Industry of the future, future of work: the case of collaborative robotics

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Abstract. This communication discusses the resulting changes in the field of design project management generated by the industry of the future and its promises, with a special focus on collaborative robotics. Among the guiding issues of this work, we will focus on the importance of including such an intention to cobotize some or all of the tasks initially assigned to human operators, during the strategic stakes of the design process and to instruct and support it by the potential contributions of a bottum up approach centered on the real activities, mobilized and deployed during the realization of the tasks which are objects of cobotization. This discussion is based on an industrial case study, aimed at assisting a finishing workstation (the last stage of a production process) for fragile mechanical parts used in the manufacture of metal parts for the aeronautics sector.

Keywords: Industry of the future, Collaborative robotics, Design project management.

1 Introduction and methodology

1.1 Introduction

The emergence of new technologies presents a major challenge to the transformation of the work and activity of human operators. These technologies once again raise questions about the place of humans in the new work organizations, and about their potential impact on the work and activity of operators [1, 2].

The appearance of robots that can share the same workspace with human operators (cobot(s)) [3] generates multidisciplinary discussions related to the multi-stakeholder aspect of these new technological devices [4], including the nature of the new forms of human - cobot(s) interactions, called collaborative interactions, and the health and safety of users [5], the transformation of their work [6], its organization, the relationship to work and the collective, the new skills to be acquired and developed as well as the profitability of these investments (impact on the quality and productivity of the existing system) [7, 8].

In this sense and in order to contribute to the new classes of problems and debates raised by these emerging technologies, we present in this paper a brief feedback of a research-intervention study conducted in a French SME, interested in these new technological devices (cobots), with the aim of assisting manual finishing stations for fragile mechanical parts intended for the manufacture of technical devices in the aeronautical and other sectors.

This research and development involve a multidisciplinary team of engineers and ergonomists with the main objective of carrying out a feasibility study to answer the following questions: how could the use of industrial cobotics provide a relevant, realistic and feasible response to the strategic issues of improving production performance, health (MSD risks) and working conditions? In which way does a mobilization and involvement approach of the operators concerned by the cobotization project, in particular through the analysis of their actual activities, represent an essential condition to succeed the design project?

1.2 Methodology

To address the issues and objectives outlined above, we have conducted an action-research project with a French SME. This project aimed to integrate a collaborative robotics solution for the refining workstations used to manufacture mechanical parts for the aeronautics sector with high quality, reliability and safety standards.
During this project, we sought to:

- Understand and analyze the strategic issues of the different stakeholders of the design project in order to contextualize the choice of this technology as an answer and solution to the issues of customer retention, the perspectives of modernization of the manufacturing equipments, a more efficient performance by reducing rejects, prevention of MSD risks and global work conditions improvement, etc.;
- To mobilize and involve the concerned operators, in particular by the precise analysis of the gestural refining activities, to model the operations of manipulation and refining of the cores; to investigate the possibilities of cobotisation of the refining operations to support the gestural activity and to reduce the hardship of these workstations.

All these steps are part of a mobilization process of the involved design project participants, including the refining operators, and required the setting up of a strategic monitoring group of the project.

2 Analysis and modeling of the refining activity

2.1 Analysis of the refining activity

Initially, the team focused on understanding the issues related to the finishing activity targeted by the cobotization project. The exploratory interviews conducted with members of management, local managers and finishing agents highlighted the following strategic dimensions:

- The strategic stakes of winning new shares of the product market, higher reliability of the produced products answering more and more strict specifications, etc.;
- The strategic stakes of increasing product market share, greater reliability of the produced products in response to the more and more demanding specifications, etc.;
- Quality and reliability requirements: A high product rejection rate is observed in the manufacturing process. This is due to customers' strict standards for aviation safety reasons.
- Dimensions related to the employment, training and hiring of finishing operators, their overall cost and the insecurity of retaining them;

2.2 Modeling of the refining activity

After the strategic analysis phase, the team focused on the analysis of finishing activities. Observation campaigns equipped with audio and video tools were organized following a schedule consisting in observing the finishing activity of parts of different complexity (parts qualified by the workshop manager from complex to simple) by operators with different levels of experience (4 months, 5 years, 10 years and 17 years of experience).

