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The Rise of Social Robots: A Review of the Recent Literature

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Abstract

In this article I explore the most recent literature on social robotics and argue that the field of robotics is evolving in a direction that will soon require a systematic collaboration between engineers and sociologists. After discussing several problems relating to social robotics, I emphasize that two key concepts in this research area are *scenario* and *persona*. These are already popular as design tools in Human-Computer Interaction (HCI), and an approach based on them is now being adopted in Human-Robot Interaction (HRI). As robots become more and more sophisticated, engineers will need the help of trained sociologists and psychologists in order to create personas and scenarios and to "teach" humanoids how to behave in various circumstances.

1. Social robots and social work

The social consequences of robotics depend to a significant degree on how robots are employed by humans, and to another compelling degree on how robotics evolves from a technical point of view. That is why it could be instructive for engineers interested in cooperating with sociologists to get acquainted with the problems of social work and other social services, and for sociologists interested in the social dimensions of robotics to have a closer look at technical aspects of new generation robots. Regrettably, engineers do not typically read sociological literature, and sociologists and social workers do not regularly read engineers' books and articles. In what follows, I break this unwritten rule by venturing into an analysis of both types of literature.[1]

This type of interdisciplinary approach is particularly necessary after the emergence of so-called "social robots." A general definition of social robot is provided by social scientist Kate Darling:

> A social robot is a physically embodied, autonomous agent that communicates and interacts with humans on an emotional level. For the purposes of this Article, it is important to distinguish social robots from inanimate computers, as well as from industrial or service robots that are not designed to elicit human feelings and mimic social cues. Social robots also follow social behavior patterns, have various "states of mind," and adapt to what they learn through their interactions.

On the same page, Darling provides some examples:

> interactive robotic toys like Hasbro's Baby Alive My Real Babies; household companions such as Sony's AIBO dog, Jetta's robotic dinosaur Pleo, and Aldebaran's NAO next generation robot; therapeutic pets like the Paro baby seal; and the Massachusetts Institute of Technology (MIT) robots Kismet, Cog, and Leonardo. (2012, 4)

As we can see, social robots are mainly humanoid or animaloid in form. Their shape is of fundamental importance, since their function is to interact with humans *on an emotional level*, and this type of interaction is grounded in visual and tactile perception no less than in verbal communication.

The use of animaloid robots to comfort and entertain lonely older persons has already triggered an ethical debate. By discussing the manufacture and marketing of robot "pets," such as Sony's doglike "AIBO," Robert Sparrow (2002) has concluded that the use of robot companions is misguided and unethical. This is because, in order to benefit significantly from this type of interaction, the owners of robot pets must systematically delude themselves regarding the real nature of their relation with these machines shaped like familiar household pets. If the search for truth about the world that surrounds us is an ethical imperative, we may judge unethical the behavior of both the designers and constructors of companion robots, and the buyers that indulge themselves in this type of fake sentimentality. Russell Blackford (2012) disagrees with this conclusion by emphasizing that, to some extent, we are already self-indulgent in such fake sentimentality in everyday life and such limited self-indulgence can co-exist with ordinary honesty and commitment to truth. In other words, Blackford does not deny that a disposition to seek the truth is morally virtuous; however, he points out that we should allow for some categories of exceptions.

Pet robots for dementia treatment could constitute one of such exceptions. In the case of patients affected by dementia the priority is not giving them an objective picture of reality but stimulating and engaging them. The main goal of the social worker is helping them to communicate their emotions, to reduce their anxiety, to improve their mood states, and this may be achieved also by the use of animaloid and humanoid companion robots (Odetti et al. 2007; Moyle et al. 2013).

The relevance of social robots should not be underestimated, especially by applied sociologists. In technologically advanced societies, a process of robotization of social work is already underway. For instance, robots are increasingly used in the care of the elderly. This is a consequence of two other processes occurring simultaneously: on the one hand, we have an aging population with a resulting increase in demand for care personnel; on the other hand, technological developments have created conditions to deal with this problem in innovative ways. Priska Flandorfer explains the view of experts from several fields that

> assistive technologies nowadays permit older persons to live independently in their home longer. Support ranges from telecare/smart homes, proactive service systems, and household robots to robot-assisted therapy and socially assistive robots. Surveillance systems can detect when a person falls down, test blood pressure, recognise severe breathing or heart problems, and immediately warn a caregiver. (2012, 1)

