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ARTICLE

# Humanoid social robots as a medium of communication

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## Abstract

This article examines the emerging phenomenon of humanoid social robots and human–humanoid interactions. A central argument of this article is that humanoid social robots belong to a special type of robotic technology used for communicating and interacting with humans. These robotic entities, which can be in either mechanical or digital form, are autonomous, interactive and humanlike. Some of them are used to interact with humans for utilitarian purposes and others are designed to trigger human emotions. Incorporation of such robotic entities into the realm of social life invariably alters the condition as well as the dynamics of human interaction, giving rise to a synthetic society in which humans co-mingle with humanoids. More research is needed to investigate the social and cultural impact of this unfolding robotic revolution.

## Key words

android • artificial intelligence • communication • human–computer interaction • human–humanoid interaction • robot • symbolic interaction

I am certain that our future, our near future, will include a burgeoning relationship between humans and intelligent machines. I do not see this as a 'cyborg' future, nor do I see it in the overly dramatic science-fiction terms of a

> potential future competition between humankind and machine . . . It is clear to me that the arrival of new nonhuman virtual intelligence is a wholly natural step for humankind. (Hammond, 2000: 340)

A revolution of humanoid social robots is quietly taking place in our society: autonomous, interactive and humanlike entities of various sizes and shapes are leaving research laboratories in large numbers, making their way into the world of our everyday lives (Menzel and D'Aluisio, 2000; Nightline, 2002). Automated teller machines (ATMs), vending machines and automated telephone response systems are standing in for human attendants to serve real people; online search agents, game bots and chat programs are working for and playing with human users; and robotic dolls and pets are cuddling up with children and talking to the elderly. A large army of 'relational artefacts', 'friendly machines' and 'socially intelligent robots' are invading the realm of human social life, sharing the living environment with people, communicating emotionally with humans and learning 'right' and 'wrong'. Some of these sociable robots are even capable of interacting with humans with facial expressions, gaze directions and voices, mimicking the affective dynamics of human relationships. This emerging movement of social roboticization is causing a fundamental change in the meaning of social interaction and the nature of human communication in society.

Human–humanoid interaction, which is the focus of the present study, needs to be distinguished from computer-mediated communication (CMC), human–computer interaction and 'post-human' cyborgization. CMC is human-to-human contact through electronic mediation (Hiltz and Turoff, 1978). There, 'computer' is used as a generic term referring to those electronic devices which enable physically separated individuals to communicate with one another instantaneously across distances. Two-way radios, telephones, networked computers and, more recently, the internet are examples of such devices. Humanoid social robots differ from CMC technologies in that they are not a medium through which humans interact, but rather a medium with which humans interact. Acting as human surrogates, humanoid social robots extend the domain of human expression, discourse and communication into the computerized world.

Human–computer interaction overlaps with human–humanoid interaction to a certain extent. Both involve computers that serve as an interactive medium. However, in human–computer interaction, often the computer is part of a larger technical operation that requires human participation. Research in human–computer interaction as pioneered by people such as Douglas Engelbart (1963) aims to augment human intellect through the creation of 'user-friendly' interfaces that are optimized to the physical and psychological characteristics of human operators. The optimization of computer–user interaction at the interface level allows humans to work more effectively within a technical system. Unlike human–computer interaction, human–humanoid interaction goes beyond the level of interface exchange in becoming part of the discursive communication that characterizes human–human interaction. Humanoid social robots are not user-friendly computers that operate as machines; rather, they are user-friendly computers that operate as humans.

'Post-human' cyborgization refers to the phenomenon of technological restoration, augmentation and alteration of human natural capacities and functionality (O'Mahony, 2002). 'Cyborgs' thus includes not only those who embed silicon chips in their brains to be able to manipulate objects with mere thoughts, but also people wearing restorative prostheses such as pacemakers, artificial limbs, dentures, contact lenses and those who 'pump iron' or take steroids to enhance their muscles or take Viagra to increase their sex drives and prowess (Bell and Kennedy, 2000). Some scholars go even further to include within cyborgization the use of nearly all forms of technologies, ranging from screwdrivers, bicycles, cars and airplanes to the internet. In this broader sense of the term, human–humanoid interaction can be regarded as part of the general process of cyborgization, namely, 'extending humanity' by means of technology (Zylinska, 2002).

