Industrial Collaborative Robot Design

A guideline for future design activity

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Abstract. This study explores the rapidly expanding Collaborative Robot market and the recent literature in *social robotics*. An attempt is made to interpret both resources to define macro-parameter trends that could be useful guidelines for robot designing. The market shows a trend towards anthropomorphism in collaborative robot design, though some studies suggest that functionality of robots (not sociality) should always be explicit and evident in their design. An unknown area of convergence between these two trends is hypothesised; here hides the most anthropomorphic design accepted by human collaborators.

Keywords: Design, Collaborative Robot, Robot Design, Industrial goods, HRI

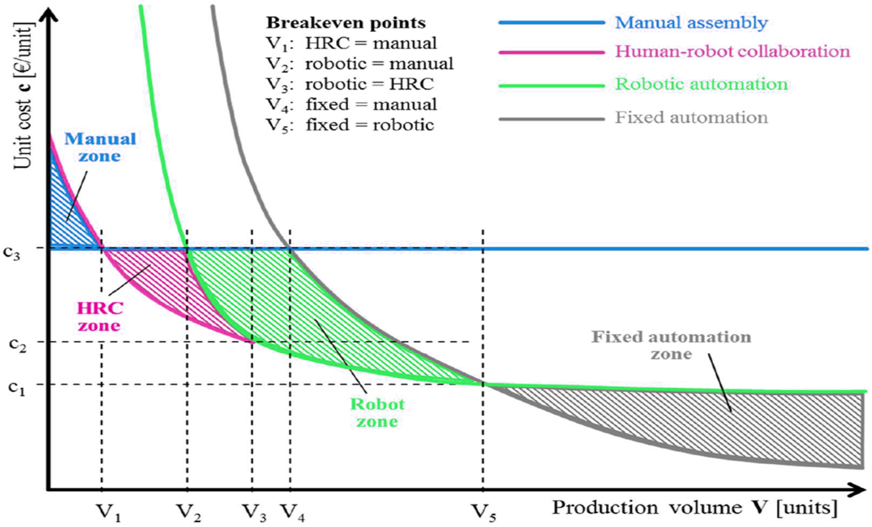
1 Introduction

Scientific sub-fields within *Robotics* are increasing and exploring its specificity in depth. Increasing results in the last decade underlines how this discipline is becoming central in shaping future society. The Human Robot Interaction (HRI) conference is an example of the latter: in its 10th annual congress it has collected many of remarkable works confirming its landmark status in robotic studies [15,16]. Being strongly interdisciplinary the HRI board suggests reflecting on the current and future relation we have with robots, underlining the pervasive presence of this “entity” constantly less recognized as simple product or industrial good. There are an increasing number of *Social Robotics* studies that analyse and test humanoid robot’s effects designed for social or service purposes, where interaction dynamics are the main focus of interest. Between 2006 and 2015, 8 out of 10 most cited articles focus on interaction between people and humanoid robots, some of these are [17,18,19,20,21].

2 Collaborative Robots

The technological expertise that the world of robotics boasts has been largely exploited in industries, especially where the flexibility of the productive system is a strategic competitive factor. The rapid growing benefits brought manufacturing companies to an increase use of robots alongside human operators, since they are becoming safer, smarter and cheaper. Collaborative Robots (CR) or Cobots formerly introduced by Colgate, Wannasuphoprasit and Peshkin [8], are now in expansion; working cooperatively with humans, they reach high efficiency in operations that previously were handled only by them, for instance complex product assembly lines. In Fig.1 the pink coloured area shows the production volume gap in which HRC is convenient.

Fig. 1. Adjustment from Matthias [14]



The CR is a safe robot that interacts and works alongside operators with no cages required, opening a large number of new possibilities. Human robot collaboration (HRC) will be a competitive factor for a number of undiscovered or untested tasks and functions. Main robot manufacturing firms, committed to fabricating robots with multiple purposes, are now offering at least one CR product on the market. The main products and producers are listed below.

- Apas (Bosch)
- Baxter and Sawyer (Rethink Robotics)
- Biorb (Bionic Robotics)
- DexterBot (Yaskawa Motoman)

- iiwa (Kuka)
- M1 (Meka Robotics)
- Nextage (Kawada Industries)
- PF 400 and PP100 (Precise Automation)
- PRob (F&P Personal Robotics)
- Roberta (Gomec, ABB group)
- Speedy10 (Mabi)
- UR3, UR5 and UR10 (Universal Robots)
- YuMi (ABB)

The growing scientific community focused on CRs is largely committed to studies related to functional interaction between robots and humans: the literature supplies designers with tools to increase cooperation efficiency in some specific tasks as [9,10,11,12]. Thus, if our goal is to test the robot's formal design and the effect that this produces, we need to set specific focus parameters to our study. The past ten years of social robotics study results could be invaluable for CR optimization. Along this we think that Design, with its multidisciplinary and user centred predisposition, could be a strategic mediator between these two worlds.

Donald A. Norman in his essays *Emotional Design* and *The Design of future Things* had already reflected on the implications of robot introduction in our private and professional environment [6,7]. His thought, developed during his groundbreaking studies on cognitive sciences, analyses interactions on three levels: visceral, behavioural and reflective elaboration. Similarly [1] proposes a recent model that categorizes interaction levels based on influential factors: visceral, social mechanics and social structure. If we acknowledge this representation as a shared model of analysis, it could be useful not only in social robotics but also in mapping results with implications in CR. As previously mentioned, the aim is to focus on design activity for formal and aesthetic purposes, not functional ones.