These observation campaigns were followed by exchanges and explanatory interviews with the observed operators, with the aim of understanding and analyzing their finishing activity. This phase made it possible to propose and validate (by the finishing operators) a characterization of the finishing gestural activity according to a view of the professional gestures not only from a biomechanical and physical point of view but extended to a greater complexity mobilizing the cognitive, collective and psychic dimensions. Such a conception of the professional gesture will make it possible to enrich the reflection and the choice of the technological solutions in the perspective of an allocation of the functions between the human and the cobot. An allocation of functions that takes into account the usefulness of the cobot and its integration in the course of the actions of the operators concerned, its participation in reducing the risks of Musculoskeletal disorders (MSD) related to the manipulation of parts and to preserve, or even develop new forms of efficient activities that produce meaning and recognition for the final users.

In order to go more deeply into this characterization, and inspired by the work of Chassaing [9] and Benchekroun et al [10, 11], gestural activity would be located, invested, constructed and developing:

- Situated as long as the gesture is permanently inscribed in changing and evolving contexts on the organizational, technological, spatio-temporal, historical, social and cultural levels;

- The invested character of the gestural activity refers to its subjective dimension of the moment that it is singular and that everyone attaches values and meaning to it. The invested character of the gestural activity refers to its subjective dimension of the moment that it is singular and that each person attaches values and meaning to it. The gesture is not reduced to what is realized, it is also this activity that cannot be done and that risks being prevented;

- The constructed and developmental character of gestural activity refers to the processes of training and learning on both the individual and collective levels. In these processes of construction and development, Weill-Fassina [12] gives an important place to reflexive activities which, according to her, can be spontaneously made by the subject, develop in the work group or be provoked by various forms of questioning or interviews.

On the basis of this characterization of the gestural activities of the finishing operators, we come to represent them according to the following model (Fig. 1):

Situated gesture of the finishing operator: from a historical, cultural and organizational point of view • Difficult employment pool ; • Availability of a technical know-how that can adapt and evolve in the production of the SME.	**The gesture is being built and developed** • Training ; • Apprenticeship ; • Mutual support ; • Different levels of expertise ; • The use of interim.
Composed gesture of the finishing operator : • Perceptual-cognitive: Knowledge of the parts, its different parts, knowledge of the material, tools, knowledge of the organization (objectives, strategic issues related to the parts, etc.) etc. ; Visual perception and tactile perception (the touch), etc.; • Biomechanics: carrying the parts; • Skills (automatism) ;	**Invested gesture of the finishing operator:** • The quality of the parts ; • "Loving" the parts: beauty and appearance ; • The recognition by the pairs; • The quality qualified at times as Over-quality (form of non-recognition, time invested for nothing, etc.); • Conflicts between quantity requirements/quality requirements/fragility and risk of breakage of the parts; • Risk of quality actions obstructed;

Fig 1. The 4 squares scheme for the analyzed activity

This type of analysis made it possible to broaden the discussions and to develop the project on dimensions that had not been questioned until then, with a projection of the finishing operators on the part of their activity to be assisted possibly by a cobotic solution. If the right hand fulfils the essential role of finishing the part by filing, sanding, filling, using different finishing tools, operations considered to be the key role of the finishing operator, which valorize them and give a recognized brand image of the SME; the role of the left hand remains essential as long as it carries the piece, manipulates it to prepare and anticipate the actions of the right hand, but capitalizes on the complaints of all finishing operators in terms of pain, discomfort and potential risk of Musculo-skeletal disorders (MSD). They unanimously believe that if their work is to be helped and relieved, it must be through a solution to reduce the discomfort felt in the left hand and left shoulder (see Fig. 2 which details the distribution of operations between the right and left hands).

<table>
<tr><td colspan="2"><u>Perceptive and Cognitive Mobilization</u>
- Initial inspection of the workpiece;
- Continuous control of the progress of the finishing operations on the different areas of the part;
- Choice of the appropriate tool according to the step and the finishing zone (sandpaper, file, blower, binocular).
- Coordinate operations of both hands;
- Maintain product quality requirements ;
- Meet the assigned time;
- Protect the part;</td></tr>
<tr><td><u>Left Hand</u>
- Carry the workpiece;
- Preparing right hand operations ;
- Present the workpiece;
- Anticipate right hand operations;
- Protect the workpiece against damage;</td><td><u>Right Hand</u>
- Remove the burrs ;
- Polishing the worked surface;
- Blow to clear the material (blower/mouth);
- Turn the workpiece;
- Caution not to break or damage the worked part;</td></tr>
</table>

Fig 2. Schematization of the finishing gesture activity targeted by the cobotization project

This diagram shows the following dimensions:

– Finishing work mobilizes knowledge about products, their destination, their complexity, their sensitivity, the different kind of methods and used tools, gestural finishing skills mobilizing precision, accuracy, detection of imperfections, caution not to break the products; the different uses made of the light source to support and anticipate the lighting and its quality on the different treatment areas, etc.;

– The left hand has an essential role in preparing the operations of the right hand and protecting the pieces -which are very fragile- from breakage by continuously adapting their position according to the operations to be carried out by the right hand, the orientation in relation to the light source, the effort exerted by the right hand, etc.

