# Human-Centered-Design for Definition of New Collaborative Scenarios

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**Abstract.** Recent technological advances have changed user-centered design criteria in industrial work contexts. The growing potential of technologies is changing industrial activity, in particular the use of collaborative robots able to involve the production operator.

Starting from the study of the regulatory framework of the Robotics and the state of the art, the paper provides an overview of the different categorizations in the literature related to human-robot collaboration through the identification of illustrative industrial application associated with these categories.

From a Human-Centered perspective and through the methods and approaches of the design discipline, the contribution proposes new evolutionary scenarios for the identification of "implementations" to be introduced in collaborative robotics, where human-robot interaction methods optimize the production process in terms of predictability, reliability and usability.

It will be possible to focus on regulatory aspects and on the hypothesis of new regulatory tools and protocols needed to clearly and effectively define human-robot interactions.

**Keywords:** Manufacturing industry · Human-oriented · Collaborative categories · Intelligent systems · Robotic standards

## 1 Introduction

From the analysis of industrial contexts, the collaboration between production operator and robotic system allows the increase of productivity and the improvement of working conditions through the reduction of health risks and the definition of innovative technological paths for the improvement of the production performance, product quality and safety of production operators. The evolution of the industry is therefore characterized by the synergy between robotic capabilities and human skills [1] for the definition of efficient and human-centered production systems [2].

The increase in production speed – supported by the use of technologies – makes it possible to raise the level of efficiency and productivity and therefore it is necessary to pay special attention to the human factor, safety and well-being of the user who interfaces with the robot. In fact, the massive use of robotic solutions in industrial environments leads to the optimization of production processes and the identification


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of new solutions and “smart” workstations based on physical, cognitive, sensory, social and emotional interaction between man and robot for the enhancement of human capital. Industrial workspace management imposes new requirements to satisfy such as the reliability and safety of the users who generally use robots and work in spaces dedicated to collaborative robotics [3]. Current collaborative robots have limitations in “interactions” and insufficient safety protocols exist suggesting the need to rethink factors related to human-robot interaction and adaptability of robotic systems through the correct safety assessment of the system to be deployed. Previously, no user was allowed to cross the robotic cell, but thanks to technological and regulatory advances – albeit slow ones – human-robot interaction is now allowed.

However, without concrete safety guarantees, users are not allowed to work with robots in the immediate vicinity. In fact, collaborative tasks require a shared location, simultaneous efforts, less rigid physical barriers, or only in some cases absent [4]. The implementation of collaborative systems defines the paradigm shift from traditional methods of ensuring the safety of production operators without the use of fences or light barriers [5]. The issue of safety assessment for the user in the performance of collaborative tasks is an essential component in the evaluation of human-robot systems. The paper, in this sense, investigates the collaborative workspace and the activity of the robotic system in relation to the user-operator. In particular, industrial interaction environments are identified through the analysis of collaboration that meets regulatory requirements and safety standards that affect the user during the performance of operations.

## 2 Human Robot Collaboration in Production Processes

The transition of manufacturing towards the adoption of collaborative systems projects, manufacturing systems towards the development of the factory that proactively responds to changing market demands. The inclusion of robotic systems in the industrial fields, aims to implement “smart” workstations by optimizing human-robot interactions. This approach changes the concept of work and invests in new skills aimed at smart, sustainable, and inclusive growth by improving autonomy in automation processes. The Human-Robot Collaboration methodology changes the design criteria of collaborative workstations and foreshadows innovative ways of future production, aiming to identify the cells that benefit most from the application of collaborative robotics. Human Robot Collaboration refers to ISO Technical Specification TS/15066[1] which integrates the provisions and information on the operation of collaborative industrial robots given in ISO 10218-1[2] and ISO 10218-2[3] and provides guidance for the operation of collaborative systems that share the same workspace as people, where process parameters such as speed and force are controlled.

[1] ISO/TS 15066. Robots and Robotic Devices: Collaborative Robots; International Organization for Standardization: Geneva, Switzerland, 2016.

