Analysis of New Job Profiles for the Factory of the Future

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Abstract. Industry 4.0 is being promoting the digitisation of manufacturing sector towards smart products, machines, processes and factories. The adoption of disruptive technologies associated to this industrial revolution will lead to reshaping the manufacturing environment, decreasing the low-skilled activities and increasing the high-skill activities, being expected to grow the complexity and number of new job profiles. In this context, this paper aims to analyse the literature and recruitment repositories to identify the new job profiles in the factory of the future (FoF) across six industrial technological sectors, namely Collaborative Robotics (Cobots), Additive Manufacturing (AM), Mechatronics and Machine Automation (MMA), Data Analytics (DA), Cybersecurity (CS) and Human-Machine Interface (HMI). The performed analysis allowed to compile a catalogue of 100 new job profiles that were characterised and analysed in terms of technical and soft skills, type and level of profile, as well as the frequency demand.

Keywords: Job profile · Factory of the future · Digital skills · ICT · Automation

1 Introduction

Occupations and job profiles are evidenced in several areas of study, e.g., economics, sociology, history and management, which shows their social, economic and relevance to the job market in general. In this way, the topic is notorious and constantly required to be updated, once there has been a continuous evolution of occupations and work profiles since prehistory. In this sense, it is known that the evolution of job profiles is linked to some important factors, such as social changes focused on human behaviour, changes in policies and legislation, recession, and new technologies and means of communication. Such factors were present in the several industrial revolutions and changed the professional profiles across each era, as illustrated in Table 1. As illustrated in the previous table, job profiles follow the demanded characteristics for each industrial revolution, mainly related to technologies, means of communication and transportation,
Table 1. Characterization of the different industrial revolutions.

|                      | 1st industrial revolution | 2nd industrial revolution | 3rd industrial revolution | 4th industrial revolution |
|----------------------|---------------------------|---------------------------|----------------------------|---------------------------|
| **Approximated dates** | 1750                      | 1870                      | 1973                       | 2013                      |
| **Localization**     | UK                        | USA / Germany             | USA                        | Germany                   |
| **Main disruptive technologies** | Steam machine            | Electricity               | Robotics and Information and Communications Technology (ICT) | Cyber-physical Systems, Internet of Things and Artificial Intelligence |
| **Means of communication** | Telegraph                 | Telephone                 | Commercial Internet        | Real-time Internet        |
| **Means of transportation** | Train                    | Automobile                | Airplane                   | Autonomous vehicle        |
| **Process type**     | Artisanal                 | Mass production           | Mass/customized production | Customized production     |
| **Examples of job profiles** | Telegraph operator         | Factory operator, Factory book reader, Knocker-upper, Coil changer, Telegraphist, Typist | Computer technician, Robotics technician, Maintenance technician, Microelectronics technician | *What will be the relevant job profiles?* |

and types of production. Some job profiles are relevant to the respective industrial revolution, emerging to face the current market challenges, but others are non-existent in the subsequent industrial revolution. As example, the lamplighter was highly demanded during the 1st industrial revolution, but with the emergence of electricity and light bulbs in the 2nd industrial revolution, this job profile was extinguished. However, some job profiles remain in the next industrial revolution and others need to be adapted, e.g., the robotic technician appears in the 3rd industrial revolution but will need to expand his skills to be adapted to the digital characteristics required in the 4th industrial revolution.

In this sense, it is clear that the relevant characteristics of each industrial revolution directly influence the job market scenario, professions, careers, job profiles, types of profiles, and in particular the necessary skills for the workers carry out their responsibilities and duties according to the demanded requirements. Several reports show that 75 to 375 million people around the world may change their professional category by 2030 due to the new job market scenario [1], and 8–9% of 2.66 billion workforce will have new occupations by 2030 [2].

