# Development and Evaluation of Various Modes of Human Robot Interface for Mobile Robot

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## Abstract

In the near future, robots are expected to be more acceptable and commonly used by human beings. Therefore, human robot interface (HRI) is essential to enable efficient and effortless communication between humans and robots. The main objective of this work is to develop, evaluate and then to improve current HRIs, such as teleoperation, manual, speech and vision interaction, by eliminating the weakness in these techniques. An enhanced teleoperation technique using portable devices was introduced as a better HRI technique for human to wirelessly control and communicate with mobile robot. Through this method, user can use their portable device to communicate with the robot as long as they are using the same wireless communication protocol and wireless devices. The portable devices tested in the project were the Personal Digital Assistant (PDA), a laptop and a remote PC. Comparison between different HRIs through experiments shows that portable device interaction is more reliable, efficient and easy to use compared to manual, speech and vision interaction.

## Keyword

Human Robot Interface, PDA interaction, mobile robot

## 1. Introduction

The field of robotics is currently undergoing a dramatic change. While in the past, robots are mainly used in factories for purposes such as manufacturing and transportation, nowadays, there is an increasing effort spent on service and entertainment robots. This is manifested through the various research projects on service robots such as Robox at Expo.03 [1], robot-waiters [2], tour guide robot [3], robot cleaner [4], wheelchair robot [5][6], museum robot [7], entertainment robot [8], robots that care for the elderly [9] and some of which are already operational in the real world like Sony AIBO dog [10].

Human Robot Interface (HRI) is of great importance for robots that are to interact with ordinary people. The type of interaction faced by such robot is spontaneous and short term especially for users who have no prior exposure to robotic technology. To enable new users to interact with the robot, the interface needs to be intuitive and have the ability to interpret the sometimes vague specifications from the user, so that untrained and non-technical users can operate the system without prior instructions. For applications involving human interaction, a robust HRI is also an important feature, in order to tell the robot the task it must perform or to provide it with information about the environment. The robots require the integration of sensing, acting, planning and communicating within a single system.

Robot with intelligent capability must guarantee safety and reliability while considering users' intention as it enters human environment and come in contact with inexperienced users. Some of the important criteria when designing a HRI are as follow [11]:

- Ease of use
- Usability
- Effectiveness
- Efficiency
- Satisfaction
- Safety

Certainly, no one claims that people must interact with the machines in the same way that they interact with other humans. Using the interface should be as simple as possible and as reliable as possible. Passive type of interactions such as speech and vision interaction are well known for their limitation in environmental conditions. Manual interaction is not suitable for service robots that are meant to move around. Indeed, a new and commonly accepted method of HRI is needed. This new approach should have the effectiveness of control, does not need any physical link, meant for public usage and robust enough in a working environment like office, school, street and shopping mall.

We should have a device that would be a medium of communication between robot and human, which streamlines the communication between them. When robot asks a question "Can I pass through?", the device shall display all the available possible answers such as "Yes" or "No" via an intuitive and user-friendly graphical interface. Human only need to click on the "Yes" option. User interface can be customized for different languages, reducing learning effort for users with different languages capability. Subsequently, a very high reliability of information exchange can be achieved.

The criteria of device which is suitable as the medium of communication between human and public robot is that it should be something commonly owned and always carried around by human. Common portable devices such as mobile phone, PDA and future integrated portable devices shall fit in. On top of that, the most important criteria is that all portable devices and robots should have the same communication technology and protocol.

Four techniques of HRI, namely manual, vision, speech and teleoperation techniques have been developed and evaluated for their performance on a mobile robot. The **manual** HRI employs push buttons and keyboard to execute commands for the robot. HRI using **vision** is implemented by capturing different colors to differentiate commands. At the moment, the robot is trained with six colors. HRI using **speech** enabled users to command the robot with spoken words. The robot is trained with limited number of recognizable words, which is sufficient for evaluation purpose. Lastly, an enhanced version of the **teleoperation** HRI is developed to communicate with the robot using portable devices. The teleoperation technique exploits the cheap and rapidly growing wireless communication technology, the Bluetooth. Bluetooth provides promising and attractive features; especially its size which is small enough to fit into any portable devices and its architecture which can be expanded with newly defined standard services' profile. Bluetooth's LAN Access Profile is used in this work, as the channel to access the baseband service where TCP/IP (Transmission Control Protocol/ Internet Protocol) will be the network communication protocol.

