User Centered Design of a Knowledge Management System for Production Workers

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***Abstract*—This paper depicts a knowledge management system developed by the authors as a service to be used by workers of the production sector. The service has been developed within the framework of FACTS4WORKERS project, which aims to provide software, hardware and organizational strategies to improve the workers satisfaction. The approach to collect the workers requirements is based on the creation of artifacts able to support a smarter and easier communication with the end users. The solution presented in this paper is a Knowledge Management System developed to cope with the specific requirements of manufacturing workers. It aims to provide a real-time decision support to the workers and create a collaborative and inclusive work environment. The solution has been tested in a real production environment by the project partners.**

Knowledge Management System; Workers Satisfaction; Smart Services.

I. INTRODUCTION

One of the challenges that the European Community must cope with in the next years is the low attractiveness of jobs in the manufacturing sector. As highlighted in the Factory of the Future agenda [1], the reduced interest on younger generations for manufacturing jobs constitutes an obstacle for the re-industrialization of many European regions. In the last years, European Community has promoted many calls for proposal for the development of solutions to increase the satisfaction of workers in the manufacturing areas, creating new approaches and tools to empower and reskill the workers. One of the funded initiatives is the FACTS4WORKERS project, whose outcomes are briefly presented in this paper.

The general picture is that young people are not excited by the idea of working in a manufacturing plant since the perception of this job is connected to "old fashion" activities that are mainly focused on dirty-hands tasks without the use of modern communication tools, common in everyday life.

Many strategies have been proposed to tackle this issue. **Figure 1** shows a priority list of the possible actions, developed by the World Economic Forum [2]. Among these, the most important is the reskilling of the operators. This is not a trivial task since the operators that must be reskilled come from very different demographic, expertise, educational, and skill background. The challenge is to develop a smart approach that could be adopted proficiently by most of the actual workforce and that could generate interest and motivation for its continuous use.

Figure 1. Future strategies for manufacturing workers

Many companies are looking to invest in operator reskilling while trying to keep low the costs, like the time required and the impact on the organizational structure of the workforce, especially in the Small and Medium Enterprises (SMEs). The most common approach is to develop a vertical solution based on the very specific requirements of a company, creating a reskilling path that is only partially

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reusable in other contexts. In all cases, the starting point should be an analysis of the reasons that led the company to implement a reskilling plan. The analysis starts with the evaluation of the role of the manufacturing workers. This has tremendously changed in the last decades: continuous automation of manufacturing processes has reduced their manual efforts, whereas managing the increasing complexity of the production system requires them to acquire higher skills. The Web has been one of the main sources of inspiration for new tools that enable the sharing of information and ideas; applications such as Wikipedia and Facebook created a new "social" environment where people could exchange information using new approaches. Nowadays, users do not only consume, but actively produce information and engage with the information produced by others in a collaborative way. This creates new possibilities and challenges for the industrial sector. Whereas younger workers "expect" to be able to work with recent technologies, older workers must not be left behind by creating a "digital divide" [3]. A growing number of studies has shown how social and mobile technologies can help capture and process social information [4]–[7].

When facing problems, especially of a technical nature, in their daily life most people use social environments to look for a solution. Some examples include repairing a broken household appliance, consulting information about the use of electronic devices, etc. The challenge of the developed service is to transfer this approach to the shop floor, enabling a smarter and faster problem-solving attitude of the workers and creating a more motivating and supporting social environment. A usability study of the online training approach highlights how the perception of new and innovative tasks could increase the satisfaction of the users [8]. Hence, production workers, often involved in manual work, could benefit from this innovative industrial social environment.

To meet this goal, the creation of a social environment within a manufacturing plant is required, supported by a highly usable platform and infrastructure, that will adopt smart services to enable the exchange of information among peers. The system will be composed of a Web front-end, able to run on a smart device, and a number of services that provide communication service and access to consult, generate and modify a knowledge database.

The rest of the paper is structured as follows. In Section II, the architecture of the developed solution is presented, while Section III depicts the approach used for the collection of worker requirements. Section IV describes the features of the developed Knowledge Management System, while Section V concludes this work.