Humanoid social robots serve as 'prosthetic extensions' of human individuals by acting as their surrogates in social interaction. Standing in proxy for bank tellers, shop assistants, telephone operators, tour guides, housemaids and playmates, to name but a few, humanoid social robots interact with humans, as humans and on behalf of humans. As a special interactive medium, humanoid social robots enable human individuals to engage in communicative exchanges with others in solitude. Characterized by programmed interactivity, artificial intelligence (AI) and synthetic emotion, this emergent form of human communication is playing an increasingly prominent role in today's computerized society.

Despite the growing prevalence of humanoid social robots in everyday life, there has been a lack of sociological interest in human–humanoid relationships. In recent years, a great deal of attention has been devoted to computer or internet-mediated human–human interactions (DiMaggio et al., 2001) and only a small number of sociologists have concerned themselves with issues related to social robotics. Of those sociologists, some have explored the prospects of using AI technologies to improve sociological analysis (Bainbridge et al., 1994; Carley, 1996), others have looked into the contributions that sociology might make to the social robot project (Collins, 1992; Restivo, 2001), and only very few have examined the social impact of human–humanoid interaction (Turkle, 1984, 1995; Wessells, 1990; Wolfe, 1991). Overall, sociologists know relatively little about humanoid social robots and their effects on individuals and society. A major reason for this is that, for the most part, robotic artefacts have been regarded mistakenly as mere technological gadgets or matters that are of concern only to roboticists and, as such, the sociological implications of this important technological development has been overlooked.

This study aims to achieve three objectives. The first objective is to define humanoid social robots. In the existing literature, humanoid robots have been referred to variously as 'interactive machines', 'autonomous agents', 'mobots' and 'bots'. Obviously, not all of these concepts carry the same connotation. 'Autonomous agents', for example, includes all forms of self-directed entities, whether natural or human-made. While 'mobots' denotes mobile mechanical robots, 'bots' refers to online software agents. In this study, however, 'humanoid social robots' has been chosen as a generic concept referring to all the robotic entities, either physical or digital, that are designed to interact with humans in a humanlike way.[1]

The second objective is to examine the interactions between humans and humanoid social robots. This article would like to argue that, while human–humanoid interaction differs from human–human interaction in important ways, the former resembles the latter in language use, relationality and normativeness. As human surrogates for communication, humanoid social robots are designed to interact with humans not as machines but as humans. Thus human–humanoid interaction is inherently more akin to human–human interaction than human–machine interaction.

The final objective is to reflect upon the sociological implications of human–humanoid interaction. It will be argued that recent incorporation of humanoid social robots into the realm of human communication is giving rise to an important social transformation that will eventually redefine society as well as individuals. The social and psychological impact of this unfolding robotic revolution deserves our attention.

## HUMANOID SOCIAL ROBOTS

The *American Heritage Dictionary for Windows* (1994) defines the robot as 'a mechanical device that sometimes resembles a human being and is capable of performing a variety of often complex human tasks on command or by being programmed in advance'. The second college edition of the *American Heritage Dictionary* (1991), however, defines the robot as 'a mechanical device that resembles a human being and is capable of performing human tasks or behaving in a human manner'. The differences between these two definitions are subtle but non-trivial. While both describe robots as 'mechanical devices' which perform complicated 'human tasks', the second college edition makes human resemblance ('resembles a human being' and 'behaving in a human manner') a necessary rather than optional condition. Furthermore, the electronic edition allows robots to be either externally controlled ('on command') or internally controlled ('being programmed in advance'), whereas the second college edition leaves unspecified the level of autonomy required of a robot. These definitional variations reflect actual differences in existing subtypes of robots.

Humanoid social robots are a special category of robots formally defined here as human-made autonomous entities that interact with humans in a humanlike way. This definition contains three essential components: 'human-made autonomous entities' (robotic), 'interact with humans' (social) and 'in a humanlike way' (humanoid). These three components are elaborated in turn as follows.