# 2. Hardware Design

## 2.1 BeMR

One of the main objectives of this project is to develop a mobile robot with various human robot interface methods. Thus, the hardware of the robot should be able to meet all the HRIs' requirements.

A mobile robot is fabricated for this project. It is called Bluetooth Enabled Mobile Robot or BeMR. BeMR is built up from different hardware components such as the controller, interface circuit, USB Bluetooth dongle, motors, wheels, camera, microphone, batteries and other peripherals. Figure 1 shows hardware components on BeMR.

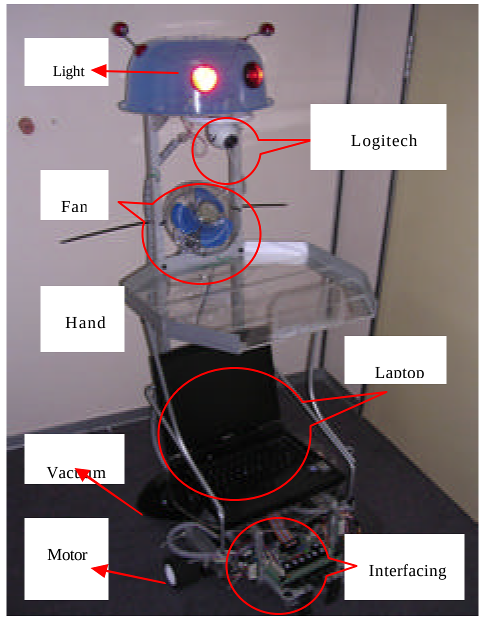



Fig 1: Hardware components on BeMR

A laptop TOSHIBA TE 2000 Pentium 3 (Figure 2) is used as the controller. Laptop is chosen because this project is still in the early development stage and it is more convenient and faster for developing a new application.

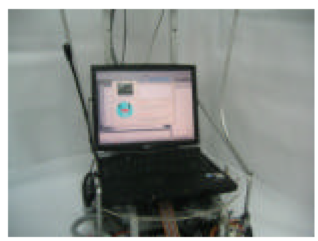


Fig 2: Laptop used as controller

The motor used is AXHM230k-GFH from VEXTA (figure 3). This series is a brushless DC motor adopting a thin, high torque motor and a 24 VDC input open case type high-precision driven. It is equipped with a special-purpose gear head with ratio of 20 (GFH2G20) which is best suited to high-torque operation by gear speed reduction.

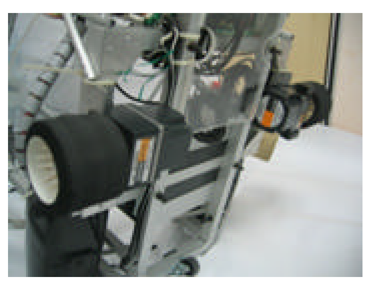


Fig 3: Motors

BeMR is connected with a USB Bluetooth Dongle from CADMUS. This USB Bluetooth Dongle is a Bluetooth Version 1.1 compliant, USB spec 1.1 compliant and working distances up to 100 meter. The dimensions of this Bluetooth device is 72.2mm x 29.8mm x 8.5mm (L x W x H). Built-in Bluetooth profile support includes Generic Access Profile, Serial Port Profile, Service Discovery Application Profile, Generic Object Exchange Profile, Object Push Profile, File Transfer Profile, Dial-Up Network Profile, LAN Profile, Fax profile, Headset Profile, Personal Area Network and Human Interface Device. Figure 4 shows the USB Bluetooth Dongle.

A Logitech QuickCam Pro is used to capture images for vision recognition. This Web Cam is connected through USB, can capture up to 640x480 pixels and capable of capturing 30 frames per second. Figure below shows the Logitech QuickCam installed on the BeMR.

Fig 4: USB Bluetooth dongle (Left) and Web Cam.