II. FACTS4WORKERS PROJECT AND INDUSTRIAL CHALLENGES

This activity has been developed within the larger frame of FACTS4WORKERS project, whose aim is to create a smarter and a more satisfying working environment for manufacturing operators. The developed tool, able to support the knowledge sharing among workers and sustain the development of a collaborative environment, is only one of the industrial challenges defined by the project. These are summarized in **Figure 2** and briefly described in the following list:

- Industrial Challenge 1: Provide a personalized and augmented reality (AR) tools for the workers through which they can get immediate, context aware and hands free access to information on the shop-floor.
- Industrial Challenge 2: Provide a worker-centric knowledge management system through which the users can capture and access the knowledge shared by the rest of the coworkers, with main focus on the shop-floor level flows instead of office centered functionality.
- Industrial Challenge 3: Self-learning manufacturing workplaces are established through linking heterogeneous information sources from the worker's environment and beyond, and extracting patterns of successful production, transferring the result as decision-relevant knowledge to the worker.
- Industrial Challenge 4: The use of generated knowledge through knowledge management system and insight provided by the self-learning manufacturing workplace for an in-situ mobile learning to instruct and support operators during production.

Figure 2. Industrial Challenges of F4W project

The objective of the developed tool is to support the workers in all the Industrial Challenges with different approaches.

Industrial Challenge 1: The augmented operator will profit from a social platform especially for the possibility to define specific "channels" for the information posting. One operator could decide to be updated about all the content created by a specific operator, that has more experience with the manufacturing process or is usually well trained in problem solving. Moreover, the data fed to the operator could be studied and analyzed thanks to the support of the other workers that "animate" the social platform and, in the past, have carried out similar task or have verified a similar behavior in the collected data.

Industrial Challenge 2: the second challenge is about the knowledge management and sharing. Here the developed service has the aim to enable the sharing among the peers of the knowledge about defect solving. In this case the class “defect” must be considered in a broader sense: a defect could be any issue that the production worker has to solve in order to have the production running smoothly. The database of the service stores all the encountered defects and the solutions adopted by the operators. The descriptive information will be augmented with multimedia content, such as video and audio tracks that show and further improve the provided solution. Additionally, social interactions will be captured in the form of comments and ratings, that again can include multimedia content to integrate the knowledge content for further use. The success rate of each solution will be calculated based on the feedback of the operators in order to allow the selection of the best solution available based on the evidence of the validity of the approach and the social comments received.

Industrial Challenge 3: the third challenge is related to self-learning; in this case the social exchange of data will enable the training of the operator directly thanks to the access to the data created by the other users. The availability of comments, video and other media created by expert workers will enable a self-learning of the operators. This will allow an easier organization of the workforce at the different machines in the shop-floor, incrementing the mobility of the workers in the plant and empowering them into the use of a larger number of machines/stations.

Industrial Challenge 4: the last industrial challenge wants to deal with in-situ learning, for which the operator needs to access a lot of different documents and multimedia contents. In this case is crucial to have a system able to motivate the production of media contents able to populate a training platform. The social service backbone is going to support the development of a repository of peer-to-peer process information. This information will be highly usable by the workers because produced by his peers. It is expected that the material will be produced by workers for workers, characterized by a very focused problem-solving attitude and a functional language and representation approach. Moreover, the content rating and the associated success rate of the solutions will allow the workers to select quickly the most interesting material to use, avoid time-consuming search and the reading of a lot of less-useful material.

After the definition of the objective of the service, an analysis of “off-the-shelf” solutions has been performed, highlighting the need to develop something smarter and more focused on the specific case. In order to have a tailored solution for the project objectives, many interviews have been carried out with manufacturing workers, implementing a user centered approach.

III. User centered approach to design the service

The knowledge management system could be a powerful tool to be deployed in an industrial environment, but some barriers could limit its successful introduction on the shopfloor. For this reason, a user centered approach has been designed and adopted in order to define the architecture of the optimal solution, keeping always the workers within the loop. Many authors, like Kukko [9], report that some barriers must be overcomed to have an effective sharing system, that otherwise lead to a knowledge mismanagement, responsible for unsatisfactory performance. These are mainly related to the users acceptance of the solution and a correct definition of the rules for managing the knowledge. However, supporting the knowledge sharing is one of the main drivers for continuous improvement actions [10]; it is one of the most useful approaches to cope with fast changing environment and context.