## The robotic component: 'human-made autonomous entities'

Humanoid social robots are technological artefacts made by humans. These artefacts can take either physical (e.g. machine) or digital (e.g. animation) form and are endowed with at least a minimum level of autonomy or the ability to act on their own (thus remote-controlled robots deployed in teleoperation are excluded from this category). An autonomous entity is self-directed and self-direction, in this case, is created through automation and simulation. An autonomous robot may or may not be environmentally situated (Suchman, 1987). On the one hand, a non-situated autonomous robot, such as an automated paint sprayer, repeats a given routine of operation by strictly following a set of pre-programmed instructions. On the other hand, a situated autonomous robot is able to adjust itself to variations in the environment. An anti-lock brake system, for example, responds differently to varying road conditions for the purposes of maintaining the balance of an automobile. However, a truly situated robot, according to some roboticists, must be able to improve its responses to a changing environment through learning (Brooks, 1999).

Depending on where they are deployed by the users, autonomous robots can be grouped into two major categories: mechanical robots that reside in physical space and software agents or bots that reside in cyberspace. For the sake of simplicity, unless otherwise specified, the generic label 'robots' will be used in this article to refer to both mechanical robots and software agents.

## The social component: 'interact with humans'

Not all robots are designed to interact with humans. Robots that are designed to interact with non-human objects are often called 'industrial robots' (Frude, 1984). Examples of autonomous industrial robots include automated packaging devices, paint sprayers and waste cleaners. These robots are deployed to carry out repetitive and/or hazardous tasks in place of humans. Most robotic home appliances also belong to this category. Air conditioners, washing machines, automatic cookers, self-directed vacuum cleaners and lawnmowers are all robotic entities that work autonomously for humans to make home a more comfortable place in which to live.

Social robots are autonomous entities designed specifically to interact with humans (Breazeal, 2001). However, not all robot–human relationships are social. For example, interactions between a robotic wheelchair and its user, a hearing aid and its wearer, or an automobile and its driver are prosthetic rather than social. A large part of what is known as assistive technologies deals with the ergonomic aspect of such human–machine interactions (Gill, 1996). To be social is to be communicative. A social robot orients itself to the mind of an individual and acts upon the individual for purposes of eliciting certain behavior and emotion; similarly, its human partner tends to believe that the robot has a mind and seeks to interpret the meaning of its action (Nass and Steuer, 1993). Social robots interact with human individuals both verbally and non-verbally. Automated telephone response systems, for example, answer callers' inquiries in voice; online 'chatter bots' chitchat with their human counterparts in text; and robotic dolls and pets win the hearts of children with smiles and hugs.

## The humanoid component: 'in a humanlike way'

Just as not all robots are social robots, not all social robots are humanoid robots. Mechanical dogs or digital cats that play with humans are no doubt social robots, but they are not necessarily humanoids. To be humanlike, a robot must show 'an uncanny ability to simulate human behavior' (Wiener, 1950: 1), particularly, the ability to use natural human language. Linguistic communication through symbol manipulation has been long recognized as a distinctive human faculty. Although it is arguable whether robots can actually understand human language (Searle, 1990) or whether they should be considered intelligent (Dreyfus, 1992), it is undeniable that robots now can be programmed to converse with humans. Recent advances in the technologies of speech recognition and synthesis, continuous dictation and text-to-speech conversion have made it possible for robotic entities to communicate with humans in natural human language (Allen et al., 1987; Lee, 1989).

Another important humanoid attribute is the resemblance to human morphology, which can take either physical or digital form depending on where a robot resides. A static human appearance proves to be less effective than a dynamic one that responds to the varying situations of social interaction. For this reason, efforts have been made to equip embodied humanoid robots with the capabilities of communicating with humans using gaze direction, gesture and facial expression (Cassell et al., 2000).

It must be pointed out that certain humanoid features can be found also in industrial robots. For example, there are 'washy talky' machines that speak with a 'warm female voice' (Ananova, 2002) or light switches on the wall that respond to human voice commands (Takahashi, 1998). The purpose of adding a humanoid touch to a non-social robot in this situation is to create a 'human-centered interface' (Norman, 1993) that is user-friendly.[2] But, as such interfaces may be 'part of the microwave, stove and sink' (Dertouzos, 1998: 118), they are not considered humanoid social robots that are specially designed to interact with humans.