[2] ISO 10218-1. Robots and Robotic Devices—Safety Requirements for Industrial Robots—Part 1: Robots; International Organization for Standardization: Geneva, Switzerland, 2011.

[3] ISO 10218-2. Robots and Robotic Devices—Safety Requirements for Industrial Robots—Part 1: Robot Systems and Integration; International Organization for Standardization: Geneva, Switzerland, 2011.

It is mainly based on the collection of data of the performance parameters deriving from the analysis of the ergonomic factors and of the position of the user-operator with respect to the robotic system in the production line as well as from the analysis of the times and of the logistic system in order to improve the performance in carrying out the tasks in a collaborative perspective.

In particular, the ISO/TS 15066 technical specification responds to the new needs that have emerged from the implementation of collaborative robotic systems within industrial production contexts and the need to provide concrete answers in terms of safety, defined as a tool in favor of collaboration between robots and human operators [6]. ISO/TS 15066 regulates robotic operating cells, according to different applications without the inclusion of protective perimeter cages. Through the application of safety measures on various levels and the definition of invisible barriers with boundaries not to be crossed, the robotic system slows down to a standstill in case of unsafe contact with the operator.

## 3 Categorizations of Human-Robot Collaborations

The prospect of configuring a robot as a human "collaborator" currently represents one of the most encouraging frontiers of the industrial world able to meet the needs of fields and to ensure precision, efficiency, and flexibility. The Human-Robot Collaboration is able to effectively perform collaborative actions, reducing costs, safely, and preserving the specific skills and abilities of operators in interactions by enabling ergonomic reconfiguration of production processes.

Different modes of classifying human-robot collaboration can be found in the literature in the context of industrial scenarios, starting from the classification realized to describe the three levels of collaboration identified by Shi et al. [7] based on the possibility of sharing the workspace and the way the robot operates and moves. In detail, low level collaborations are considered when the user does not enter the robot's field of work; medium level when the robot's servo systems are disengaged while the human is present; high level when the robot has the possibility to be close to the human to perform simultaneous actions.

In the same year, Someshwar et al. [8] introduced time and synchronization in relation to cooperative task performance. They then describe how the robotic system can be activated in three different ways: time-dependent based on previously established fixed intervals; sensor-dependent on the system where the robot adapts its actions to those of the user; and finally the environmental parameters that take into account buffering and the presence of single and multiple robots, exclusive or shared tasks, and repetitive or single processes. A further categorization is offered to us by Michalos et al. [9] who describe task sharing through various levels of interaction to optimize the synergy between user and system. In detail, they classify: the shared task and workspace, the shared task in separate workspaces, and finally the shared task and workspace with the inactive state of one component at a time. Subsequently, Cesta et al. [3] realize a categorization based on the degree of spatial and temporal interdependence of the tasks of each agent. The different categories identified are shown below: independent in which for individual production processes the robot and the operator work on separate parts independently (Fig. 1).