This situation is most evident in pandemic periods, such as COVID-19, where there is a greater demand for technology and digital resources to mitigate the effects of physical distancing. According to [3], COVID-19 is the most serious health crisis that the world is facing in this century, provoking a strong impact in the world job market, particularly causing the loss of 195 million jobs. However, due to the COVID-19 pandemic in United States from February to March 2020, there was an increase in the demand by some professionals focused on digitisation, e.g., approximately an increase of 20% of cybersecurity engineers and 12% of net developers [4,5]. Also illustrative is the increase of 775% in demanding cloud services, reported by Microsoft, in regions where the physical distancing is being more impacting [6]. As a result, millions of people may need to acquire new digital skills, and others will need to change careers and improve their skills to be adapted to the new job market reality. In this context, there is a need to
understand the challenges and trends about new job profiles, in order to help employers and employees to perform the necessary up-skilling initiatives to implement/attend according to their individual needs.

Having this in mind, this work aims to identify the new job profiles for the FoF across six technological sectors, namely Collaborative Robotics (Cobots), Additive Manufacturing (AM), Mechatronics and Machine Automation (MMA), Data Analytics (DA), Cybersecurity (CS) and Human-Machine Interface (HMI), that emerge with the introduction of digitisation in the context of the 4th industrial revolution. For this purpose, several pieces of data were extracted and analyzed from different information sources, namely technical and scientific literature and recruitment repositories, using proper data analytics techniques and the feedback from experts. This analysis allowed to characterize the requirements for the specialized training of the current workforce in terms of technical and soft skills, and type and level of profile.

The rest of the paper is organized as follows: Section 2 describes the methodology used to identify the new job profiles and Sect. 3 summarizes the preliminary catalogue of 100 new job profiles for the target six sectors. Section 4 provides a characterization of the new job profiles, particularly analysing the distribution per sector, type of profile and level of profile, as well identifying the most relevant soft skills for each type of profile and technical skills per sector. Section 5 rounds up the paper with the conclusions and points out the future work.

2 Methodology

As previously described, Industry 4.0 is re-shaping the FoF and also contributing for the emergence of new jobs or new profiles with skills and competences associated to information and communications technology (ICT) and automation emergent technologies. Under the scope of the FIT4FoF project (https://www.fit4fof.eu/), the definition of new job profiles will assist in informing education and training requirements for the current workforce, allowing professionals around the world to adapt and develop skills based on the FoF requirements, particularly in the six sectors aforementioned.

The adopted methodology to identify the new job profiles, illustrated in Fig. 1, follows an iterative approach that comprises three distinct phases: collection and analysis of the data to identify at least 100 job profiles, consolidation of the characterization of the identified job profiles and identification of relationship with technological trends and relevant skills. Furthermore, this methodology considers the use of automatic data analysis techniques, such as text mining, and also feedback from experts of each of the addressed areas.
The first phase comprises the analysis of different data sources, namely a literature review and an analysis of recruitment repositories, which should be mapped with the results of the gaps in technical and soft skills described in [7]. The literature review consists of a detailed systematic review of reports from consultancy companies or organizational entities to extract a list of job profiles that reflects the recent tendencies in this field. The analysis of the recruitment repositories uses advanced data analytics techniques combined with natural language processing to complement the identification of new job profiles, taking into consideration the actual demand by the job market in each one of the six sectors.

The analysis of these two data sources allows to compile a list of 100 new job profiles across the six industrial areas, being each one characterized by a short description, a list of relevant soft skills, a list of technical skills, and the type and level of the profile.

The second phase aims to consolidate the characterization of the new job profiles, namely refinement the list of soft and technical skills through the feedback collected from experts and stakeholders, i.e., professionals with expertise in at least one of six target sectors. Finally, and performed in parallel, the third phase is related to analysing the catalogue of new job profiles in a perspective that allows to identify the relationship with technological trends and emergent skills. This analysis allows to identify the skills that most impact the job profiles, supporting stakeholders to prepare their skills agenda towards training their workforce towards these new profiles.

