# A Methodology to Formulate User Requirements for Designing Collaborative Robots*

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***Abstract*— In this paper, we are going to present a methodology for gathering user requirements to design industrial collaborative robots. The study takes place within CoLLaboratE, a European project focusing on how industrial robots learn to cooperate with human workers for performing new manufacturing tasks, considering four use cases. The project follows a User-Centered Design approach by involving end-users in the development process. The user requirements will thus be gathered by applying a mixed methodology, with the purpose of formulating a list of requirements which can be generalized, but also case specific. This methodology is preliminary, and it will be improved during the following months, when the data will be collected and analyzed.**

## I. Introduction

In the last 30 years, robotics technology has brought remarkable efficiency gains to industrial manufacturers. Robots can be deployed in many different market domains, each having its own needs and requirements. Nonetheless, industrial robots need precise programming, each task having to be broken down into an array of movements. This path does not provide the ability to learn from experience, new programs being required in order to perform new tasks. Consequently, the robot market for industrial applications with predictable and well-defined tasks is limited. Despite the costs of industrial robots being cut, it is still difficult to improve their ease of use in the industrial robot space. More challenging robotic tasks, such as the assembly application, allow even less flexibility and higher programming time. Robotic assembly has proven challenging to automate due to e.g., complex materials, precise grasping requirements, part variations, operations requiring high precision, etc. [1].

Hence, when designing a robot, the entire system should be taken into account, considering all the factors that influence the robot itself, as well as the humans interacting with it [2]. An increasing interest has been observed over the past few years, as the notable potentials and benefits of human-robot collaboration (HRC) have become more obvious within the scientific and industrial sectors. As robots are known to improve the quality of life, humans can provide experience, transfer knowledge and supervise robots' functionalities, contributing to a successful achievement of a wide range of tasks [3][4]. Thus, the human as a user, can interact directly with a robot by sensing its position, by manipulating its configuration, or by using an interaction device [2]. By considering these facts, the initial study performed in the CoLLaboratE project focuses on gathering requirements from users, to design an entire robot technology which recognizes all the factors within a given scenario.

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## II. Project Background

The CoLLaboratE strategy is based on a continuous, iterative and synergic interaction between the end-user community, setting the requirements for integrating robotic platforms in collaborative assembly lines, and the Artificial Intelligence (AI) Technologies providing new and advanced tools for introducing robustness and flexibility to the robotic assembly platforms and autonomous vehicles. By combining industry needs and AI research on robotics, CoLLaboratE follows a User-Centered Design approach, by involving end-users with the ultimate goal of developing a solution that will be effective due to its ease of deployment and flexibility. To accomplish this, the project's objectives are:

- To equip the robotic agents with basic collaboration skills easily adaptable to specific tasks
- To develop a framework that enables non-experts teaching human-robot collaborative tasks from demonstration
- The development of technologies that will enable autonomous assembly policy learning and policy improvement
- To develop advanced safety strategies allowing effective human-robot cooperation with no barriers and ergonomic performance monitoring
- To develop techniques for controlling the production line while making optimal use of the resources by generating efficient production plans, employing reconfigurable hardware design
- To investigate the impact of Human-Robot Collaboration to the workers' job satisfaction, as well as test easily applicable interventions in order to increase trust, satisfaction and performance
- To validate CoLLaboratE system's ability to facilitate genuine collaboration between robots and humans.

Four use cases have been identified within CoLLaboratE, from different industries and applications: performing a (1) car starter assembly, (2) LCD TV assembly, (3) windshield visual quality check and (4) aerospace structure riveting. They will enable to capture, analyze and communicate user needs and requirements.

## III. Methodology

In order to have a comprehensive analysis of the use cases, a mixed methodology, a combination of qualitative and quantitative methods, is applied [5]. The qualitative perspective offers an understanding of the users' perceptions by considering non numerical data such as text, pictures or videos [6], while the quantitative approach uses numerical values, used here to quantify the data and validate choices [7].

Gathering requirements can take multiple forms. Therefore, user requirements formulated within CoLLaboratE should answer the following questions, retrieved from [2]: (a) In what environments must the robot operate? (b) Are there any dangers, which the robot must react to? (c) What interaction is required with the environment? (d) Does the user require sensory feedback from the environment? (e) Is it necessary to manipulate the environment? (f) What interaction is required between the user and robot? (g) What is the workload of the user? (h) What training is available? (i) What are the mission requirements? (j) How accurate must it perform its operations? (k) What functions must the robot perform? (l) Are there any optimisation criteria? However, these questions should represent the minimum of received information, as other areas of interest might also be identified as the outcome of the study. The process of formulating user requirements consists in data collection, analysis and interpretation, as presented in Fig. 1.