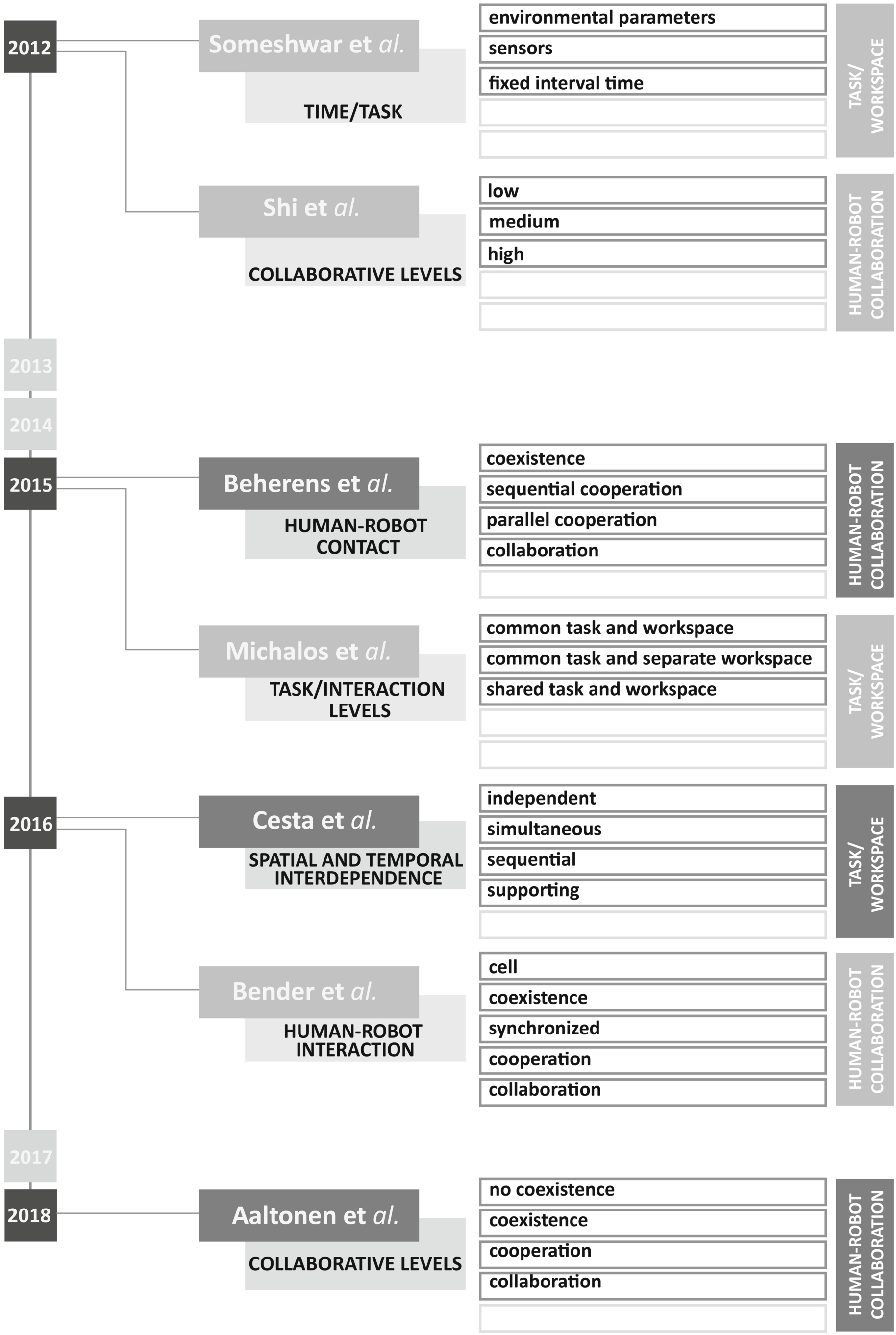


**Fig. 1.** Evolution of human-robot collaborative characterization typologies.

Collaboration occurs through the co-presence of the operator and robot in the same workspace without protection and enclosure; simultaneous where the cobot and operator work simultaneously but on separate processes on the same part; sequential where the cobot and operator perform sequential machining processes on the same part.

In this situation there are time dependencies between the robot and the operator and a machining process performed by the cobot represents an input needed to support the operator in the next task; support where the operator and cobot work in the same process and on the same part interactively, defining temporal and spatial dependencies between the actions of both.

The five levels of interaction described by Bender et al. [10] are interesting to investigate the relationship between robots and operators after analyzing several industrial applications such as coexistence, assembly, and interaction. The identified levels are cell without cooperation, coexistence with non-shared workspace, synchrony involving the presence of the robot or the user, cooperation with shared spaces and non-simultaneous tasks, and finally collaboration with simultaneous work on the same product.