3 Catalogue of New Job Profiles

The catalogue of the new job profiles across the six technological sectors related to the FoF was obtained by performing first a literature review followed by an analysis of recruitment repositories (e.g., www.glassdoor.com). The catalogue of 100 new job profiles, compiled after an iterative process, is presented per sector in Table 2. At this stage, it is important to notice that a new job profile can be a completely new job profile that does not exist in the past or an existing job but now with a new profile enhanced with emergent skills.
Table 2. Catalogue of identified new job profiles

| Sectors | Job Profiles                                                                 |
|---------|------------------------------------------------------------------------------|
| AM      | (1) 3D printer technician, (2) Nanotechnology engineer, (3) Advanced materials specialist, (4) Modeling engineer, (5) 3D model expert, (6) Modular engineering expert, (7) Micrometallurgy engineer, (8) Modeling and microcenography specialist, (9) Parametric designer, (10) Digital construction and manufacturing engineer, (11) Digital fabrication sculptors, (12) Bio-microfabrication engineer, (13) Biotech products and processes expert, (14) Multi-sensor data fusion expert, (15) Customer experience specialist, (16) Customer relationship management specialist, and (17) Mimicry and biomimicry engineer |
| Cobots  | (18) Intelligent robotics expert, (19) Artificial body programmer, (20) Drones engineering expert, (21) Drone route developer, (22) Drone route technician, (23) Cobots expert, (24) Industrial cobots developer, (25) Cobots technician, (26) Cobots responsible, (27) Humanoid expert and (28) I4.0 project manager |
| DA      | (29) Data analyst, (30) Big data analyst, (31) Data scientist, (32) Data analytics consultant, (33) Data analytics manager, (34) AI engineer, (35) ML engineer, (36) Data engineer, (37) Quantum systems engineer, (38) Cloud services engineer, (39) Risks analyst, (40) Cloud services manager, (41) Digital marketing manager, (42) Business analyst, (43) Business Intelligence developer, (44) Industrial process data analytics engineer, (45) Route logistics specialist, (46) Benchmarking metrics manager, (47) Predictive maintenance expert, (48) Data infrastructure architect, (49) Digital Twin architect, (50) Smart grids specialist, (51) Circular economy specialist, (52) Industry 4.0 architect, (53) Chief digital architect, (54) Digital development specialist, (55) Business chief developer and (56) Industrial process optimizer |
| CS      | (57) CS architect, (58) CS specialist, (59) CS manager, (60) Vulnerability manager, (61) Threat landscape analyst, (62) Forensics analyst, (63) Malware analyst, (64) Defensive security technician, (65) Cyber internal auditor, (66) Security incident-handling designer, (67) Security monitoring specialist, (68) Data detective, (69) Data protection officer, (70) Data security administrator, (71) Blockchain expert and (72) Test engineer |
| MMA     | (73) CPS architect, (74) Smart sensors developer, (75) Smart clothes expert, (76) IoT engineer, (77) IoT solution technician, (78) Real time systems expert, (79) Digital systems integrator, (80) I4.0 PLC programmer, (81) Machine decision supervisor, (82) Smart factory designer, (83) Factory operation assessment expert, (84) Condition monitoring expert, (85) Resource-efficient intralogistics engineer, (86) Scheduling and planning expert and (87) System engineer |
| HMI     | (88) Operator 4.0, (89) Augmented operator, (90) Smarter operator, (91) Digital worker, (92) Collaborative operator, (93) Virtual and augmented reality developer, (94) Factory virtual system designer, (95) VR technician, (96) AR/VR Immersive content developer, (97) Extended reality architect, (98) Extended reality software engineer, (99) Industrial UI designer and (100) Industrial UX designer |

The most important literature used in this review is mentioned in [8–20], from where the majority of the 100 job profiles were identified. For instance, 10 different job profiles covering different sectors were retrieved from the *Catálogo de Perfiles Profesionais*
de Futuro report [15], namely Advanced materials specialist, Intelligent robotics expert, Drones engineering expert, Smart grids specialist, Cybersecurity specialist, Blockchain expert, Real time systems expert, Extended reality architect, Circular economy specialist and Customer experience specialist. On the other side, some job profiles are identified in more than one reference, e.g., Big data analyst [12, 18], Factory virtual system designer [8, 9, 12] or IoT solution technician [8, 10].