Humanoid social robots are not a modern concept. The idea of mechanical maidservants, automated music players and other humanlike machines, for example, can be found in the designs of Medieval and Renaissance clockmakers (Wosk, 1992). However, it is generally agreed that the contemporary project of humanoid social robots began with the famous Dartmouth Summer Conference on AI in 1956, where the agenda for building a machine with the general intelligence of an average human being was set. The first autonomous humanoid robot, 'Shakey', was built at the Stanford Research Institute in the late 1960s. For a while many researchers believed that humanlike artificial intelligence was within reach (Minsky, 1967). However, the AI project became stalled in the 1970s and 1980s after repeated failures to overcome the so-called 'world knowledge' problem (Lenat and Guha, 1990). In the early 1990s, the AI project took a new turn, adopting the strategy of developing 'situated and embodied' robots that are adaptive to the environment (Brooks, 1999). Cog (Brooks, 2002) and Kismet (Breazeal, 2001) became the first two research prototypes for such humanoid robots. In addition, in the 1990s a barrage of humanoid robotic pets, toys and dolls, such as Tiger's Furby (see www.furby.com/about), Sony's Aibo (see www.us.aibo.com) and Hasbro's My Real Baby (see www.irobot.com/toys/default.asp) hit the consumer market, all designed to trigger human emotions with believable social interaction. Parallel to the development of various mechanical social robots was the emergence of socially intelligent software agents that communicate with human users in natural human language. The first well-known chatter bot (Mauldin, 1994) was 'Eliza', a computer program capable of conversing with people in text by playing the role of a psychiatrist (Weizenbaum, 1966). The spread of the internet in the 1990s contributed to the rise of numerous online conversational agents, such as 'Julia' (www.lazytd.com/lti) and 'Alice' (www.alicebot.org), which chat with people round the clock on topics ranging from politics to sex (Foner, 2000). We are now living in a world that is being cohabited by an ever-increasing number of humanoid social robots.

According to the roles that they perform, humanoid social robots can be divided into two major types: utilitarian humanoid social robots and affective humanoid social robots (Breazeal, 2000). Utilitarian humanoid social robots are humanoid social robots designed to interact with humans for instrumental purposes. Currently, such robots are being used widely in commercial sectors, replacing human attendants in serving human customers. Besides ATMs, vending machines and automated telephone answering systems, which are already commonplace, many other types of utilitarian humanoid social robots are deployed to stand in for humans as telephone operators, helpdesk receptionists, salespersons, private tutors, travel agents, hospital food servers and museum tour guides (Dertouzos, 2001).[3] These autonomous robots interact with humans either as disembodied entities or as embodied anthropomorphic figures capable of verbal (text or voice-based) as well as non-verbal expressions (Cassell et al., 2000).

Affective humanoid social robots are humanoid social robots that are designed to interact with humans on an emotional level. These robots are used mostly in two kinds of environment: online chat and private homes. The anonymous settings of online chat have become the natural habitat for chatter bots that are disguised as humans by design. If programs such as Eliza were 'brittle' enough to be seen through easily in the early days, new generations of conversational software agents can now pass the Turing Test in a number of restricted domains (Goodwins, 2001). Embodied conversational agents capable of non-verbal expression are being developed also to enhance their 'friendship relations' with humans (Stronks, 2002). In private households, affective humanoid social robots act as pets (e.g. Furby, Aibo) and dolls (e.g. Robota: http://robota.epfl.ch; My Real Baby) that cohabit with people on a daily basis, making humans bond to them (Woodall, 2001). A full-sized adult female, 'Valerie', is currently under development in a research lab. When fully built, it is said that she will be able to 'speak several languages', 'remember previous conversations with you', 'have a sense of touch all over like people do' and 'dress or undress herself', in addition to being able to perform simple household chores (Androidworld, 2002). Unlike utilitarian humanoid social robots that are employed by human users for work, affective humanoid social robots are kept by their human owners as 'pleasant characters' (Frude, 1984) for play and companionship.

In addition, an integrated type of humanoid social robot (e.g. R100), which combines both utilitarian and affective functions, has been created. These robots are able to play different roles in human social life. They can be used to serve, for example, as assistants and companions to the elderly (Johnstone, 1999; Kerr, 2002) and therapists and playmates for children with autism (Dautenhahn and Billard, 2002).

