# Literature Review

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**Abstract**

The field of human-robot interaction is very broad. This paper will provide a background on human-robot interaction, and describe a multimodal system of interaction between a human nad a mobile robot. Bluetooth technology is briefly described and the application of human-robot interaction for a mobile robot are described.

## 1 Introduction

This paper introduces the field of human-robot interaction by making use of a LEGO robotics kit to demonstrate the interactions, the different modalities or methods of interaction relevant to the project, and the communication channels and applications of this work. The first section introduces human-robot interaction and the current work being done in the area. The next section describes the LEGO NXT robotics kit and all its components. The third section discusses multimodal systems and the different modalities focussed on for human-robot interaction. The following section provides a brief outline of Bluetooth technology as this is the main communication channel between the LEGO NXT robot and a personal computer. The final section of the chapter discusses the uses of mobile robots and human-robot interaction.

# 2 Human Robot Interaction

Human-robot interaction (HRI) is a fairly new subfield of human-computer interaction (HCI). A great deal of effort and research in the robotics field has focused on the development of hardware and software to improve and extend robot functionality and intelligence. Relatively little research has been done on the techniques and controls people use to interact with and command robots, despite the fact that robots are continually being deployed in broader fields and more demanding areas of work where meaningful, efficient and effective interaction between humans and robots is essential [15].

## 2.1 Background

Robots are increasing in power and are able to do much more than ever before. However, integrating them into our daily lives and interacting with them in natural meaningful ways remains a challenge. The goal is the integration of classic interfaces such as graphical I/O devices, newer interfaces such as speech, and remote control and mobile interfaces.

To develop human-machine interfaces that allow for intuitive human interaction and control is the goal of the leitproject MORPHA, an acronym for Interaction and Communication between Humans and Anthropomorphic Robot Assistants [28]. Communication, collaboration and interaction between humans and robot assistants is the central idea behind MORPHA. The communications between humans and robots should be human-friendly, in other words, easy for humans to interpret [20]. MORPHA is made up of a consortium of research institutions based in Germany, industry, and small and medium enterprises. MORPHA is intended to “pave the way for new types of assistance systems in the fields of industrial production, housekeeping, and home care.” [20].

The goal of effective interaction between humans and robots makes it essential to provide a number of utilizable, redundant communication channels. The challenge is to integrate these interactions to enable the robot to perform useful tasks [20].

## 2.2 Current Work

Currently there is a lot of research and work on equipping robots with the capacity to interact with humans in a natural way, where both share the same interaction channels [18]. A big area of research at the moment is in space robotics [9]. The interactions between humans and robots during extended space missions will be unlike anything that NASA has designed and implemented to date. Robot teams may at times be operated from ground control, while surface astronauts may communicate with robots using voice-commands, gestures, and wireless mobile communications [9].

# 3 Lego Mindstorms NXT

The LEGO Mindstorms NXT is a programmable robotics kit, released by LEGO in July 2006 [21]. There has recently been much interest in achieving educational and research objectives through the use of low-cost robot kits such as the NXT [14]. The main component of the NXT set is a brick shaped device known as the NXT Brick. It can accept input from up to four sensors and control three servo motors.

## 3.1 Technical Specifications

The technical specifications of the NXT Brick are as follows:

- 32-bit AT91SAM7S256 (ARM7TDMI) main microprocessor @ 48 MHz (256 KB flash memory, 64 KB RAM)
- 8-bit ATmega48 microcontroller @ 4 MHz (4 KB flash memory, 512 Bytes RAM)
- CSR BlueCore 4 Bluetooth controller @ 26 MHz (8 MBit external flash memory, 47 KB RAM)
- 100×64 pixel LCD matrix display
- Can be programmed using Windows or Mac OS (NBC/NXC supports Linux as well)
- Users create programs with new software, powered by LabVIEW from National Instruments
- A single USB 1.1 port full speed (12 Mbit/s)
- Bluetooth (Class II) wireless connectivity, to transfer programs to the NXT wirelessly or offer ways to control robots remotely (through mobile phones and possibly PDA's)
- 4 input ports, 6-wire cable digital platform (One port includes an IEC 61158 Fieldbus Type 4/EN 50 170 (P-NET) compliant expansion port for future use)
- 3 output ports, 6-wire cable digital platform
- Digital Wire Interface, allowing for third-party development of external devices [29]