The job profiles were classified according to the type of profile, being considered the following five categories (definitions adapted from www.dictionary.com):

- **Architect**: a person professionally engaged in the design and conception of a certain idea, system or product that must be innovative and skilled in different fields.
- **Developer**: a person who develops or innovates, with a creative thinking and specialised in some subject.
- **Engineer**: a person trained and skilled in the design, construction and use of engines or machines, or in any of various branches of engineering.
- **Specialist**: a person who has special skills or knowledge in some particular field.
- **Technician**: a person who is trained or skilled in the technicalities of a subject.

In the same manner, the new job profiles are also classified in three levels: operational, tactical and strategical. These three levels are related to the scope of the decision making over the time; if the decision has a short-term impact and related to individual employees/units, the job profile will be categorized as operational. On the other hand, if decisions persist over the time and influence the performance of the plant as a whole then the levels will be classified as tactical and strategical, with strategical having a longer influence in the performed decisions.

Additionally, each job profile has a set of soft skills and a list of technical skills, that represents the requirements for the job position. The jobs shown in Table 2 are associated to one sector due to simplicity of representation but the majority of them are relevant to more that one sector. As examples, in a general way, there are profiles related with Cobots that are also related with MMA and job profiles in DA that are also related with CS.

### 4 Characterisation of the New Job Profiles

In this section, a characterization of the identified 100 new job profiles will be presented and discussed. Figure 2 illustrates the categorisation of the job profiles, and some relevant aspects can be described. Regarding the type of profile, the most representative category, with approximately 42% of the job profiles, is the “Specialist”, while the less representative is the “Developer” with only 11% of the jobs of the catalogue. The remaining categories count with 19% of the jobs labeled as “Engineer”, 16% as “Technician” and 12% as “Architect”.

Fig. 2. Categorisation of the new job profiles.

Looking to the level of profiles, the majority of the new job profiles may be considered as “Tactical” jobs (62%), 28% were considered “Operational” jobs, and only 10% as “Strategical” jobs. These percentages support the observed distribution of the types of profiles since the majority of them are related with tactical level jobs positions, with a minority being considered as strategic level jobs, and only the “Technician” type of profile being categorised as an “Operational” level job position.

Considering the distribution of the new jobs across the six industrial sectors included in this study, approximately 28% of the listed jobs are on Data Analytics and 16% on the Cybersecurity areas. Together both areas comprise 44% of the new job profiles revealing the “value of data” in FoF. Also 39% of the identified new job profiles are distributed by Mechatronics/Machine Automation, Collaborative Robotics and Human-Machine Interface areas. Finally 17% of the jobs are related to the Additive Manufacturing sector. All of this categorisation reveals the importance of the listed new job profiles in the smart factories in the context of Industry 4.0.

Additionally, a deeper analysis was performed to identify if each identified job profile is a really “new job” and consequently has a “new profile”, or if it is an “existing job” but with a “new profile”. The result of this classification is illustrated in scattering diagrams (see Fig. 3) where each number corresponds to a specific job profile listed in Table 2, and the colour specifies the type of profile.
Fig. 3. Dispersion of new job profiles: left) industrial sector and type of profile, and right) type and level of profile.

The analysis of both diagrams shows the dispersion of the job profiles included in the catalogue, and brings together all the performed categorisation. It is possible to verify that 64% of the job profiles were considered to be “New Job/New Profile”, and 36% of the jobs in the catalogue are existing jobs positions but with a new profile. As an example, we can refer that we have sixteen job profiles labelled as “Technician”, and so they are categorised as “Operational” level job profiles. Moreover, other types of profiles were considered of “Operational” level, e.g., the “(72) Test engineer” job position demanded by the cyber-security sector is considered as an “existing job” but with a “new profile”, and categorised as an “Engineer” profile type. A similar analysis can be performed for all the job profiles included in the catalogue.

In summary, it is important to point out that although the majority of the jobs identified in the catalogue are new jobs profiles positions needed by the employers, there are also existing job positions that will have new profiles as such requiring new skills and competencies.