## HUMAN–HUMANOID INTERACTION

Traditionally it is held that there is an inviolable boundary between human–human interaction and human–machine interaction. Human interactions are symbolic, communicative and meaningful; interactions between humans and machines, on the other hand, are devoid of meaning (Searle, 1969). For this reason, some argue that the concept 'social interaction' should be applied only to engagements between human beings and it is inappropriate when used to describe human–machine contact (Liestol, 2003). The emergence of human–humanoid interaction, however, seems to pose a challenge to this simplistic dichotomy.

Humanoid social robots are machines designed to emulate humans. As Zylinska points out: 'What we are witnessing here is a process in which the human is extrapolated onto an external agent which is supposed to be both a replacement for "man" and "his" perfect simulation' (2002: 2–3). Interactions with these 'extrapolated humans' resemble human–human interactions in that they are linguistically based, relational and normative. These three distinctive features of human–humanoid interaction are illustrated vividly in the following excerpt from a dialogue between a digital humanoid real estate agent, 'Rea', and a human customer, 'Lee' (Cassell et al., 2000: 47).

> [Lee approaches the projection screen. Rea is currently turned side on and is gazing idly about. As Lee moves within range of the two cameras mounted above the screen, Rea turns to face him.]
>
> Rea > Hello. How can I help you?
> Lee > I'm looking to buy a place near MIT.
> Rea > [Rea nods, indicating that she is following.] I have a house to show you.
>
> [A picture of a house appears on-screen behind Rea, who blinks and looks at the house and then at Lee.]
>
> Rea > It's in Somerville.
> Lee > Tell me about it.
> Rea > [Rea looks up and away while she plans what to say.] It's big. [Lee makes an expansive gesture with her hands. Lee brings his hands up as if he is about to speak and so Rea does not continue; instead, she is waiting for him to speak.]
> Lee > Tell me more about it.
> Rea > Sure thing. It has a nice garden. [Rea sketches a curve gesture with her hands indicating that the garden extends along two sides of the house.]
> Lee > How far is it?
> Rea > It is five minutes to the Porter Square T station. [Rea makes it clear that it is five minutes on foot from the T station by making a walking gesture with her fingers.]
> Lee > How big is the house?
> Rea > It has four bedrooms, three bathrooms . . . [Lee interrupts Rea who stops speaking immediately.]
> Lee > Wait. Tell me, where is the master bedroom?
> Rea > I'm sorry, I didn't catch that. What did you ask me?
> Lee > Where is the master bedroom?
> Rea > It's upstairs. [Rea points up.]
>
> [And the house tour continues. . .][4]

This episode of human–humanoid encounter bears a striking resemblance to human–human communication in the following three aspects. First, the interaction between Rea and Lee is linguistically based. From orality to literacy, humans have developed the skills of communication using both spoken and written languages (Ong, 1982). Like humans, humanoid social robots are capable of communicating in natural human language. In the above example, Rea and Lee are engaged in an oral dialogue. When interacting online with chatter bots, however, verbal exchanges are conducted in text. Similar to face-to-face human–human interaction, 'face-to-face' human–humanoid interaction may involve non-verbal expressions. Being digitally embodied, Rea acts as a person nodding and gesturing while talking on the screen. Physically embodied humanoid social robots are able to use body language also, as demonstrated by Kismet (Breazeal, 2001).

Relationality is another feature of human–humanoid interaction, which is also characteristic of human–human interaction. Human–human interactions are relational in the sense that interlocutors identify themselves and locate others within a complex web of interpersonal relations, such as the relationships between mother–son, father–daughter, husband–wife, neighbors and friends. A generic form of relational identification is the use of personal pronouns such as 'I', 'you', 'we' and 'they'. Rea, for example, uses the pronoun 'I' to refer to itself and the pronoun 'you' to Lee. Baby 'Hal', an affective humanoid social robot, calls its human caretaker 'mummy' (Laxon, 2001). Instead of giving telegraphic answers such as 'unauthorized request', many automated service robots are now programmed to reply to human requests in a 'you-and-me-against-the-world' tone of voice, such as 'I'm sorry, my supervisor doesn't allow me to make that transaction' (Hapgood, 2001). Research has shown that the use of anthropomorphic pronouns makes human partners more likely to treat humanoid social robots as real people (Brennan and Ohaeri, 1994). 'I tried to call Hal 'it' at the beginning', Hal's caretaker reports, 'but as our communication deepened, I found it harder. Yes, I'm attached to him. You just can't help it' (Laxon, 2001).