In spite of the fact that we tend to associate physical support with machines and psychological support with the intervention of flesh-and-blood social workers, this rigid distinction vanishes when social robots are involved in elderly care. Indeed, Flandorfer elaborates that

> Interactive robots cooperate with people through bidirectional communication and provide personal assistance with everyday activities such as reminding older persons to take their medication, help them prepare food, eat, and wash. These technological devices collaborate

> with nursing staff and family members to form a life support network for older persons by offering emotional and physical relief. (2012, 1)

Social robots are specifically designed to assist humans not only in social work, but also in other activities. One of the main sources of information about robotic trends is a book series published by Springer and edited by Bruno Siciliano and Oussama Khatib. As Siciliano states:

> robotics is undergoing a major transformation in scope and dimension. From a largely dominant industrial focus, robotics is rapidly expanding into human environments and vigorously engaged in its new challenges. Interacting with, assisting, serving, and exploring with humans, the emerging robots will increasingly touch people and their lives. (2013, v)

As Siciliano has noticed, the most striking advances happen at the intersection of disciplines. The progress of robotics has an impact not only on the robots themselves, but also on other scientific disciplines. In turn, these are sources of stimulation and insight for the field of robotics. Biomechanics, haptics, neurosciences, virtual simulation, animation, surgery, and sensor networks are just a few examples of the kinds of disciplines that stimulate and benefit from robotics research. Let us now explore a few examples in greater detail.

2. Effectiveness and safety of human-robot interaction

In 2013, four engineers – Jaydev P. Desai, Gregory Dudek, Oussama Khatib, and Vijay Kumar – edited a book entitled *Experimental Robotics*, a collection of essays compiled from the proceedings of the 13th International Symposium on Experimental Robotics. The main focus of many of these pieces is the problem of interaction and cooperation between humans and robots, and it is frequently argued that the effectiveness and safety of that cooperation may depend on technical solutions such as the use of pneumatic artificial muscles (Daerden and Lefeber 2000). Moreover, each technical device has advantages and disadvantages. For example, one may gain in effectiveness but lose in safety, or vice versa (Shin et al. 2013, 101–102).

An inspiring book on the issue of safety in robotics is Sami Haddadin's *Towards Safe Robots: Approaching Asimov's 1st Law* (2014). Haddadin points out that the topic of research called Human-Robot Interaction is commonly divided into two major branches: 1) cognitive and social Human-Robot Interaction (cHRI); 2) physical Human-Robot Interaction (pHRI). As Haddaddin defines the two fields, cHRI "combines such diverse disciplines as psychology, cognitive science, human-computer interfaces, human factors, and artificial intelligence with robotics." It "intends to understand the social and psychological aspects of possible interaction between humans and robots and seeks" to uncover its fundamental aspects. On the other hand, pHRI

> deals to a large extent with the physical problems of interaction, especially from the view of robot design and control. It focuses on the realization of so called human-friendly robots by combining in a bottom-up approach suitable actuation technologies with advanced control algorithms, reactive motion generators, and path planning algorithms for achieving safe, intuitive, and high performance physical interaction schemes. (2014, 7)

Safety is obviously not a novel problem in robotics, nor in engineering more generally. It has been a primary concern in pHRI, since in this field continuous physical interaction is desired and it continues to grow in importance. In the past, engineers mainly anticipated the development of heavy machinery, with relatively little physical Human-Robot Interaction. The few small robots that were able to move autonomously in the environment and to interact with humans were too slow, predictable, and immature to pose any threat. Consequently, the solution was quite easy: segregation. Safety standards were commonly tailored so as to separate the human workspace from that of robots.

Now the situation has changed. As Haddadin puts it:

> due to several breakthroughs in robot design and control, first efforts were undertaken recently to shift focus in industrial environments and consider the close cooperation between human and robot. This necessitates fundamentally different approaches and forces the standardization bodies to specify new standards suitable for regulating Human-Robot Interaction (HRI). (2014, 7)

These breakthroughs, and in particular the developments of cHRI, have opened the road to a new subdiscipline, or – if one prefers – a new interdisciplinary field: Social Robotics. In spite of the fact that the name appears to speak to a hybrid between the social sciences and engineering, at present, this subdiscipline is mainly being cultivated by engineers, although with a "humanistic" sensitivity.

It is important to keep these aspects in mind, as it is often the case that both technophiles and technophobes tend to anticipate fantastic or catastrophic developments, without considering the incremental, long and painstaking work on robotics which lay behind and ahead. There are many small problems like those mentioned above that need to be solved before we start seeing NDR-114 from the film *Bicentennial Man* (1999) or Terminator-like machines walking around on the streets.