Another aspect that can be highlighted is the fact that the FoFs will require more workers with specific competencies since a significant number of the analysed job positions (72%) were labelled as tactical or strategic level were several specific skills and/or competencies may be mandatory.

With the aim to emphasize the more relevant skills for the identified new job profiles, the soft and technical skills required for each job profile were also identified. Figure 4 illustrates, in a network graph, the relationship between the required soft skills and the different types of job profiles.
Our analysis revealed that some of the listed soft skills are cross-cutting among the considered types of profiles. For example, “critical/analytical thinking”, “team work”, “capacity to adapt to new situations”, and “communication skills” are required in all the considered types of profile. Nevertheless, some skills are more often required by employers. On the other hand, “creativity”, “communication skills”, “leadership”, “problem-solving”, and “team work” soft skills are of great importance to the “specialist”, the “architech”, the “developer”, and the “engineer” type of profiles. For a “technician” job profile, it is possible to notice that the set of the most demanded soft skills is quite different because this is an operational level job profile and skills such as “team work”, “capacity to adapt to new situations”, “continuous lerning”, and “continuous skill development” are more often required.

A similar analysis was also conducted to understand the relationship between the most often demanded technical skills and each one of the six industrial sectors included in this study. Figure 5 illustrates the most required technical skills for each target sector.
Taking into account the technical skills that are demanded in the new jobs profiles, a large number of different technical skills was found since the job profiles cover six different technical sectors. However, it is possible to emphasize some cross-cutting skills and also some of the most relevant technical skills for each one of the six studied industrial sectors.

We may point out that some technical skills such as “scheduling”, “smart sensors”, “IoT”, “ML”, “programming”, “AI”, “digital skills”, “virtual reality”, “augmented reality”, “optimisation”, “simulation”, “statistics”, and “communication networks” may be considered cross-cutting skills since they are demanded on job profile positions announcements of the different industrial sectors. For example, “AI” is a required skill on job profile positions for all the industrial sectors and “digital skills” is a necessary skill of AM, HMI, and Cobots sectors. Additionally, it is also possible to observe the relevance of each skill for a specific industrial sector. According to the network graph shown in Fig. 5, the greater the thickness of a line, the greater the relevance of that skill for the sector. For example, considering the HMI industrial sector, the “augmented reality”, “virtual reality” and “digital skills” skills, together with both “AI” and “programming”, appear as the most relevant technical skills since they were frequently required among the job profiles requirements of this sector.
5 Conclusions

Along several industrial revolutions, the job profiles evolved to face the disruptive technological changes. Also presently, at the fourth industrial revolution, the introduction of Industry 4.0 principles and technologies are re-shaping the workforce profiles, being noticed a decrease in the demand for low-skilled activities and an increase of high-skill activities. This change causes that a significant number of existing job profiles will be obsolete and new job profiles will emerge.

This paper aims to identify the new job profiles for the FoF across six industrial technological sectors, namely Cobots, AM, MMA, DA, CS and HMI. The performed analysis allowed to compile a catalogue of 100 new job profiles that were characterized and analysed in terms of technical and soft skills, type and level of profile. The characterization of these new job profiles allowed to analyse the distribution by type and level of profile, as well as industrial sector. A deeper analysis allowed to conclude about the relevance of soft skills and technical skills for these new job profile, particularly analysing the most relevant soft skills per type of profile and most relevant technical skills per industrial sector.

It is also important to notice that the developed analysis can answer to what jobs profiles the future holds in the FoF field. This information may assume a crucial role to support companies’ managers and stakeholders to decide what upskilling initiatives should be attended by their workforce according to the needs, particularities and goals for their organization. In fact, having identified the relationship between new job profiles and relevant skills, the decision-makers can look for the positioning of relevant skills in the desired type of profile and sector, and select the proper training programs’ topics.

Future work will be devoted to analyse the relationship of new job profiles with technological trends and with the demand over the time found in job recruitment repositories.

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