16.0 HUMAN-ROBOT INTERACTION (HRI)

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ABSTRACT

Human-Robot Interaction (HRI) is a new born field that is gaining more and more interest. From the 90s robots became to be more present in the society, in parallel the attention reserved to HRI has grown. From the industrial world, where robots started, they are moving to public places e.g. hospitals, museums and schools. Nowadays is not futuristic to have a robot in our home. A quantitative review of the literature linked to HRI has been performed with the scope of understanding the HRI state of the art concerning REELER's themes. The queries and the analysis of the meaningful articles highlighted the necessity of renew design tools to include ethical and moral issues.

16.1 Opening

Human-robot interaction (HRI) is a novel discipline born in the mid-90s. According to Goodrich and Schultz[1] HRI is "a field of study dedicated to understanding, designing, and evaluating robotic systems for use by or with humans". Its scope, continue Goodrich and Schulz[1], is "to understand and shape the interactions between one or more humans and one or more robots". Another very interesting definition of HRI is stated by Kerstin Dautenhahn[2] that says: "HRI is the science of studying people's behaviour and attitudes towards robots in relationship to the physical, technological and interactive features of the robots, with the goal to develop robots that facilitate the emergence of human-robot *interactions* that are at the same time efficient (according to the original requirements of their envisaged area of use), but are also acceptable to people, and meet the social and emotional needs of their individual users as well as respecting human values". This definition clearly shows how HRI field is strongly liked with REELER.

HRI is thus a strong multidisciplinary field. Indeed research can be conducted from roboticist aiming at improving technical aspects of the robot, anthropologist and ethologist interested in the human and in the way he interacts with the new entity, and also from artificial intelligence researchers using robots as natural bodies to test their algorithms.

16.2 Methodology

This review adopted the quantitative approach. A preliminary literature search has been performed for the concept 'Human-Robot Interaction' to determine how it has been studied thus far. This first research allowed to choose a cut-off from which a more in-depth analysis has been performed.

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1 Michael A. Goodrich and Alan C. Shultz. Human-Robot Interaction: A Survey. Foundations and Trends in Human-Computer Interaction Vol 1, No 3 (2007) 203-275.

2 Kerstin Dautenhahn. The Encyclopedia of Human-Computer Interaction, 2nd Ed. Chapter 38 Human-Robot Interaction. https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/human-robot-interaction (28 march 2017)

The SCOPUS database was used for search over single word (Human-Robot interaction) and combined words (Human-Robot Interaction + learning / collaborative learning / ethics / human/ user / ethnography / anthropology/ cyber physical system / intelligent autonomous system). Most of the articles were excluded from first screening on title and abstract, whereas final significant articles were selected after full reading.

The review has been carried on having in mind REELER objective: "close the proximity gap in human-robot interaction design and development to ensure a more responsible, ethical uptake of new robots by affecting the process of robot design".

16.3 Discussion

Despite growing interest in HRI, confirmed by our previous findings and other articles e.g. (Malle, Scheutz, Arnold, Voiklis, & Cusimano, 2015), a first important fact noted in almost all articles read is the common certainty that more research in HRI is needed. Indeed in (Sheridan, 2016) is said: "the needs for research on human interaction aspects and participation in robot research and design are huge", and in (Zhang, Liang, & Yue, 2015) that: "the relationship between people and robots is still underexplored. There is need to further investigate how robots can be integrated in a natural manner into the environments where people usually frequent and live". Another consideration supporting this argument is that in the analysis of the selected articles a great amount were novel studies. For example (Buchner, Wurhofer, Weiss, & Tscheligi, 2013) is the first including temporal aspect in his analysis of HRI and user experience, (Sequeira et al., 2016) introduces a new restricted-perception wizard-of-oz method for robots' design, (Warta, 2015) presents a new way in which attitude toward robots can be measured and (Malle et al., 2015) is the first studying how people judge robots.