Finally, human–humanoid interaction is normative. 'Normality' in this context refers to social conventions that regulate human interaction, such as politeness norms, turn-taking rules and other ethical, moral and legal constraints. Many of these regulatory principles have been shown to be applicable to human–humanoid interaction. In the dialogue cited above, Rea was not only knowledgeable but also courteous and polite. She apologizes for having to ask Lee to repeat and pauses when Lee cuts in to ask a question. Studies have shown that the personalities, such as dominant or submissive, exhibited by interactive machines have a significant effect on human users (Nass et al., 1995). As in human–human interaction, people prefer to interact with machines that exhibit a personality similar to theirs.

Furthermore, people subconsciously apply normative criteria, such as gender stereotypes, to the autonomous humanoid entities with which they interact (Green, 1993).

Language use, relationality and normality generate a communicative context in which humanoid social robots engage in meaningful exchanges with humans. Never before has it been possible for machines to interact with humans in the way that humans do. However, human–humanoid interaction is not exactly the same as human–human interaction. Perhaps the most important difference between the two lies in what Collins (1990) calls the 'interpretative asymmetry' believed to be inherent in human–machine interaction. As machines act according to programmed instructions rather than true understanding (Dreyfus, 1992), human–humanoid interaction is an unavoidably asymmetrical process in which the interaction is only meaningful to the human. For example, an affective humanoid social robot can be programmed to utter 'I love you' to humans, but these affectionate words, which may move a human to tears, have no meaning to the robot. The question is then why humans will ever take humanoids seriously. There are at least two plausible explanations. The first is that people may regard the responses of humanoids as representing the intentions of human programmers (Biocca, 1992), so from the users' standpoint, whenever they interact with a humanoid they are interacting with those who programmed the robot. The second is that certain behavioral cues tend to elicit human responses. Examples of such cues include humanlike voices, written signs and human faces. It has been shown that even simple representations of these cues are 'sufficient to evoke social responses' from humans (Nass and Steuer, 1994: 556). For these and perhaps other reasons, human users end up treating humanoid social robots as humans even though they are aware of the asymmetrical nature of such interactions.

Another important difference between human–humanoid interaction and human–human interaction has to do with the restrictiveness of the domain of communication. 'Domain' is defined here as the knowledge base in relation to a given subject matter. Human communication is domain-related, but not domain-restricted. It is domain-related because human communication is always about something or some subject matter; but it is not domain-restricted because communication is also a vehicle by which humans acquire new knowledge. Learning is a constant process of consolidating the current domains of knowledge and developing new ones. In contrast, human–humanoid interaction is both domain-related and domain-restricted. Unlike humans, who are able to expand their knowledge base through exploring unknown territories, humanoids are entirely dependent on the existing stock of knowledge with which they are provided (Forsyth, 1984). Within the programmed domain of knowledge (e.g. chess games), humanoid social robots can be highly 'intelligent', but they become completely 'dumb' the moment that the interaction moves beyond the given domain. Such 'brittleness' of the artificial intelligence of robots makes human–humanoid interaction helplessly domain-confined.

A further factor is the indexical nature of human communication. 'Indexical' refers to the reliance of an expression on the situation of its use for significance (Garfinkel, 1967). A human expression can have both literal and indexical meanings. The literal meaning can be looked up in a dictionary, but the indexical meaning needs to be ascertained from the situation in which the expression is made. An expression is synchronically embedded in a situation when it takes its meaning from the circumstance in which the expression is made (e.g. 'That's a nice one'; Suchman, 1987: 59). An expression is diachronically embedded in a situation when it takes its meaning from a prior circumstance the current expression makes reference to (e.g. 'Dana succeeded in putting a penny in a parking meter today without being picked up'; Garfinkel, 1967: 25). Many human expressions are both synchronically and diachronically embedded, which means that understanding of them requires knowledge of both current and past circumstances. The situatedness of human interlocutors in a common lifeworld makes indexical human communication possible. However, as humanoid social robots are not socially situated with human users, human–humanoid interaction is essentially non-indexical. It remains to be seen whether the development of situated humanoid social robots (Brooks, 2002) will change the non-indexical nature of human–humanoid interaction eventually.