– Dimensions related to the health and hardship of the work: observation of significant solicitations of the upper limbs, in particular the hands, fingers and wrists. These solicitations are described as painful by the operators, particularly those of the left hand, which seems, to an outside observer, "not to be strongly solicited", etc.

Par un travail systématique d'observation, de traitement et d'analyse, nous avons identifié différents « patterns » de port et de manipulation des pièces par la main gauche. Ces patterns présentent les pièces à la lumière selon des plans longitudinaux et sagittaux rendant possible les opérations précisent, rapides et délicates de la main droite.

3 Discussion and perspectives

The analysis of the finishing activity in this case study has made it possible to direct the reflection of the finishing station' assistance (the objective of this case study) towards a more precise objective which is the assistance of the left hand (the hand that carries the parts during the finishing activity).

In fact, the analyses and modeling carried out have shown, on the one hand, that it is this part of the gestural activity that causes the most pain to the finishing operators, especially if the parts are heavy or too small. On the other hand, the perceptive-cognitive activity mobilized and the skills developed by the finishing operators constitute the central part of the finishing activity, and any intervention on this part will transform the central part of the finishing activity. With regard to the gestural activity of the right hand that performs the intervention on the parts to be finished (burr removal, polishing, drilling, turning the parts to be finished, etc.), the great variability of the operations performed makes it difficult to think about technological assistance paths. This assistance track was subsequently discussed with the finishing operators who expressed their curiosity and interest in seeing what a solution of this kind could look like, and that they were in favour of testing a prototype of this technological solution.

Based on the analyses carried out, the design team pointed out that a few constraints must be considered in this potential future system in order to ensure its goal of providing assistance without compromising too much on the quality and scrap rate of the manufactured parts, the productivity of the finishing department and the sense of this activity. These constraints are formalized below (see Table 1.).

Table 1. Table of necessary constraints the future system must consider

Constraint reference	Example
Constraint 1	Ensuring parts carrying
Constraint 2	Allow to carry a variety of parts
Constraint 3	Allowing parts to be rotated and inclined smoothly
Constraint 4	Allow to feel the forces applied on the parts (force feedback)
Constraint 5	Do not damage or break the carried parts
Constraint 6	Allows parts to be assembled and disassembled quickly and easily
Constraint 7	Ensuring user safety & CE conformity (Machinery Directive)

Currently a feasibility study is underway to propose technological directions that would be able to meet all the constraints related to the activity to be assisted. As the strategic analysis and activity analysis stages, this phase is conducted by a multidisciplinary team of robotics engineers and ergonomists. Potential technological approaches will be discussed with the finishing operators and the piloting committee to decide whether to go further in this assistance track or iterate to specify or modify the constraints to be fulfilled by the assistance system.

4 Conclusion

The development of collaborative robotics and the emergence of new technologies more generally will continue to transform production systems and the activities of human operators. These new technologies, although they present significant potential for the future, must be thought out and implemented with great caution. In fact, what is supposed to improve performance or improve working conditions represents at the same time a risk of disturbing the existing system, degrading productivity [9] or even placing additional constraints on human operators [10].

To avoid undertaking unnecessary investments, it is necessary to verify the need in terms of these technologies and the presence of a real potential added value for the existing system (increased productivity, improved quality, reduced effort and hardship). A preliminary analysis of the strategic challenges and the real activity targeted is essential before starting the technical feasibility study of any new technology, especially technologies with high interactivity with humans, such as collaborative robotics.

Even after the emergence of potential technical solutions, they must be tested and evaluated to ensure their adequacy with the requirements of the activity being transformed. This transformation must not downgrade the activity of human operators; the dimensions related to the perception of this transformation, its acceptability and the meaning of the work of human operators must be at the heart of the design, evaluation and deployment processes of potential technological solutions.

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