To design the architecture of a solution that could effectively support the workers and have a high degree of acceptability, it is crucial to fully understand the daily tasks and main issues that a worker must face. The approach used to collect such needs is based on widely known standards, like ISO9241-210, and human-centered design of interactive systems and Design Research’s process model approach [11]. Both approaches are based on the assumption that complex problems [12] cannot be solved in a straightforward way but needs usually many iterations.

The used approach is based on the development of an initial context-of-use analysis that evolves in the definition of application scenarios. These scenarios have been developed by the researchers of the projects and later validated with the operators. An interesting solution developed by Heinrich & Richter [13] is the use of comics to contextualize the developed scenario and facilitate the communication with the workers, keeping the information level to its core and using a simple and context aware language. After the definition of the scenarios, the software developers elaborated a preliminary solution to cope with the challenge, providing mock-ups for its evaluation by the workers. Based on their feedback, the final release of the software has been deployed on the shop floor. During the whole process, the users are kept in the center of the definition process, with the aim to develop a user-centered application.

IV. Developed Knowledge Management System

The Knowledge Management System developed allows the workers to share their experiences and knowledge. The system supports a worker in case of a defect - general definition for a problem in the production area - and provides the support to deploy a corrective action. The study of different industrial organization, carried out within the framework of FACTS4WORKERS project has highlighted how the knowledge required to support the worker’s activity could be described in the form defect->solution. This is a result exploited by many authors, like Vera et al. [14], that recognized how the knowledge required in a production environment is usually in the form problem/defect-> solution, since most of the cases that require a direct operation of the workers are related to the events’ occurrence. Hence, the required knowledge is the causal relation between an event (defect) and a possible corrective actions (solution). This is not a univocal link since multiple solutions could be adopted to solve the same problem. To cope with this issue a solution ranking concept has been introduced, where the ranking is a measurement of the effectiveness of the suggested approach to resolve the events' occurance. General solution (e.g., "clean the device") could be applicable to a large variety of defects but have a poor effectiveness in some cases. The solution ranking allows the use of the same solutions based on their context effectiveness. The ranking is measured thanks to the worker's feedback on the adopted solutions. As the amount of the workers' feedback increases over time through the use of the system, the ranking functionality becomes more rapresentative of the best solutions for the frequently encountered defects.

The knowledge is initially generated by the users in term of new solutions that are able to solve a specific problem. After a training period in which the database is populated by the workers, following use of the system will enable the worker to receive a suggestion by the system about how to solve a specific issue, with the indications and suggestions of workers that have dealt with the same issue previously. In case of no solution for a defect, the system will use a semantic search engine to guess the best solution for the specific case looking for similar problems or offer the possibility to register a new solution. The algorithm uses natural language processing approach in order to extract information from the defect and solutions definitions, as stated by the operators in its own language – usually without a structured definition. Moreover, the Artificial Intelligence of the system will keep track of the acquired experience of the workers and suggest if the operator has enough experience with the application of a specific solution and, if necessary, will call a supervisor (Team Leader) to support the implementation of the suggested solution. The basic scheme of the solution is reported in **Figure 3**.

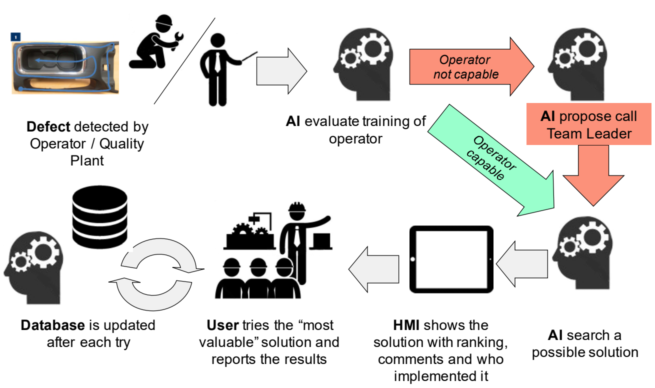

Figure 3. Scheme of how AI manage the workers generated knowledge

Moreover, the knowledge is filtered considering the worker profile. Profiling is fundamental to provide the correct/adequate information to a specific worker. The basic idea is that some information is not useful, or sometimes misleading, for people that do not have enough training to correctly understand them or are not authorized to deploy the corrective action. An example could be a complex maintenance operation. In general, the most skilled machine operators have some experience in maintenance operations. Based on the action required, the system recognizes if the operator is able to carry out a specific maintenance operation autonomously and provide all the needed instruction to him, otherwise another skilled operator is called in order to solve the problem as soon as possible.

