Human-robot Interaction: Literature Review (Final Report)

Akash Rampal
Department of Electrical and
Computer Engineering
The University of Auckland,
New Zealand
aram087@aucklanduni.ac.nz

ABSTRACT

Human-robot interaction deals with the science of the interaction between robots and humans which use these robots to perform tasks to achieve particular goals. Robots differ from simple machines in that they are more than often designed to be mobile and autonomous. They have an ever increasing role to play in healthcare, industry, modern medicine and disaster relief, enabling a kind of social interaction that requires continuous improvement and study. Recent developments in parallel and distributed computing have allowed for faster computation and communication through multiple processors and researchers are increasingly taking advantage of such developments by designing robots that are more responsive and interactive and able to carry out a wider array of tasks. While robots have the great potential to offer improvements to mankind, it is also becoming increasingly important to address ethical issues that are associated with particular human-robot interactions that may encourage anthropomorphism, deception and zoomorphism.

Author Keywords

MR Helper	Anthropomorphic
DR Helper	Zoomorphic
MS DanceR	Infantilisation
BCI	Sony AIBO

INTRODUCTION

This literature review covers various different articles and themes related to human-robot interaction, ranging from robots used in healthcare that allow elderly patients to have greater social interaction and robots that supervise and monitor infants and babies. The issues of acceptance and ethics associated with such human-robot interaction are also covered. Increasing research is being done into autonomous robots that gather information from their immediate surroundings and prior knowledge and this review covers research into autonomous vehicles and brain-computer interfaces that aid users who may not have effective motor function.

Robots in Healthcare

Socially interactive robots are increasingly being used in the healthcare industry to provide elderly patients with supervision, social interaction and care. Research in this field is burgeoning as the proportion of elderly people in western societies increase. From an engineering perspective, a lot of work has gone into developing robots in such a way that encourages users to form relationships with them [1]. This means that robots are being designed with features that create the illusion of animacy [1] through shape, spoken language, speech and face recognition, flexible materials and artificial intelligence.

From an engineering perspective, there has been an increasing focus on designing robots with features that allow greater levels of social interaction which fosters relationships between the robot and the patient/user. Features such as speech and face recognition, skin-like materials and spoken language create an illusion of animacy for healthcare robots [1]. Such interactions encourage anthropomorphic and zoomorphic behaviors that raise many ethical questions for the field of HRI research. Sparrow [2] suggests that any resulting benefits from human interaction with pet robots are “predicated on mistaking, at a conscious or unconscious level, the robot for a real animal”[2]. He goes on suggest that a level of delusion is involved in such an interaction where the user “must systematically delude themselves regarding the real nature of their relationship with the animal”[2]. At the same time however, it has been suggested that many humans treat robots as a social actor and human-robot interaction may not necessarily be based on mindlessness or deception. The computer-as-social-actor paradigm states that humans treat computers as social actors, just like other humans[3].

Sharkey and Sharkey suggest that "being anthropomorphic may be an unavoidable part of being human" [1] and note that anthropomorphic design is not exclusive to robotic applications. It is important however to consider the negative consequences of human-robot interaction that encourages anthropomorphic behavior. Mackenzie et al conducted a pilot study on the use of dolls for people with dementia in aged care homes [4]. While the study noted that the introduction of dolls resulted in specific benefits for users such as increased social and emotional interaction not only with the doll, but with staff and other residents; residents were also found to be putting the interests of the doll ahead of their own and arguing over ownership. There were also issues found with over stimulation and infantilisation.

Acceptance

In another study, user acceptance for a Sony AIBO and a battery-driven toy dog was compared at a geriatric health care facility which housed patients with severe dementia[5]. Such facilities provide patients with rehabilitation and therapy which trains them to say at home. Such patients are also often found wandering at night. Occupational therapy helps patients recall past feelings of comfort and memorable experiences because their short term memory deteriorates over time, making them agitated. Traditionally, animal-assisted therapy (AAT) has been used in such facilities however some facilities cannot afford such services. In this experiment, the effectiveness of the entertainment robot AIBO was compared with that of a battery powered toy dog[5].