An attention to HRI research is shared in both the industrial world and non-industrial one, however is interesting to note the different objectives and weights of this effort. In the industrial world can be noted that the final objective is the increase of competitiveness, as said in (Buchner et al., 2013). Furthermore, future challenges will regard more technical aspect as "planning, teaching, display, control, and supervisor monitoring of automatic action" (Sheridan, 2016). On the other hand, for the non-industrial world the focus is on the user acceptability, the ethical issues arisen, and in particular on human-robot social interaction. For example (Sequeira et al., 2016) says that a further research in how to develop and sustain effective social interaction with robots is needed and, again, (Sheridan, 2016) identifies the major challenges in the areas relating to lifestyle, fears, and human values. Now that robots are moving from factories to our homes, hospitals, public spaces and so on, ethical aspects and research in service robotics are becoming more and more relevant for an effective design.

In order to accomplish these challenging objectives many articles present different ways in which they can be reached e.g. with novel design approaches. Indeed, the necessity of changing the design process to tackle new issues is frequently recognized, e.g. (David et al., 2016) says: "socio-technical transformation towards the factory of the future will need new design and engineering philosophies for twofold 'human-centric' and 'cyber-physical' production systems where automation, robotics, and other advanced manufacturing technologies are seen as possibilities for the further enhancement and augmentation of the human's physical, sensorial and cognitive capabilities rather than for unmanned, autonomous factories". A first example can be found in (Sequeira et al., 2016), as already said, where a new version of wizard-of-oz methodology with restricted-perception is presented. In his paper the design process is subdivided into data collection, strategy extraction, and strategy refinement. Core concept of the methodology is the restriction of wizard's, i.e. the person controlling the robot in the data collection phase, senses to better map the identified social interaction strategies to robot's actions. The results of the evaluation phase demonstrate the effectiveness and how the user is positively engaged with the robot.

Considering the design process as user-centered represents the main trend of HRI. Slightly different from this is (Cheon & Su, 2016) that moves the focus on roboticist values and how they are embedded in robots. The author says: "[t]his perspective would go beyond the user-centered view that dominates much of HRI literature". In his paper a more in-depth study of roboticist's values and how they are transmitted to robots is presented and eventually a value sensitive design (VSD) approach is advocated to improve robots' uptake. Analysing interviews done to famous roboticists interesting results have been inferred. First of all is noted that robotics is a strong multidisciplinary field, indeed it is defined as the science of integration. Furthermore, the most important finding is that roboticists rarely talks about values and ethics, probably, (Cheon & Su, 2016) says, is because they are influenced by their background, i.e. engineering. Another issue to take into account is that "values are situated in a variety of places during the design process: stakeholders (users, designers and engineers), the intention behind research projects, external and internal regulations, codes of ethics, etc. We envision that a framework that accounts for values in robot design will need to take into account the multiple places in which values have a role during design". From this consideration emerges the necessity of VSD, especially because "[w]e lack any design frameworks or guidelines for responsible robot design". The objective of this design process is to integrate values into conceptual, empirical and technological investigation. The conceptual part has the scope of investigate "where possible values are identified and redefined as a new concept appropriate to the target context", indeed "depending on contexts and agents, the same value could have diverse meanings". The empirical investigation has the scope of assess values embedded in technologies, here the author makes an interesting digression about robot's definition arguing that "cultural and spiritual values (e.g. mind, emotions) should be acknowledged as one of components in the definition of robot. This may facilitate not only the development of a standardized definition among the same culture but also an understanding of robots in different cultures". The last part, i.e. technological investigation, allows to evaluate how conceptualized values are identified throughout one's interaction with the technology, this is carried on including final users in the design phase.

This different approach comes from work in Human-Computer Interaction (HCI) and science and technological studies (STS) by (Wallach & Allen, 2008). It is an example of collaboration between different disciplinary fields for a useful scope, however it is not always easy. (Cheon & Su, 2016) reported that one interviewee "remarked on trying to work with psychologist but failing to find common ground in their goals". Another contribution, about collaboration, can be found in (Sheridan, 2016): "[h]uman factors professionals can obviously benefit by improved understanding of dynamics, control, and computer science (artificial intelligence) but at least should find ways to collaborate with engineers in these fields in research, conceptual design, and evaluation". Furthermore, he believes that "human factors scientists are more attuned to the realities of living and working with robots than is the general public. Therefore, human factors professionals have an obligation to participate in discussions and policy planning on these issues, including public education". Thus, is clear the importance and the challenges intertwined with collaboration between different fields such as engineering and social sciences.

