce those skills in the future to face the employers' requirements.

B. Additive Manufacturing Sector

Additive Manufacturing refers to the process of producing 3D objects from digital models, using a technique that is based on the layer-by-layer deposition of material, in opposition to the traditional subtracting methods, where the material is removed to obtain the final part.

Figure 5 summarizes the results for the skills gap and impact in the AM sector. The results reveal the existence of two clusters. The first one comprises skills with a gap median of "1", e.g., "Knowledge transfer", "Simulation", "Design engineering", and "Product customization", and the second comprises skills with a gap median of "0", e.g., "Material Design", "Research and Innovation" and "Engineering Fundamentals". However, with exception of "Simulation" skill that shows an impact median of "3.5", the other skills have an impact median of "4" revealing that the respondents consider that these skills will have a big impact in the future.

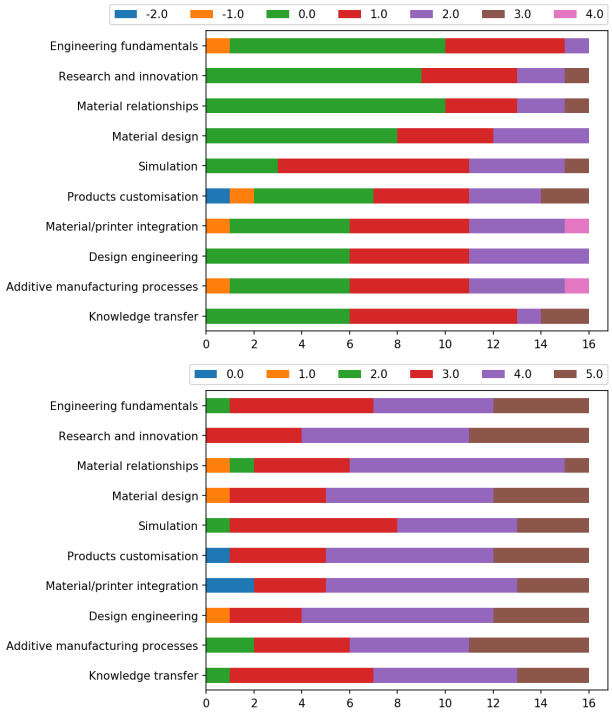

Figure 5: Gap (top) and impact (down) in hard skills for AM.

C. Mechatronics/Machine Automation Sector

Mechatronics is a multidisciplinary field that combines electrical, mechanical and computer systems, being a crucial piece in advanced automated manufacturing industry. Figure 6 summarizes the results for the hard skills gaps considering the mechatronics / machine automation sector.

For the skills listed for this industrial area, all have an impact median of "4", which means that they will have a strong impact in the workforce. Concerning the gap median, the "Artificial intelligence", as in the collaborative robotics sector, also appears with a gap median of "2" indicating that in the future it will be necessary to empower workers with this knowledge. All the others have an gap median of 1 which reveals that they will gain relevance in the future.

D. Human-Machine Interaction Sector

Human resources assume a crucial role in the CPS systems since they introduce flexibility in the performed operations, requiring the use of human-centered methods and HMI technologies, such as virtual and augmented reality, to design and deploy these systems.

Figure 7 summarizes the results for the gaps in hard skills gaps considering the human-machine interaction sector.

Looking to the collected responses related with the hard skills for the HMI industrial area, it is possible to observe a homogeneity in the gap median (i.e. "1") and impact median (i.e. "4"). Nevertheless, it is also possible to verify that the gap ranges between "-2" and "5", which indicates a wide variability in the collected responses. In particular, "Big data analytics" is the only one that gets scores of "5" and the "Development