3. Small-scale robots

This does not mean that science fiction literature cannot be a source of ideas for robotic research. Just to give an example, another direction in which robotics is moving is that of small and even smaller automatic machines, such as: millirobots, microrobots, and nanorobots. These robots would interact with humans in a completely different way from macroscopic social robots.

In the Siciliano and Khatib series, there is an interesting book entitled *Small-Scale Robotics: From Nano-to-Millimeter-Sized Robotic Systems and Applications*, edited by Igor Paprotny and Sarah Bergbreiter (2014).[2] In their preface, the editors make explicit the impact that science fiction has had on this area of research:

> In the 1968 movie *The Fantastic Voyage*, a team of scientists is reduced in size to micro-scale dimensions and embarks on an amazing journey through the human body, along the way interacting with human microbiology in an attempt to remove an otherwise inoperable tumor. Today, a continuously growing group of robotic researchers [is] attempting to build tiny robotic systems that perhaps one day can make the vision of such direct interaction with human microbiology a reality.

Smaller-than-conventional robotic systems are described by the term "small-scale robots." These robots range from several millimeters to several nanometers in size. Applications for such robots are numerous. They can be employed in areas such as manufacturing, medicine, or search and rescue. Nonetheless, the step from imagination to realization, or from science fiction to science, is not a small one. There remain many challenges that need to be overcome, such as those related to the fabrication of such robots, to their control, and to the issue of power delivery.

Engineers regularly compare the capabilities of robotic systems, including small-scale robots, to those of biological systems of comparable size, and they often find inspiration in biology when attempting to solve technical problems in such areas as navigation and interactive behavior (Floreano and Mattiussi 2008, 399–514; Liu and Sun 2012; Wang et al. 2006). Paprotny and Bergbreiter write:

> The goal of small-scale robotics research is often to match, and ultimately surpass, the capabilities of a biological system of the same size. Autonomous biological systems at the millimeter scale (such as ants and fruit flies) are capable of sensing, control and motion that allows them to fully traverse highly unstructured environments and complete complex tasks such as foraging, mapping, or assembly. Although millimeter scale robotic systems still lack

> the complexity of their biological counterparts, advances in fabrication and integration technologies are progressively bringing their capabilities closer to that of biological systems. (Paprotny and Bergbreiter 2014, 9–10)

Presently, the capabilities of microrobotic systems are still far from those of microscale biological systems. Indeed, "biological systems continue to exhibit highly autonomous behavior down to the size for a few hundred micrometers. For example, the 400μm dust mite is capable of autonomously navigating in search for food and traversing highly unstructured environments. Similar capabilities can be found in *Amobeaproteous* or *Dicopomorpha zebra*" (Paprotny and Bergbreiter 2014, 9–10). By contrast, microrobotic systems have only limited autonomy; they lack independent control as well as on-board power generation. In spite of the stark performance differences between biological systems and small-scale robots, engineers are far from being resigned to second place. Rather, they think that "these gaps highlight important areas of research while demonstrating the level of autonomy that should be attainable by future robotic systems at all scales" (Paprotny and Bergbreiter 2014, 10–11). Such statements speak to the optimistic mindset of engineers.

4. From navigation and manipulation to interaction

In their book entitled *Human-Robot Interaction in Social Robotics* (2013), Takayuki Kanda and Hiroshi Ishiguro explain quite well the nature of the paradigm change that has accompanied the shift from industrial robots to interactive robots. They remind us that, up to recent times, robotics has been characterized by two main streams of research: navigation and manipulation. The first is the main function of autonomous mobile robots. The robot "observes the environment with cameras and laser scanners and builds the environmental model. With the acquired environmental model, it makes plans to move from the starting point to the destination" (Kanda and Ishiguro 2013, 1). The other stream in early robotics has been manipulation, as exemplified by research on robot arms. Like a human arm, the robot arm is often complex and therefore requires sophisticated planning algorithms. There are countless industry-related applications for both navigation and manipulation, and over the last several decades innovations in these research areas have revolutionized the field. Two different academic disciplines have been competing to solve the problems related to navigation and manipulation: Artificial Intelligence and robotics *sensu stricto*.