Also (Stubbs, Hinds, & Wettergreen, 2006) reported difficulties to collaborate. In their study a collaborative human-robot system made of a science team, an engineering team and a rover is analysed. They found "problems in perspective-taking and grounding between the science team, the engineering team, and the rover because of geographic distance and different disciplinary perspectives". All the partners were in different parts of the world. The result was even more interesting; indeed the author says: "was evident that both teams were working exceptionally hard to collaborate and to ensure that the mission's objectives were met". This paper eventually suggests some improvements robot's designer should have in order to help the creation of common ground. In particular robots should give information about:

- "what they do and why", e.g. "Information about the current capabilities of the robot, including technical information about the health of the robot and its instruments. This is typically available in log data but not in a format that is accessible or meaningful to users";
- "Status reports about the activities requested by the users. For example, for each data product requested, the robot should provide information about whether that data product was collected, any discrepancies between the request of the users and the location, time, or method used to collect the data, and, if the data product was not collected, why not";
- "When failures occur, specific information about exactly what failed and why. This information should be easily accessible to users and provided using terminology and language that are easily understood by users";
- "Information relevant to the constraints under which the robot is operating. For example, specific data from the robot about the time, bandwidth, and energy required to collect and transmit each data product". Finding common ground, according to authors, will be fundamental to users' ability to collaborate and trust robots.

Another key issue found analysing the literature is the user experience (UX): how the user perceives the robot and how it can be classified. In (Buchner et al., 2013) a user experience study in a factory in which a new robotic arm was deployed is described. The author monitored the changes in the operator's experience according to: cooperation, perceived, safety, perceived usability, stress, and general UX when interacting with a robot. First of all Butchner notes that the temporal aspect is not considered when previously evaluating UX, indeed the author says: "there is a need to investigate this aspect in more detail. When studying HRI over a longer period of time in the field, the working context offers one important advantage: certified robotic products that can be safely used on an everyday basis". Furthermore, observing the results of questionnaires he continues: "Compared to newly introduced robots, the longer established robots are experienced more positively in general by the operators. They are more positively perceived regarding collaboration, evoke less concerns regarding safety issues, indicate less stress, and are perceived more effective, efficient and satisfying". This is already a first result: older robot is better perceived than the newest. However, after six months the ratings of the newest robot significantly improve, this trend, in any case, didn't continue over time. After 18 months the ratings didn't significantly change compared to the second round. Indeed, this first study highlighted the importance of time when evaluating UX specially in HRI as it influences how users experience the system. Furthermore, during the study has been observed that "the younger the operators are, the less usage problems occur, the better collaboration is perceived, and the less stressful the interaction with robot B, [the newest], is perceived. These findings suggest a close relation between age and user experience".

Another interesting paper regarding the user and how he perceives the robot is (Warta, 2015). In her study Warta presents a novel robot perception scale (RPS) in order to assess attitude towards robots. The author says: “While studying the behaviour of individuals and robots in social contexts is critical to progress in HRI research and the advancement of robotic technology, one recurring limitation has been the lack of emphasis on individual differences in perceptual and reasoning processes addressing behaviour within a social environment”. RPS has the scope of surpassing this limitation. Thanks to RPS researchers in HRI can be helped to create more reliable, trustworthy and effective systems. Indeed, attitudes influence how people use the robot, but also the level of trust.

One important fact emerging from articles is that Roomba is not as other cleaning products, i.e. robots are much more than tools. We judge robots, we modify our behaviour in their presence, we built social relations with them even though no social features, e.g. speech, gaze, are embedded. For example (Forlizzi & DiSalvo, 2006) investigates the presence of Roomba, a service robot, in home and particularly how “the introduction and use of a domestic service robot might influence the habits and practices of housekeeping”.

Main findings are subdivided in three categories: people and products, people and activities, and product and space. Concerning the first category, i.e. people’s expectations of robots and of the Roomba, is noted that, whilst people had high expectations of robots, they did a distinction between Roomba and other robots, maybe because, the author says, it was a commercial product. Indeed, expectations about Roomba weren’t high. Secondly, observing how Roomba changed the practise of housekeeping, (Forlizzi & DiSalvo, 2006) says: “the scepticism of the females was mediated by the excitement of the males, and the functionality of the Roomba exceeded people’s expectation”. ”The Roomba also appealed to children and elders, beyond primary homemakers”. Furthermore, is interesting to note that participants found creative ways to use the robot. Finally, regarding the fit of the Roomba to the environment, was observed that even though the physical structure of the home constitutes a limit people were keen on helping the robot performing its task, e.g. modifying the environment or pre-cleaning. An interviewee says: “I have to help it so it can do its job, it’s like we are partners”.