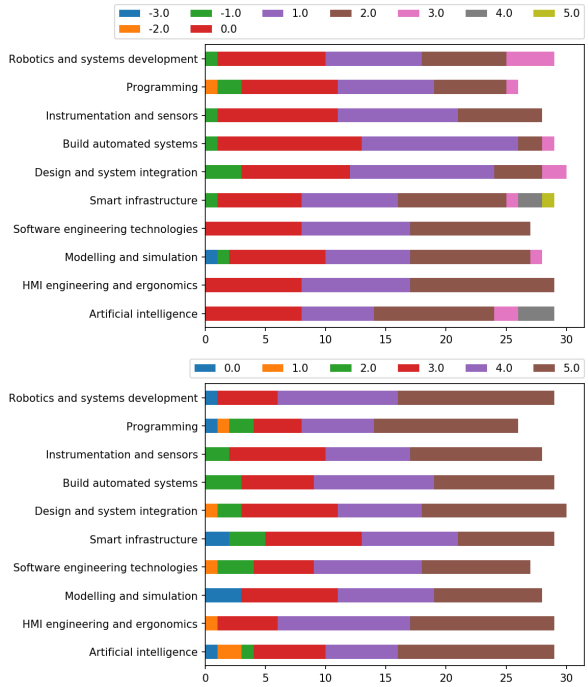

Figure 6: Gap (top) and impact (down) in hard skills for MMA.

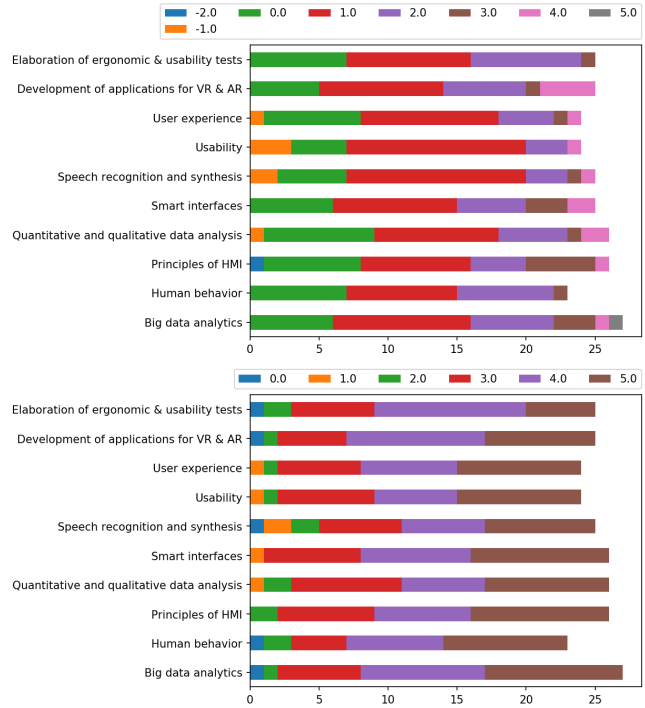

Figure 7: Gap (top) and impact (down) in hard skills for HMI.

of applications for VR & AR" presents a significant number of responses with a gap of "4".

E. Data Analytics Sector

Data analytics is the process of analysing the data sets, usually using artificial intelligence algorithms, to extract knowledge from the information, regarding the monitoring, diagnosis, prediction, planning and optimization. Figure 8 summarizes the results for the hard skills gaps considering the DA sector.

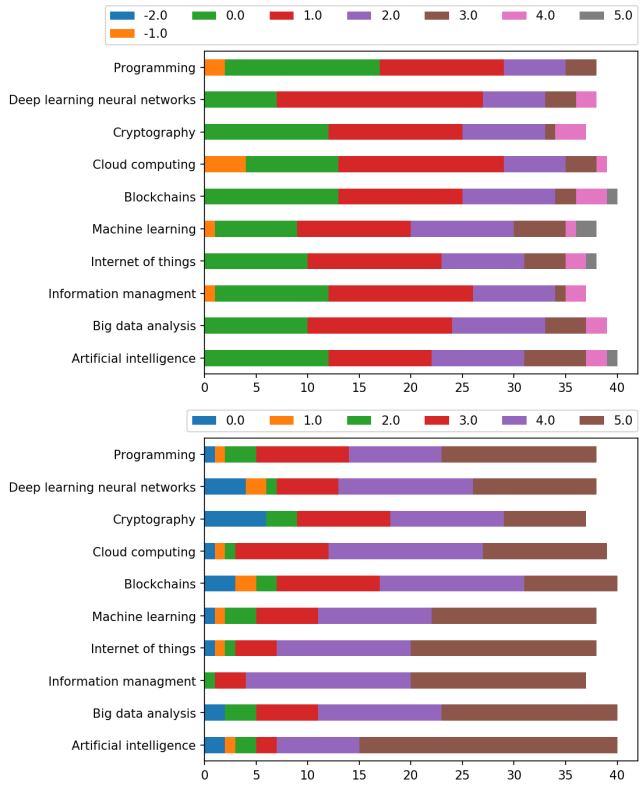

Figure 8: Gap (top) and impact (down) in hard skills for DA.