## 3.2 Sensors

The LEGO NXT kit contains the following parts:

- Three servo motors that can sense their rotations to within one degree of accuracy.
- A touch sensor that can detect whether it is currently being pressed, released or has been bumped.
- A light sensor that can detect the light level on a scale of 0 to 100, with 100 being very bright and 0 being very dark.
- A sound sensor that can detect a sound's amplitude on a scale of 0 to 100, with 100 being very loud and 0 being no sound.
- An ultrasonic sensor that can measure the distance from an object. It can measure up to a distance of 233cm with a precision of 3cm. [29]

# 4 Modalities

With an integrated system, users need not be concerned with how to communicate with the robot, leaving them free to focus on the task at hand. By integrating the modalities to create a multimodal system, a user can choose any combination of the modalities [27]. The advantage of working with a multimodal system lies in redundancy.

Human-robot interaction becomes more natural and intuitive as the level of flexibility and redundancy of the human interface increases [17]. Moreover, a multimodal system is able to function more robustly and is less error prone than using an individual technology [26].

## 4.1 Web

One of the earliest implementations of Internet robots was the 1994 Mercury Project [13]. This project was set up as a feasibility study to allow a robot to be manipulated and controlled via the World Wide Web. The primary goal was to develop a system that would be reliable enough to operate 24 hours a day. It was the first project of its kind to be undertaken, and over 50 000 unique hosts accessed the interface during its availability period between September 1994 and March 1995.

The World Wide Web provides an easy, low-cost and widely accessible interface to a mobile robot. However, direct robot control is not suitable for Internet based mobile robot operation because of the high-latency associated with the Internet communications [22]. For Internet robots, it is common to use supervisory control by giving the robot more local intelligence [22]. Thus, an Internet controlled robot uses the Internet mainly as a command transmission and sensor feedback medium [16].

There are 3 major issues faced by Internet Robots [16]:

1. High latency, lag and packet loss means that data transmission cannot be guaranteed.

2. The Internet allows inexperienced users to guide the robot. The user may not be familiar with the technology and could potentially harm the robot.

3. The web interface has to be easy to understand.

## 4.2 Mobile

Although there has been unprecedented growth in wireless services and technologies in recent years, very little research has focused on the possible uses of these systems for remote mobile robot interaction [6]. An existing interface for remotely controlling a mobile robot makes use of a Mobile Information Device Profile (MIDP)-enabled mobile phone [6]. This interface was designed at the University of Madrid to send direct control commands to the robot. This mobile method of interaction opens up many new possibilities to businesses and industries to provide innovative security services.

In 2002 Fujitsu [12] announced the release of a mobile phone controlled robot, the MARON-1. The robot can be remotely controlled via a mobile phone to operate home electric appliances or to monitor household security. With the remote operation the robot is able to take pictures of its surroundings and relay these to the mobile phone.

## 4.3 Game Controllers

Tangible user interfaces (TUIs) take advantage of embodied interaction by coupling physical objects with their computerized counterparts [15]. This provides users with simple, natural physical interaction metaphors. TUIs make efficient and effective use of affordances [15], which provide clues as to how things work or are operated. For example, it would make logical sense for an up arrow button on a TUI to represent the forward movement of a mobile robot. TUIs allow users to "perceive and act at the same place and at the same time" and to be more attentive and focus on the current task [15]. "Tangible user interfaces (TUIs) exploit embodied interaction, coupling physical objects with computerized qualities, and ideally empowering users with simple and natural physical interaction metaphors." [15].

### 4.3.1 Nintendo Wiimote

The Wiimote is a rectangular hand-held device included with the Nintendo Wii console, but which can also be purchased separately. The primary features of the Wiimote are the three-axis accelerometer, seven buttons including a four-way directional keypad and Bluetooth connectivity [8]. The Wiimote can be seen as a generic 3D TUI as well as a very successful 2D TUI. The Wiimote can also be seen as a gestural interface, representing a gestural/TUI duality [15].