In conclusion, the author says: “[f]rom the interviews and descriptions of experience of using the Roomba, it is clear that a robotic vacuum differs from a traditional vacuum in several ways. First, the point of entry for the product into the family is critical, and affects the social relations of the family. Second, unlike other cleaning products that are described merely in terms of functionality, the Roomba is described for its functionality, aesthetics, and symbolic merit”. Therefore, continues, “[a] better understanding of the relationship between introducing the technology in a particular context, and shaping the experience and effect or consequences of using the product, is needed”.

Another contribution to the fact that robots are much more than simple objects is given by (Malle et al., 2015). The author states that robots are nor mere tools neither “human”. Indeed, they are judged in a different way with respect to humans: people expected the robot to undertake actions that sacrifices one person for the good of many, i.e. utilitarian actions. To understand how people judge robots is fundamental for Malle since: “[i]n order to properly design robots that have moral capacities, we need to know — before we design them — how humans would respond to such robots. Only empirical studies can inform this design process”. Continuing in his paper Malle raises questions about the possible connection between the moral judgments people makes and the type and capacities of robot. The author recognizes the importance of this question. For sure a huge part of HRI is focused on “just” humanoid robots, maybe because they meet our imagination about robots. In any case, even though a rapid growth of service robots is expected[3], we don't have to forget that the majority of robots are not humanoid ones. Thus, generalizing the results will be a crucial point for future researches. Furthermore, differences in the judgment are found whether the test made explicit comparison between human and robot in the question.

A step forward is done by another paper: (Malle, Scheutz, Forlizzi, & Voiklis, 2016). This time Malle delves into his study addressing the question of robots' aspect and how people's judgement change according to it. Even though he recognizes the necessity of further studies a first interesting result is obtained. Indeed, the author says: "In the present studies, we set out to examine whether this HR asymmetry still holds when the robot agent is depicted with a specific appearance and whether the HR asymmetry varies as a function of this appearance. In two out of three studies, we were able to demonstrate that the HR asymmetry indeed holds, but only when people make judgments about a mechanical-looking robot, not about a humanoid-looking robot. Patterns of blame for humanoid robots were very similar to those for human agents". Malle concludes stating: "our results do raise an important, and familiar question for robot design: Do we really want robots to look like humans and be treated like humans if they do not nearly have human-like capacities? For it appears that even moral judgments may be influenced by a robot's human-like appearance. Robot designers get to control what signals the robot emits to people who interact with it. However, if the signal does not match the capability, then sooner or later predictions on the human side will fail, expectations will be disappointed, and interactions with the robot will deteriorate. It may be particularly problematic to accept the risk of deceiving people about the robot's moral faculties, for false predictions of such facilities might end up causing significant personal and social harm. That is especially true in situations of life and death—the very ones that our experiments have begun to model".

Going back to (Malle, 2016), he concludes with possible implications for the design process e.g. "should a robot always invoke comparison to a reference human or to another robot?" or "should discussion of robots' rights and duties emphasize or downplay the direct comparison to humans". Lastly, Malle argues that "[i]t is now a joint task for HRI and moral psychology to identify the underlying causes for these differences and whether they depend, for example, on various properties of robots (e.g., appearance, capabilities, role) and the human-robot relationship". One gain the necessity of collaboration between such different fields is highlighted.