3 Visceral factor of interaction with CR

Kaplan in his famous study [13] gives an interesting and effective panoramic to understand the cultural phenomenon of robots in both Japan and occidental countries. By analysing the differences of the two contexts, the obstacle factors for humanoid robots diffusion in USA and Europe are well explained; hence in occidental countries mechanomorphic robots are more widespread than humanoid ones. In other studies like [2], the user's aesthetic preferences are analysed and vary depending on the engaging activity. Human-oriented robots are preferred for social tasks and product-oriented robots for functional tasks. General industrial robots belong to the second group, while CR, sharing proximity and working in symbiosis with human operators, require some social skills and mannered movement that may improve work environment.

Collaborative robots Baxter and Sawyer are an example of how Rethink Robotics, leading US robot producer, interprets this opportunity: the robot eyes, always visible on the monitor, have the functional aim of revealing to the human operator the next task area and as a second effect they create a personal link with him increasing the perception of active agency [1]. People collaborating with it for a long time start to consider it as a human entity rather than a machine, as Allison Sauppé confirm studying some Baxters at Steelcase [8]. Another experience that guides us to the same conclusion comes from the research project that Kuka lead developing iiwa [3]: the design shift from the second to the third version of the product results in wire integration and more organic shape styling. The result of augmented anthropomorphism is one of the preferred upgrades their customers recognize. In a similar way YuMi (fig.2) from ABB has human-like shape properties too that can stimulate our unconscious in a visceral way, producing a natural empathy for him. In [5] is analysed how the redundancy of the 7 axis arm mimics the movements of a human arm and how this feature promotes better human-robot coexistence: co-operators are less stressed with this kind of kinematics. The market shows us a general trend for anthropomorphic shapes though sometimes there is no functional need for them. DexterBot from Yaskawa is provided with two 7 axis arms like Dexter and YuMi and, for promotional needs, is exhibited with a non functional head (fig.3).

Fig. 2. Co-worker stress test with YuMi [5]

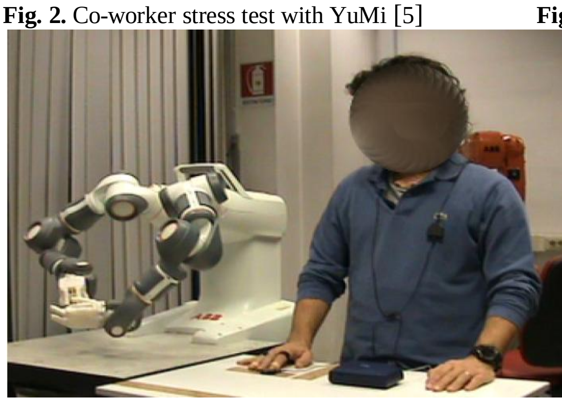
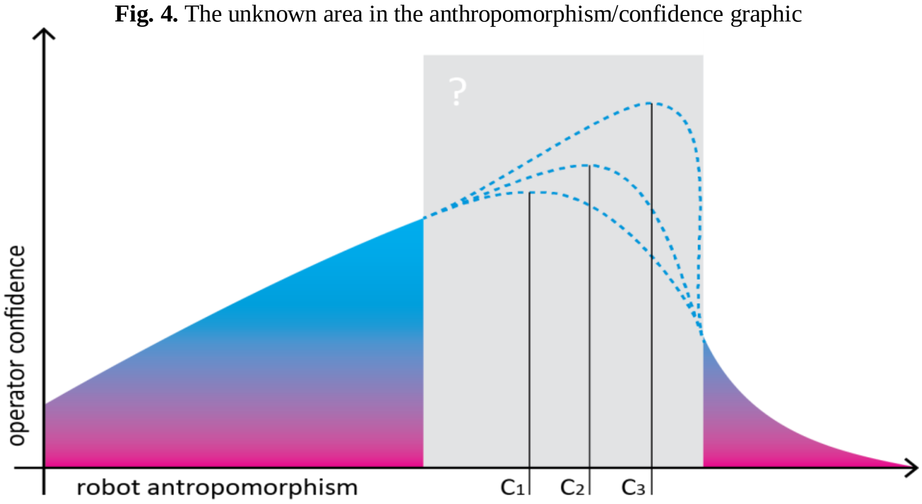


Fig. 3. Non-functional head - DexterBot

4 Future implications.

An in depth reading of the uncanny valley theory [4] suggests a guideline for future robot design activity: coherency between the anthropomorphism level of the robot's diverse features. The presence of human-like and machine-like characteristics could provoke a natural repulsion for this entity. For instance, a human-like robot performing a 360° degree shoulder rotation is unnatural and unsettling for human coworkers. Since it is not possible to design collaborative robots without key functional kinematics, beyond human limits, a strong "functional design" is required. In conclusion, the market analysis suggests that insurmountable limit for anthropomorphism is yet to be found; at the same time literature warns of its existence (C_1, C_2, C_3 in fig.4). An unknown area of convergence between these two trends is hypothesised in the graphic below. Designers should design future collaborative robots following this balance. Yumi and Dexter-bot robots are CR that explore this unknown area; due to their anthropomorphic double arm configuration they are more likely to evoke active agency, and humans tend to behave socially with them. Baxter goes farther and promotes interaction through its monitor eyes. The guideline suggested in this paper is to develop CR with these kind of anthropomorphic features, designed with a clear mechanical aesthetic: the result shouldn't mimic humans just inspire their social way of interaction.

Fig. 4. The unknown area in the anthropomorphism/confidence graphic



5 Conclusions & Aknowledgment.

This study reflects upon CR market trends and the future role of designers. The hypothesis suggests the possibility of mediation among robot functional, technical, social and interactional characteristics due to designer's multidisciplinary study background. After, a view on contemporary anthropomorphic CR design trends is suggested to supply designers with a useful guideline for their projects.

This study about CR, is part of a broader work entitled "Design driven innovation for Industrial Goods", doctoral research that the author is conducting at the Department of Architecture, University of Bologna.

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