Further classification was defined by Behrens et al. [11] taking into account the presence of physical contact between cobot and human, and in detail, the categories identified are coexistence where adequate distances or separation structures are present, without physical overlap between the work areas of the two agents; sequential cooperation during which physical contact can occur and where on the same workpiece in order, the human and the cobot perform successive tasks; parallel cooperation where human and robot simultaneously perform tasks on the same workpiece in the shared workspace, but physical contact is excluded; and cooperation where physical contact is essential in joint and simultaneous actions.

As reported by Aaltonen et al. [12], collaboration must be expressed through the use of multiple factors to obtain the satisfactory and clear classification, proposing a classification model based on four levels of collaboration: no coexistence where there is physical separation between humans and robots; coexistence where humans work with robots in shared space but without shared goals; cooperation where humans and robots work for a common goal in a shared space; collaboration where humans and robots work simultaneously on a shared object in a shared space (Fig. 1).

## 4 Defining New Evolutionary Scenarios for Collaborative Robotics

Starting from the categorization realized by Aaltonen et al. [12], the different "interpretations" of human-robot interactions of the authors have been individually analyzed, implementing the work done through representative illustrations of collaborative applications found in industrial contexts (Fig. 2).

Subsequently, starting from the overview of the different categorizations in the literature and the identification of reference applications, it was possible to propose a further classification that takes into account the technical specification ISO/TS 15066 of 2016 "Robot and robotic devices - Collaborative robots" and refers to the criteria for assessing the risks generated by the use of collaborative robots and the levels of safety such as to be able to work next to operators without danger (Fig. 2).

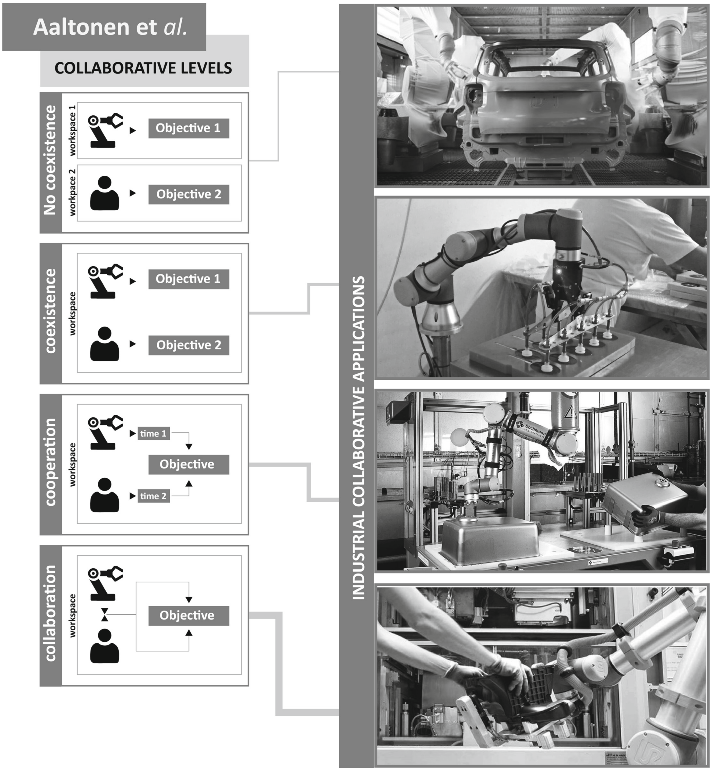


**Fig. 2.** Correspondence between characterizations identified by Aaltonen et al. and industrial applications.

The proposed categorization is in line with the operations foreseen by the above-mentioned regulation in particular:

- safety monitored stop that links robotic systems with workspaces where the robot acts alone and interacts occasionally with the user-operator;
- speed and separation monitoring that considers the minimum safety distance detected that the user-operator must respect through the use of scanners and vision systems and if not, the robot reduces its speed of action until it stops;
- hand guiding where the operator comes into contact with the cobot to guide the robotic arm and plan the desired trajectory through kinaesthetic learning modes;
- power and force limiting where the cobot is able to sense abnormal force levels by detecting excessive loads so as to stop and dissipate forces in case of impact [6]. In addition, the new classification considers the design criteria in EN ISO 13849-1[4] "Safety of machinery - Safety-related parts of the control system - General principles for design", which provides instructions for implementing safe systems (Fig. 3).