In general, the results revealed increased levels of social interaction in the presence of both the AIBO and the toy dog. However, there were some distinct differences in the way the patients interacted with each of the 'dogs'. It was found that patients had difficulty connecting emotionally with the AIBO without the intervention of an occupational therapist [5]. Once the AIBO was dressed, patients found it easier to relate the AIBO with a dog or a baby. Using a toy or a robot also removed any chances of infections that AAT would present.

A user study carried out at the University of Auckland in 2009 investigated age and gender factors that influence acceptance of robots in the healthcare industry[6]. The user study employed 'Charles', a social interactive robot that measured blood pressure. Differences in user interaction based on age (middle aged, 40-64 and the elderly, 65 or older) and gender were investigated as the robot was deployed to take blood pressure readings for 57 participants. While the study found that there were no significant differences in the attitudes and reactions towards Charles, there was a non-significant trend which showed that the older group consisting of people aged 65 and over were less comfortable with the robot measuring their blood pressure. The older group also surprisingly found the robots voice clearer than the younger group did. Kuo et al suggested[6] this may be explained by the younger group having had interaction with a greater range of computer generated voices or perhaps the loud and slow voice of the robot allowed better hearing for those with hearing difficulties. Kuo et al conclude that future design of robots in the healthcare industry should account for gender issues.

Robots are also gradually being used to provide care and supervision for little children, who along with the elderly are the most vulnerable members of society. Robots have the potential to provide substitutes for parents and caregivers when they are time-bound and require a robot to keep a child busy and occupied through play, interaction and even supervision when a caregiver is not available. Sharkey and Sharkey[1] note that a child's interaction with a robot is more likely to result in adverse consequences when compared to the same level of human-robot interaction for an elderly person. Babies and infants have a strong social drive and their knowledge of technology is likely to be minimal or none. The deceptive nature of such human-robot interaction can result in children overestimating the capabilities of the robot and spending too much time with the robot encouraging anthropomorphic behavior[1]. This sort of behavior may also impede the social development and learning of a child because robots are not able to provide the same level of "social biofeedback" that comes from motherly and/or parental contact. Sharkey and Sharkey also point out that any future advances in natural language processing could result in robotic conversation that is superficially convincing for a child. Melson[7] suggests that children may think of humans as having mechanical qualities depending on their level of social interaction with a robot and "adaptation to robotic interactions may dilute the 'I-thou' relationship of humans to other living beings, particularly pets". Sharkey and Sharkey conclude[1] that while the thought of a robot entertaining an infant might be convenient, there are negative consequences that a user should be aware of. Another point to note is that older children are less likely to face the same negative consequences that babies and infants may face because older children are likely to have formed valuable social relationships with human caregivers already[1].

Interactive Robots

While robots have proven useful in industrial environments where they execute pre-programmed tasks, they have largely been isolated from humans because of the passive operations they have been involved in. Robots are now able to operate more actively, based not only on the intentions of humans but also the information they can collect from the immediate environment and prior knowledge about the tasks to be performed.

The MS DanceR is one such robot which estimates the intention of its human dance partner to dance the Waltz as a female dance partner with a male[8]. The main feature of the MS DanceR is an omni-directional mobile base which allows the robot to move in all directions. Aided by a body force sensor, it accurately estimates the moves of the partner by processing incoming force/torque data. This results in the robot accurately coordinating dance steps based on the human's lead.