Not only STS need to contribute to HRI, but also different fields of HRI itself should start to share the effort. In (Malle, 2016) this time the author tries to merge robot ethics and machine morality. The first one, according to Malle, comprises ethical questions about how humans should design, deploy, and treat robots. The second tackles questions about what moral capacities a robot should have and how they can be implemented. These fields have been often treated alone but many examples show they are intertwined, e.g., once again, social robots. Indeed, Malle says: "[any social robot] poses serious ethical challenges to the human design and deployment of such robots, and one of the most important challenges is to create a level of moral competence in these robots that is adequate to the application at hand. This, then, offers a pivotal integration point of robot ethics and machine morality: how a robot's moral competence could help resolve

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3 Service Robotics: Sales up 25 percent - 2019 boom predicted. October 2016. https://ifr.org/ifr-press-releases/news/service-robotics (15 June 2017)

some of the ethical concerns about robots in society and perhaps even guide us to new opportunities of how robots could make valuable contributions to society".

Concerns about the feasibillity of moral competence and what, actually, are the fundamental moral competences are the natural next steps. Malle tries to outline basic elements that define moral competence. They are identified with: a moral vocabulary, a system of norms, moral cognition and affect, moral decision making and action and moral communication. Connected to these features there are ethical questions that need to be adressed e.g. "Should robots have autonomy?", "Should robot always obey to human command?", "Should we allow robot to kill human?", "Should robots have rights and protection?". Malle cloncludes saying: "[a]ll these, and more, questions are up for debate and broad societal discussion. But the discussions must consider both ethical questions about how humans should design, deploy, and treat robots and questions about what moral capacities a robot could and should have. And if robotic design commits to building morally competent robots, then those robots could be trustworthy and productive partners, caretakers, educators, and members of the human community. Moral competence does not resolve all ethical concerns over robots in society, but it may be a prerequisite to resolve at least some of them".

Another vision about roboethics is given by (Kopacek, 2012). The author says: "Currently the ethical behavior of a Robot is determined by the software. The ethical quality of the Software depends directly from the programmers. That means Roboethics is closely connected to the ethical behavior of the software developer. If a robot is good or evil depends mostly from the software or from the ethical behavior of a human". Furthermore he gives his personal answer to the question if robots will ever be more intelligent than human saying "never". This is an interesting point of view such different from general vision, I would say that this is a more 'technical' point of view.

16.4 Conclusion

The analysis of the selected literature revealed interesting results for REELER project. First of all the right timing of the project. Indeed, many articles agree on the increasing attention that HRI is gaining, publications are growing year by year but even more effort is needed. HRI will become part of our everyday life and robots will be an essential component of the society changing permanently our lives. Addressing ethical questions will permit us to decide which kind of society do we want.

To address these issues is firstly needed to define robot. Indeed (Stowers, Leyva, Hancock, & Hancock, 2016) say that "we must address many foundational premises concerning human interaction with and use of technology. For example, no unequivocal or precise boundary conditions exist for what connotes a robot in the first place". (Cheon & Su, 2016) suggest integrating cultural aspects into the robot's definition. It is clear anyway that find a shared definition of robot will be a hard task. Robotics is changing rapidly and more and more tools have a certain grade of intelligence embedded. Is a washing machine a robot? Than kind of questions need a precise and unique answer before proceeding in deeper analysis.

Another point is that a robot is not a mere tool. Many articles, e.g. (Forlizzi & DiSalvo, 2006) and (Malle et al., 2015), highlight how people has different behaviour when a robot is present in the same environment. Humans change the way in which they behave, build social relations with the robot even though, and this is very interesting, the robot is not supposed to have social interaction, only a certain grade of autonomy is needed to elicit this reaction. Thus, designers and roboticist need to pay attention in the way a robot is introduced into its working environment, they carefully need to think how it will be perceived.

Is therefore fundamental to renew the design process in order to tackle new challenges. Many new approaches are presented, the most interesting, in my opinion is the one of (Cheon & Su, 2016). Anyway, even though it is called value sensitive design or moral design, a way in which ethical questions will be embedded in the development phase is needed. Surely the point arisen by (Kopacek, 2012) depict the actual state of the art of HRI. However, the more robots become sophisticated the higher are humans' expectations (they are high even though the robot shows basic features) and chances to build a social relation with them. Therefore, the discussion about moral robot and how to embed ethics is fundamental to prevent future problems.

Eventually robotics is a strong interdisciplinary field, and, going on, it will become even more since STS will be a consistent part of this field. For this reason, collaborative learning and how to build a common ground will be challenges for the effective robots' design. Some hints are given to improve this crucial phase, anyway a deeper research is needed.

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