Human–humanoid interaction, therefore, centers on the borderline between human–human interaction and human–machine interaction. Humanoid social robots, which may be best described as 'humachines' (Poster, 2002) that combine the characteristics of both machines and humans, extend the realm of communication to the machine world by playing the role of humans. As a special medium of communication, humanoid social robots are designed to interact with, for and as humans. To interact with humans, humanoid social robots are equipped with 'artificial intelligence' so that they can understand and respond to humans. To interact for humans, they take the role of human surrogates in communicating with humans.[5] Finally, to interact as humans, they emulate human appearance as well as actions. In the sense that humanoid social robots are technological 'extrapolations' of human individuals, human–humanoid interaction is the 'prosthetic extension' of human–human interaction. From this perspective, the problems such as interpretative asymmetry, domain restriction and non-indexicality that are associated currently with human–humanoid interaction can be regarded as the inconvenience of prosthesis that needs to be tolerated. It can be argued that, as robotic technologies improve in the future, the gap between human–humanoid interaction and human–human interaction will be narrowed further.

## SOCIOLOGICAL IMPLICATIONS

A central tenet of this article has been that while humanoid social robots are not industrial machines, neither are they fancy gadgets that we play with for fun; rather, they are a special medium of communication that affects the way we see ourselves and relate to others. Autonomous, interactive and humanlike, humanoid social robots are media technologies that 'extend new possibilities for expression, communication and interaction in everyday life' (Mayer, 1999: 328).

For a long time in human history, corporeal co-presence of the interlocutors in the same physical locale has been the only condition under which real-time human contact can take place. Face-to-face from body-to-body, human individuals communicate with one another in close physical proximity using both verbal and non-verbal expressions (Goffman, 1963). The advent of the internet has made prevalent the second condition of instantaneous human interaction, namely, remote co-presence or 'teleco-presence' (Zhao, 2003). Under this condition, physically separated human individuals are able to stay in 'electronic proximity' (Dertouzos, 1998), interacting with one another synchronously through the mediation of certain telecommunications devices such as telephones, two-way radios or networked computers. The emergence of humanoid social robots gives rise to the third condition of instantaneous human interaction – virtual co-presence.[6] In corporeal co-presence and teleco-presence, both sides of the human interlocutors must be present simultaneously at the site of interaction, either locally or remotely. However, in virtual co-presence such co-location is not necessary, as one side of the interlocutors is represented by a humanoid social robot which interacts with its human counterpart on behalf of someone who is absent from the site. An automated telephone response system, for example, fields enquiries from human callers in place of a human receptionist. Technically, it is also possible for humanlike communication to take place in 'hypervirtual co-presence', where human interlocutors are all represented by humanoid social robots (Zhao, 2003).

Virtual co-presence must not be confused with what Rheingold (1993) calls 'virtual community'. Virtual communities, such as online networks or web-based groups, are human associations formed through mediated contacts in teleco-presence. In the sense that all the participating parties are real human individuals, albeit not physically located in the same place, the resulting associational ties are real rather than virtual. Virtual co-presence is a situation of human versus human surrogate, where human individuals meet humanoid social robots. This virtual social condition allows a human individual to remain in 'interactive solitude' (Carlsson, 1995) and be 'a loner, but never alone' (Turkle, 1995: 307).

Virtual co-presence is part of the so-called 'post-human condition' (Pepperell, 1995), which is characterized by the union of 'meat and metal' and the co-mingling of humans with humanoids. The possibility of engaging in humanlike interaction with humanoid social robots fundamentally alters the field of human communication, the process of meaning production and the form of social action. In a world where humans are the only communicative agents, 'social' is synonymous with human to human and 'social relationship' refers to nothing other than dealings with another human being. However, in a world where a child plays house with an interactive doll, a teenager chats online with a chatter bot and the elderly find companionship with a talking 'robopet', 'social' is no longer confined to interhuman and 'social relationship' includes the bonding between humans and humanoids.