Kosuge and Hirata also developed the MR Helper and the DR Helper[8]. Essentially, these robots make heavy lifting and movement easier for humans. The main difference between the MR Helper and the DR Helper is that the former carries out work in coordination with a human whereas the latter allows movement for larger objects where human involvement is difficult [Figure 1]. Just like the MS DanceR, the MR Helper consists of an omni-directional base that allows flexible movement. Two 7-DOF manipulators are attached to the body of the robot and the manipulators themselves have six-axis force/torque sensors attached to their wrists which measure the intentional force applied to the object to be manipulated. Such robots have the potential to allow effective collaboration with humans to achieve particular tasks whether that be learning how to dance or making it easier to lift heavy object in a domestic or industrial environment.

Figure 1: MR Helper (above) and DR Helper (below) [8]

Autonomous Vehicles

Recent advances made in the development of autonomous vehicles through increased research in areas such as machine learning, artificial intelligence and computer vision have led the way for researchers to examine various driver assistance systems for street cars. Not only is the automobile industry interested in examining human-robot interaction which achieves increased levels of environmental perception and safety, military organizations have also shown interest in unmanned vehicles for use in reconnaissance and combat operations[9].

Although the ultimate goal of developing an autonomous vehicle is to achieve unmanned driving, humans must be able to deal with system failures. This has necessitated the need for driver assistance systems for autonomous cars. The Artificial Intelligence Group, which is part of the Computer Science Institute at the Freie Universitat in Berlin, Germany developed the iDriver – an Apple iPad software solution in 2011 which was designed to navigate and act as a remote control for autonomous cars[9].

The iDriver is inherently a human-machine interface which allows users to send commands and receive status data from the vehicle without the user/driver necessarily being in the car. Passenger safety is also of utmost importance so such an application acts as a frontend for on board data that is provided to the passenger who may wish to send commands and/or manually control the autonomous car.

The main feature of the application is a 3D model of the autonomous car which is shown in the middle of the screen[9][Figure2]. At the bottom of the screen, icons give access to the control features that have been implemented. Some of these features include emergency stop, drive and pick me up. In the drive option, the user is able to take over the control of the car by steering, braking and accelerating the car. The driver is able to execute these control movements through touch and tilt movements of the iPad.

An interesting aspect of the iDriver is that it provides multi-touch controls of the screen. For the provision of safety, at least one touch must be maintained with the iPad screen to transmit data however, users are able to execute multiple commands with more than one finger simultaneously and this was one of the main reasons this application was developed on the iPad[9]. The developers also chose this software platform because they could use the Objective-C language to make system calls for TCP/IP communication protocols which form an essential part of the way communication is handled in the Client-Server architecture model of the iDriver. The mobile application was extensively tested on 2 different autonomous vehicles, the "Spirit of Berlin" and "Made in Germany"[9].

Figure 2: iDriver graphical user interface [9]

Brain-Computer Interfaces

A lot of research has also been done into using a BCI (Brain-Computer interface) to carry out tasks. A BCI allows a direct communication path between the brain and an external device. A BCI has a great potential to help a person who has been paralyzed by a neurological disorder or a spinal cord injury, but whose motor cortex is healthy[10]. Recent experiments also suggest that brain-machine interfaces could also help those who experience seizures by sensing the imminence of an attack and intervening through electrical stimulus[10].

Early experiments conducted on animals have provided promising results for brain-machine interfaces. A BCI developed at Duke University in Durham, N.C. was tested in the Human and Machine Haptics laboratory at Cambridge, Massachusetts[10]. Belle, an owl monkey was fitted with a cap glued to her head. Four plastic connectors fed an array of microwires into her motor cortex. Belle was to move a joystick left or right and was conditioned over time to merely think about performing such an action so she could receive her reward without having to physically move the joystick. Essentially, the researchers were able to reliably translate the raw electrical activity in the brain of the monkey, into signals that could direct the actions of a robot which was located 600 miles away. This experiment was conducted after a successful experiment (by the same researchers) in the mid 1990's in which a rat was taught in cage to control a level with its mind[10]. The group at Duke University did however express the need to evaluate whether highly dense microwires arrays can cause tissue damage or infections in humans.