Guo and Sharlin [15] successfully used the Wiimote as a robotic interface to control a Sony AIBO robotic dog, and came to the conclusion that a gestural input scheme with a tangible user interface outperforms traditional input devices, in this case a keypad, in terms of speed and accuracy.

### 4.3.2 Microsoft Xbox 360 Controller

The Xbox 360 controller [23] is obtainable in both wired and wireless varieties and comes bundled with the Microsoft Xbox 360 console or can be purchased separately. To connect the wireless controller to a PC, a special Microsoft wireless receiver must be used. The primary features of the Xbox 360 controller are the two analogue sticks and an 8-directional keypad.

Ballsun-Stanton and Schull [2] successfully used an Xbox 360 controller to control a cable-array robotic sculpture in the form of a Manta. Fox News [10] also has a news article depicting the use of an Xbox 360 controller to control an unmanned vigilante robot helicopter known as the Autonomous Rotorcraft Sniper System (ARSS).

## 4.4 Speech

To perform speech recognition, a signal is acquired, digitally processed and then analyzed to extract the features of the speech. The design of a speech recognition grammar is very important because human spoken language is particularly ambiguous [1]. A number of projects have succeeded in integrating speech recognition as part of a multimodal robotic interface. Perzanowski et al. [27] implemented a multimodal interface consisting of speech and gesture recognition on a team of Nomad 200 and RWI ATRV-Jr. robots. The purpose of this was to be able to control one or all of the robots. by addressing them individually or as a team.

# 5 Bluetooth Communication

Bluetooth is a short-range, low-power wireless technology for data exchange and communication. It enables the connecting of electronic devices to form Personal Area Networks (PANs) as well as ad hoc networks [7]. Since the inception of

Bluetooth in 1998, it has been adopted and is rapidly being developed by large influential companies such as Ericsson, IBM, Toshiba, Nokia, Intel and Microsoft [11].

Bluetooth technology was originally developed with the purpose of replacing cabling between devices [11]. Bluetooth operates on the unlicenced ISM (Industry Scientific Medical) band at 2.4 GHz. Bluetooth class 1 has a range of about 10 metres, while Bluetooth class 2 has a range of up to 100 metres. Due to ISM being an open band, Bluetooth is susceptible to sources of interference such as microwaves and 802.11 wireless networks [7]. To minimize such a risk, Bluetooth technology makes use of a Frequency Hopping Spread Spectrum (FHSS). This allows multiple Bluetooth networks and devices to operate concurrently without interfering with each other [7].

With wireless communication capabilities, mobile robots can connect to other mobile robots or computers. Therefore mobile robots can be controlled and monitored wirelessly using a computer. Bluetooth is well suited to this task due to its low cost, low power consumption and size. The computer acts as the master with the mobile robot being the slave device. Full-duplex Bluetooth communication enables the robot to send and receive messages to and from the computer [3].

# 6 Applications of Work

Mobile robots are often found in industry, military and security environments, as well as consumer products for entertainment or various household tasks such as a robotic vacuum cleaner.

Many researchers have reported work in the field of HRI with elderly people with dementia and children with autism [5]. A museum guidebot has been developed with the emphasis on friendly human-robot interaction through non-verbal behaviours [19].

Mobile robots have also been used as EOD (explosive ordnance disposal) robots for safely removing explosives from areas difficult for humans to reach

[4].

Mobile robots are being used in the military for unmanned exploration and even for defence and active engagement [24, 25].

Personal mobile robots can be used in homes for monitoring security, performing certain household tasks and to relay information back to the user.

# 7 Conclusion

Current and previous work in the area of human-robot interaction has been explored. It has been established that human-robot interaction research is important and necessary for effective interaction between humans and robots. Interactions should be natural and simple for human users to learn and understand so that they can focus on the tasks at hand rather than focusing on how to interact with the robot.

The LEGO NXT robotics kit was introduced and the capabilities and limitations of the sensors discussed.

Different modalities for a multimodal human-robotics interface were introduced and where relevant, previous work using a particular modality was presented.

Bluetooth communication technology was introduced and found to be a suitable channel of communication between a mobile robot and computer due to its wireless capabilities, low cost, and low power consumption.

Applications of mobile robots and interactions with humans were discussed and numerous scenarios of mobile robots in the real world were shown.

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