The knowledge is generated by the workers thanks to a visual approach; it allows them to use actual and high usability technologies to insert the linked information (defect->solution) into the database. Since the information will be retrieved by a semantic search engine, it will be possible to use free text and multimedia file (pictures and videos) to describe both the problem and the solution. A mock-up that explains the user interface for generating knowledge is reported in **Figure 4**. Comment with text and other multimedia (video) could be later added. The AI will be able to select the optimal solution based on ranking. An example of interface is reported in **Figure 5**. The ranking of the solution is calculated by the system using the feedback of the workers after the application of a specific solution. This is a measure of the success of a specific solution to solve a problem and could be used to suggest the best solution to a worker to deal with a problem.

The developed system has been installed on-premise in different working environments, thanks to the availability of FACTS4WORKERS project partners. After a period of use, the feedback of the workers has been collected. All workers involved in the test of the prototype declared their satisfaction about the functionality and potential support that the KMS could provide. During this preliminary evaluation, we received feedback about the organization of the content on the HMI. This led to a reorganization of the information, to avoid reporting data with low interest for the workers and, in general, avoid distractions or low value added steps in the software application. Some appreciated features are the low intrusiveness of the system and its user friendly interface, since it requires very low IT expertise to be operated. The expected results for this implementation is not the reduction of defect rate but an increased capability of the workers to solve autonomously the problems/defects that could arise during their daily tasks, with positive effects in production rate (reduced down time of the production machines) and increased autonomy of the workers that lead to their empowerment and satisfaction. A more detailed presentation of the developed service is reported in [15]. An important characteristic of this service is the applicability of the solution in a large variety of production contexts. During FACTS4WORKERS project, the service has been deployed and tested in different companies, with business ranging from the assembly to the production of plastic and metal parts. In every case only minor adjustments of the front-end have been carried out, to comply with the different requests of the workers in terms of available data.

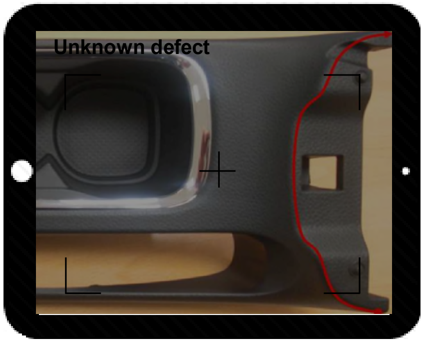

Figure 4. Mock-up for the user generated information

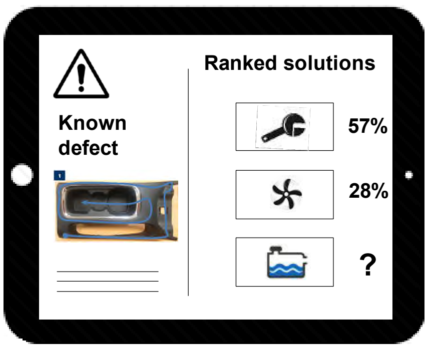

Figure 5. AI suggests the feasible solution with ranking

V. CONCLUSIONS

The knowledge management and sharing system proposed in this paper has been designed using a structured approach that enabled the smart evaluation of the workers requirements, allowing a faster and more user centered design of the service. The developed service has been installed on premises by many industrial partners, allowing a testing and validation phase of the effectiveness of the approach. The formalization of the knowledge has been carried out by the definition of a casual relation among defects and solutions, integrating in the system the tools to search and rate all the content introduced in the service database. At the end of the test phase, the developed service has been fine-tuned and the feedback form the workers have been very positive. In most of the cases, the proposed solution enabled the workers to solve the problem and promoted the culture of exchanging data and knowledge among peers, creating a more collaborative working environment.

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