The Artifical Intelligence Group from Germany has also investigated approaches to controlling a car with brain signals through a BCI- Brain-Computer Interface[11]. Gohring et al note that usability of human-machine interfaces is more important for users who may not have full body control. In recent times, Brain-Computer interfaces that require users to think of a motion in their thoughts rather than performing the motion physical have become more popular. The team based at the Computer Science Institute performed usability tests on the BCI (which controlled a car). Tests were done on the brain patterns required for steering a car wheel, braking and making path selection decisions at intersections[11]. A commercial product called the 'Epoc' cap was used which included 16 EEG sensors and required a contact fluid and training to the brain patterns of a particular user. The testing process exposed some interesting challenges associated with the human-robot interaction that was involved. It was noted that messages detected from the human brain were often arriving at irregular intervals and included 'false positives' because brain patterns and thoughts are not held steady long enough for them to be transmitted at regular intervals. It was concluded that although BCI's provide a lot of potential for free driving for people who are disabled, the control mechanisms host inaccuracies that prevent such technology to be used in autonomous driving in open traffic[11].

Brain-Computer interfaces are not restricted to autonomous cars. They have generally shown potential in all assistive technology applications such as wheelchairs for disabled people. The Defitech Foundation Chair in Non-Invasive Brain Machine Interface (CNBI) based at the Swiss Federal Institute of Technology has performed research in this very arena for more than 14 years. The aim of the team based at the institute was to introduce their BCI technology to the 'real world' instead of the laboratory and the BCI for Brain Controlled Wheelchairs developed by the institute recorded electrical activity of the brain using scalp electrodes – known as electroencephalography (EEG)[12]. Various spatial and spectral filters have to be applied to the EEG because of the weak and wide spread nature of brain signals. Various machine learning techniques allow the mental imagination of motor tasks to be translated into movements such as left and right turns. The team at the CNBI pointed out that wheelchairs, like autonomous cars require the BCI to deliver commands accurately without time delays and the CNBI employed a shared control technique for the wheelchair in which the human user and the robot are both individually two intelligent agents, making full use of the cognitive superiority of the human brain.

Summary

Robots have a very important role to play in various applications whether that is in entertainment, healthcare or transport. Improvements in design that enable easier human-robot interaction are enabling users to achieve better results. Robots being used in the healthcare industry are allowing patients to increase their social interactivity [4], provide supervision [1] and aid in providing occupational therapy, helping allow patients to recall memorable experiences [5]. The interaction between a human and a robot can be influenced not only by the design of the robot itself [1], but age and gender factors [6] along with past experiences with technology. This means that engineers must design robots by taking these factors into account so that the human-robot interaction is of benefit to a range of targeted users. There should also be a strong focus on ethics when it comes to human-robot interaction, especially in healthcare. Young children and the elderly are considered to be the most vulnerable members of societies and engineers must take factors such as anthropomorphism into account as the interaction of robots with these user groups is more likely to encourage anthropomorphism.

Research into autonomous vehicles is also showing us the possibilities of human-robot interaction within the transport sector. An increased level of transport automation is paving the way for innovative user control interfaces that require cutting edge human-robot interaction to facilitate vehicle control and navigation [9]. Brain-Computer interfaces are also showing us the possibilities for a different level of human-robot interaction where the user is able to control the robot with their mind. This has the potential to increase the quality of life for people who may not have effective motor function but have a healthy motor cortex.

Future Work

Researchers are putting a focus on making BCI's and robots more effective in terms of accuracy and timely feedback [12]. The team at the Computer Science Institute [11] found that messages from the brain were often arriving at irregular intervals because brain patterns and thoughts are not held steady long enough for them to be transmitted at regular intervals. This presents potential problems for human-robot interaction in the BCI arena and it would be interesting to see how researchers overcome the inaccuracies in the control mechanisms so that such technology can be used more widely.

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