The rise of a synthetic social world where human individuals and humanoid social robots co-mingle calls for a new conceptualization of society. The traditional view of society as consisting of only human individuals needs to be revised. For one thing, the boundary between humans and human artefacts is no longer inviolable due to the increasing technological prostheticization of human bodies (Stelarc, 2000). Technologies are becoming an integral part of the human condition. Furthermore, robotic replacement of human individuals in the processes of social interaction and communication creates a human–machine nexus that is indispensable to the operation of everyday life. Today's society comprises not only human individuals as delimited by their biological bodies, but also technological extensions of individuals, including their robotic surrogates.

Another way to conceptualize society is to redefine it in terms of communication. For example, Luhmann (1995) regards society as a system of communicative interaction. Human individuals and the technologies that they produce and use are not seen as something located within society but which belong to the environment of society. It is the communication, discourse and interaction taking place between and among them that constitutes human society. According to this conception, 'individuals think, technologies function and society communicates' (Rasmussen, 2003: 459).

Inevitably, the rise of a synthetic social world will affect the formation of self in human individuals. As individuals come to know themselves by taking the attitudes of others toward them, others become the 'looking glass' (Cooley, 1902) in which individuals see themselves. Can human surrogates such as humanoid social robots also serve as a looking glass for human individuals? Wolfe has argued that the 'other must itself be a self before a self can communicate with it' (1993: 60) and, as humanoid social robots have no self, they cannot affect the self of a human individual. However, recent studies of the interactions between children and robotic dolls have shown that humanoid social robots can be equipped with a programmed self that looks so believable that the self-view of those who interact with them will be affected (Bumby and Dautenhahn, 2000). When humanoid social robots are made virtually indistinguishable from humans at the interface level, they produce what is known as the 'Eliza Effect' (Bates, 1992), the phenomenon where individuals think that they are communicating with a real person when in fact they are interacting with a human surrogate. In a synthetic social world, therefore, the way that people view and feel about themselves is influenced not only by other human individuals but also by the humanoid social robots with which they communicate and interact.

> In sum, this represents a fundamental shift in our culture, one that is not nearly as prominent and visible as that represented by the internet and the world wide web, but with far greater potential for altering the way we learn and think. (Aarseth, 2003: 432)

Although humanoid robotic technologies may look primitive at this stage, there is no doubt that they will become only more technically advanced and socially sophisticated as time goes by. Now is the time for us to pay attention to this ongoing robotic revolution, to understand the humanoid social robot as a new medium of communication and to study its impact on individuals, society and culture.

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## Notes

1 Similar concepts suggested by other scholars include 'socially intelligent autonomous robots' (Breazeal, 2001) and 'socially intelligent agents' (Dautenhahn, 1998).
2 Not all designers of interactive machines agree that humanoid interfaces are necessarily desirable. It has been argued, for example, that humanoid features can get in the way of designing efficient machines. Thus designers have been asked to focus their energies on the real job rather than on an interface (Norman, 1990).
3 To catch a glimpse of the automated telephone response systems that are currently in testing, it is possible to try some of MIT Media Lab's human–computer dialogue systems by dialing *Jupiter* at 1–888–753-TALK for weather information and *Pegasus* at 1–877–527–8255 for airline information.
4 With thanks to MIT Press for kind permission to use this material.
5 There are two basic types of proxy relationships: real proxy relationships and non-real proxy relationships. In a real proxy relationship, the humanoid social robot acts on behalf of a real person or institution. A household answering machine, for example, interacts with callers on behalf of its owner and an ATM machine interacts with customers for a company. In both instances the interaction is legally bound because it implicates a real human–human engagement. In a non-real proxy relationship, the humanoid social robot does not act on behalf of any real person or institution.

Household robotic dolls and pets, for example, interact with people as personal playmates rather than someone else's surrogates. Therefore, this type of interaction is not legally bound.

6 Virtual co-presence needs to be differentiated from virtual presence, also known as 'parasocial' presence (Horton and Wohl, 1979), in which one encounters the virtual presence of other people through mass media such as books, radio and television. Unlike virtual co-presence, there is no two-way interaction in a parasocial situation.

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