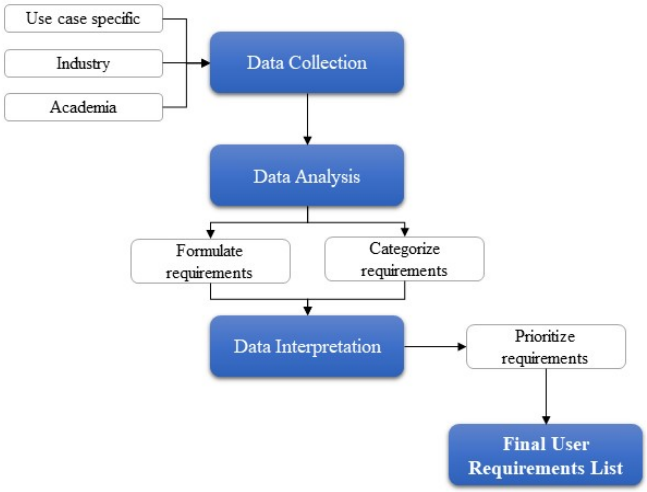


Figure 1 - The process of formulating user requirements within CoLLaboratE project

The data collection within CoLLaboratE includes interviews with use case representatives to document their needs, conducting semi-structured interviews with three predefined areas of interest, allowing to facilitate open discussions. First is to identify the problems with the current situation, how do they solve problems in each of the use cases and what other problems there are, which can be relevant for the technologies developed within CoLLaboratE. The second focus area relates to the user environment, e.g. who the end-users are, including their background information, and what kind of services would they need to use these technologies. The last area of interest is to discuss non-functional requirements such as expectations about performance, maintenance, support, security, installation, safety and others. The interviews are planned for two hours for each use case.

Besides the interviews, the use case representatives are asked to provide text, pictures and video files of the use cases, in order to better observe and understand their applications. Since these methods help in understanding and documenting the use cases, a more general approach is adopted as well, to collect information from other representatives of industry and academia. A survey with 15 questions was prepared to gather insights about collaborative robots. It focuses on the type of organization the subjects represent and depending on this, which would their needs be if they were to adopt collaborative robots to automatize their processes. A sample of minimum 20 subjects is expected to answer this survey [8].

Upon collection, the data will be analyzed with the purpose of formulating a list of user requirements and categorize them as use case specific and / or general, which can be applied to all use cases. Furthermore, all the results will be integrated in a prioritization matrix and ranked based on multiple criteria. Thus, the matrix considers three ranking perspectives: end-users, customer and development, each having three ranking criteria, yet to be decided on. A 1 to 5 Likert scale will be used and an average for each identified user requirement will be calculated. Based on these perspectives, a prioritization of requirements will be possible, based on the value for the end-user and ease of development, by also considering the value for the customers. This is important as it will facilitate discussions when transforming the user requirements into system requirements.

## IV. Results and Conclusion

The results and analysis of this study will be conducted during the following months. We expect to have a comprehensive list of user requirements which will serve a base for defining the system requirements, including the robot functionalities. Thus, the analysis will combine use case related and general requirements which will highlight similarities and differences in designing robotic solutions. This will facilitate discussions needed to successfully introduce robots within the four identified industrial scenarios.

## Acknowledgment

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## References

[1] Robotics 2020 Multi-Annual Roadmap, available at eu-robotics.net
[2] J.R. Goodwin, and A. Winfield, "A unified design framework for mobile robot systems", Diss. University of the West of England, Bristol, 2008.

[3] A. Ajoudani, A. M. Zanchettin, S. Ivaldi, A. Albu-Schäffer, K. Kosuge, and O. Khatib, *Progress and prospects of the human–robot collaboration*, Autonomous Robots, 2018, pp. 1-19.

[4] O. Khatib, K. Yokoi, O. Brock, K. Chang, and A. Casal, *Robots in human environments: Basic autonomous capabilities,* The International Journal of Robotics Research, 18(7), 1999, pp.684-696.

[5] A. Tashakkori and C. Teddlie, *Handbook of Mixed Methods in Social and Behavioral Research,* Sage, 2003

[6] J.H. McMillan, *Educational Research: Fundamentals for the consumer,* HarperCollins College Publishers, 1996

[7] O. Gelo, D. Braakmann and G. Benetka, *Quantitative and qualitative research: Beyond the debate,* Integrative psychological and behavioral science 42.3, 2008, pp. 266-290.

[8] https://forms.gle/44a3tHV6Q1ZsAGk3A