[4] ISO 13849-1. Safety of Machinery—Safety-related parts of control systems—Part 1: General principles for design; International Organization for Standardization: Geneva, Switzerland, 2015.

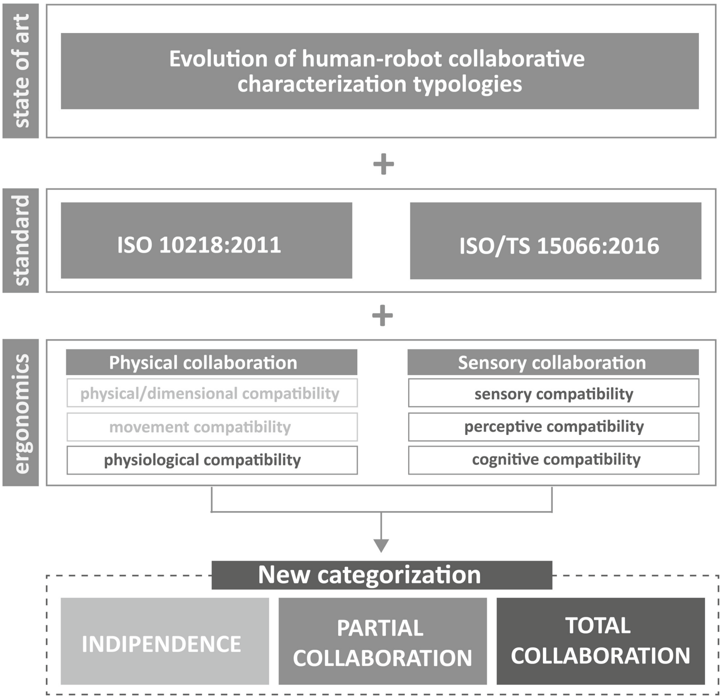


**Fig. 3.** Levels of construction of new collaborative categorization.

The classification implements the previously outlined levels of collaboration and focuses on the previous cases introduced by Behrens et al. [11], Cesta et al. [3], and Aaltonen et al. [12], while making a simplification of the subcategories into Independence, Partial Collaboration, and Total Collaboration. The Independence category includes examples of non-direct human-robot interaction, where no physical contact occurs but they can coexist even in the same workspace. Partial collaboration includes cases in which there is contact between humans and robots, but only from a physical point of view. Finally, in the Total Collaboration category, factors related to the sensory-cognitive sphere are evaluated in addition to physical interactions. Effectively, in the previous categorizations, all the factors analyzed were always found to be strictly physical in nature. Instead, the proposed implementation considers the possibility of making humans and robots interact also from a sensory and cognitive point of view through the analysis of sensory, perceptual, and cognitive compatibilities (Fig. 3). This process will allow the analysis and design of possible interactions between humans and robots for the implementation of safety levels in the use of new collaborative systems.

## 5 Conclusions

Actually, the use of collaborative robotic systems favors the study of human-robot interaction, opening new scenarios and new fields of research. The collaborative robot together with the tools of Industry 4.0 and digital manufacturing, represent valid solutions with which to meet the needs of product customization.

We are now talking about Industry 5.0, which will strengthen robot-human collaboration in an inclusive, human-centric manufacturing future that will define collaborative systems no longer as innovative tools but as concrete options applied in the industrial world.

The research has provided a framework within the categorizations of human-robot collaboration present in the literature until the definition of new collaborative modes, implementing the previous approaches characterized by the analysis of physical factors through the inclusion of additional factors of sensory-cognitive type while maintaining in the foreground the safety of human-robot interactions, defined by current standards of reference.

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