Considering the gathered results for the DA industrial area, all the 10-most important skills show a gap median of "1". It is also possible to observe that the "Artificial intelligence" skill has an impact median of "5", while all the others have an impact median of "4". Other skills, e.g., "Big data analytics", "Information management", "Internet of Things", "Machine learning" and "Programming", present an impact mode of "5", which reveals that was the most frequent answer. In particular to the "Programming" skill, Python and R are being pointed out as the most relevance programming languages for data analytics [16]. Additionally, some are aside skills, but very important to ensure the data collection (IoT) and the data integrity and privacy (cryptography).

F. Cybersecurity Sector

Cybersecurity is the practice of protecting computer systems, networks, programs and data from digital malicious attacks, usually unauthorised access that damage or make them inaccessible. Figure 9 summarizes the results for the hard skills gaps considering the cybersecurity sector.

Considering the results for the hard skills in the CS sector, it is possible to notice the reduced number of responses, which is aligned with the only 26% of companies that refer the adoption of this kind of technologies. However, the results show an

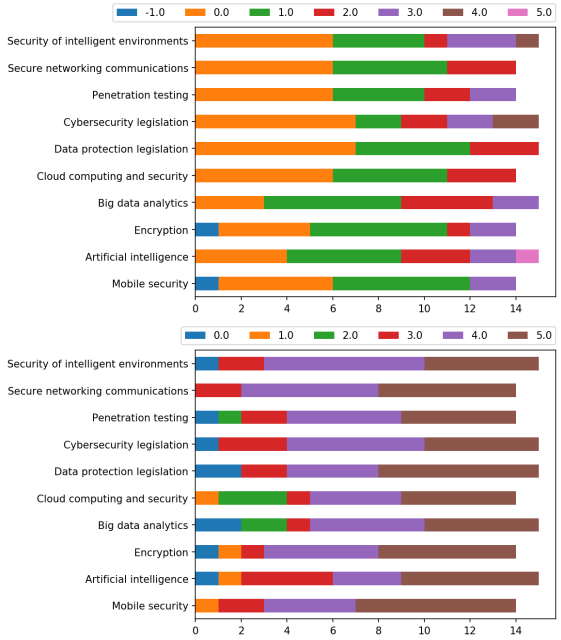

Figure 9: Gap (top) and impact (down) in hard skills for CS.

high impact median, ranging from "4" to "4,5", but a lower gap (gap median of "1" and the majority of gap mode of "0"). This means that the respondents that answer to this specific sector already have adopted these technologies, suggesting that people already have knowledge on that skills and it will not be necessary to empower more the workers.

V. Conclusions

The fourth industrial revolution is imposing a significant change in the skills and job profiles for the workforce of the FoF, particularly being more skilled to support the on-going digital transformation and contributing to increase the digital maturity level of industrial companies. The on-going FIT4FoF project aims to identify which soft and hard skills will be more relevant in the future and will have more impact in the FoF across six industrial areas, through the deployment of a questionnaire survey and the analysis of job recruitment.

This paper analyses the results for the skills' gaps and impact in terms of soft skills and hard skills for the six industrial sectors, being presented for each industrial area the 10-most relevant skills (in terms of gap and impact). In a general way, the results showed that there are several (soft and hard) skills that present gaps when considering the current situation, and consequently requires to empower the existing workforce to face the companies requirements facing the digital transformation. Also clearly observable is that the lack of skills is different in each analysed industrial sector.

The identification of the more relevant and impacting skills is crucial to support the design and deployment of training actions to support the re-qualification and up-skilling of workforce for the FoF. As example, many skills have a gap of 4 or 5, particularly in Data Analytics and Human Machine Interface, which means that this kind of skills should be deeply addressed.

Future work is related to extend the automatic data analysis considering the available data from job recruitment announcements and scientific papers, in order to complement the results from the questionnaire survey with other relevant "as-is" and "to-be" skills, that will impact the FoF workforce. Since the six industrial target areas mentioned in this work are not independent, a deeper analysis to extract the common points in terms of skills gaps will be performed.

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