According to Kanda and Ishiguro, robotics now needs to engage in a new research issue – interaction:

> Industrial robotics developed key components for building more human-like robots, such as sensors and motors. From 1990 to 2000, Japanese companies developed various animal-like and human-like robots. Sony developed AIBO, which is a dog-like robot and QRIO, which is a small human-like robot. Mitsubishi Heavy Industries, LTD developed Wakamaru. Honda developed a child-like robot called ASIMO. Unfortunately, Sony and Mitsubishi Heavy Industries, LTD have stopped the projects but Honda is still continuing. The purpose of these companies was to develop interactive robots. (2013, 1–2)

Social robotics is gaining in importance because mobile robots are increasingly required to perform tasks that necessitate their interaction with humans. What is more, such human-robot interactions are becoming a day-to-day occurrence. Japanese companies tend to develop humanoids and androids because of their strong conviction that machines with a human-like appearance can replicate the most natural of communicative partners for humans, namely other humans. In the words of Kanda and Ishiguro, the strongest reason for this research program is "in the human innate ability to recognize humans and prefer human interaction." They add: "The human brain does not react emotionally to artificial objects, such as computers and mobile phones. However, it has many associations with the human face and can react positively to resemblances to the human likeness" (2013, 5).

5. Scenario and persona: the challenge of verbal interaction

Appearance is just one of the problems related to the social acceptance of robots. Verbal interaction is equally important. Bilge Mutlu and others have recently edited a book entitled *Social Robotics* (2011) that presents interesting developments in the direction of improved HRI.[3] In one of the book's chapters, Złotowski, Weiss, and Tscheligi clearly explain the nature of this general field of research, as well as the methodology that tends to be used. To begin, they emphasize that:

> The rapid development of robotic systems, which we can observe in recent years, allowed researchers to investigate HRI in places other than the prevailing factory settings. Robots have been employed in shopping malls, train stations, schools, streets and museums. In addition to entering new human environments, the design of HRI recently started shifting more and more from being solely technologically-driven towards a user-centered approach. (2011, 1–2)

Indeed, these particular researchers are working on a project called Interactive Urban Robot (IURO): this "develops a robot that is capable of navigating in densely populated human environments using only information obtained from encountered pedestrians" (2011, 2). Two key concepts in such research are *scenario* and *persona*. These were already popular as design tools in Human-Computer Interaction (HCI), but the approach based on them has now been exported and adopted in HRI. Złotowski, Weiss, and Tscheligi explain that "Scenarios are narrative stories consisting of one or more actors with goals and various objects they use in order to achieve these goals" (2011, 2–3). They continue:

> Usually the actors used in scenarios are called personas. […] The main goal of personas is to ensure that the product being developed is designed for concrete users rather than an abstract, non existing "average user". Often, more than one persona is created in order to address the whole spectrum of the target group. (2011, 3)

An interesting aspect of social robotics is that researchers – even when they are basically trained as engineers – must adopt a sociological or psychological perspective in order to create personas. This happens because the process of persona creation starts with the identification of key demographic aspects of the human populations of interest. In their work on robot-pedestrian interaction, therefore, Złotowski, Weiss, and Tscheligi analyzed the "age range profession, education and language skills" of selected pedestrians and then augmented this with data from pedestrian interviews:

> This information was then enriched by the data obtained during interviews where we asked participants why they approached specific pedestrians. Not surprisingly, we found that one of the most important factors, which impacts the successfulness of the interaction, was whether the encountered person was a local or not. (2011, 4)

It is not difficult to predict that as robots become more sophisticated, engineers will need the systematic help of trained sociologists and psychologists in order to create personas and scenarios and to "teach" humanoids how to behave in various circumstances. In other words, the increased interaction between mobile robots and humans is paving the way for increased interaction between *social robotics* – the study of HRI undertaken by engineers – and *robot sociology* – the study of the social aspects of robotics undertaken by social scientists.

Notes

1. This was also my approach in *Humans and Automata: A Social Study of Robotics*. Some ideas in this article are indeed taken from section 1.4 of that book (Campa 2015, 29–35).

2. The book contains selected papers based on presentations from the workshop "The Different Sizes of Small-Scale Robotics: From Nano- to Millimeter-Sized Robotic Systems and Applications," which

was held in conjunction with the International Conference on Robotics and Automation (ICRA 2013) in May 2013 in Karlsruhe, Germany.

3. This volume collects the proceedings of the third International Conference on Social Robotics (ICSR), located in Amsterdam, The Netherlands, November 24–25, 2011. Equally interesting are the volumes related to the previous and the following conferences. See: Ge et al. 2010; Ge et al. 2012; Herrmann et al. 2013.

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