A microphone is used to capture speech for speech recognition. The microphone is plugged into audio input port on the main controller. Figure 5 shows the microphone used in BeMR.

Fig 5: Microphone on BeMR.

There are two types of light bulb on the BeMR. One type is the12V DC red bulb to replicate the eyes of the BeMR. Another is the 12 V DC fluorescent bulb located underneath the BeMR head. This light is added for extra illumination to improve vision recognition. Besides, it also lightens up an area as required. A normal 12 V DC car fan is attached on the BeMR. This fan can cool down an area as required. Figure 6 shows the location of the light and fan.

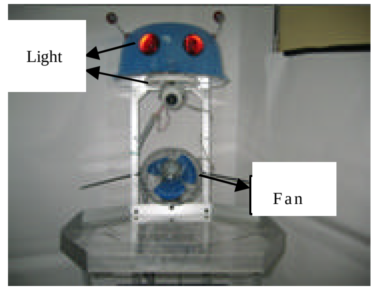



Fig 6: Light and Fan on BeMR.

Two 12V DC vacuums are attached underneath the BeMR. It can be used to vacuum dirt. Figure 7 shows vacuum attached on BeMR.

Fig 7: Vacuum used on BeMR.

## 2.2 BePD

One of the Bluetooth Enabled Portable Device (BePD) selected for this work is a PDA. The PDA used is the Hp iPAQ Pocket PC h2210 which has 3.5-transflective TFT display with 64K colors running at 400 MHz Intel XScale technology-based processor (see Figure 8 for the PDA used in this project). Most importantly, it is integrated with Bluetooth device, microphone, speaker and stereo headset jack.

Fig 8: PDA Hp iPAQ Pocket PC h2210

Other portable devices used for this project are a personal computer and a laptop. Computer is chosen because it is commonly available and easy for new application development.

Since Hp iPAQ PC h2210 comes with Bluetooth device integrated on it, no external Bluetooth device is required for PDA. Meanwhile, the Bluetooth device used for computer is the same model as the one used by BeMR.

## 3. Software Design

### 3.1 Manual Interaction

Manual interaction is achieved through the software module interfacing commands/inputs received from human via the BeMR hardware (Keyboard and mouse). User can control the robot basic controls such as navigation, modify speed level and switch on/off lights, fan and vacuum.

Two modes of manual control are implemented namely direct mode and autonomous mode. Direct mode is direct command to the BeMR to execute as per command and the autonomous mode sends command to the BeMR to execute pre-programmed automation such as path planning. Figure 9 shows the robot manual interaction main graphical user interface.

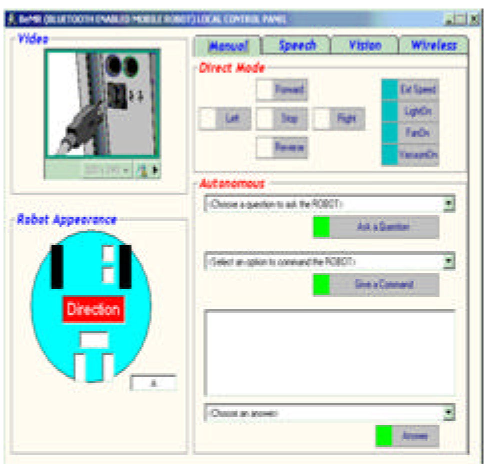


Fig 9: Manual Interaction GUI.

### 3.2 Speech Interaction

Speech interaction is achieved through the software module interfacing audio input via microphone and audio output via speaker. Speech recognition capability is provided by Microsoft Speech SDK v1.1. Figure 10 is the GUI snapshot for the Speech Control. Similar to Manual Control, two modes of control, direct and autonomous, are implemented where the control input is speech.

### 3.3 Vision Interaction

Vision interaction is achieved through the software module interfacing external camera to capture images as required. Image capturing utilizes the functionality provided by QuickCam SDK. Simple vision recognition is also implemented to provide capability to recognize 6 colors (Red, Blue, Green, Black, White, and Yellow) which can be mapped to any function/command. Figure 10 is the GUI snapshot for the Vision Control. Three modes of control (Testing, Direct and autonomous) are implemented where control input is via vision recognition.

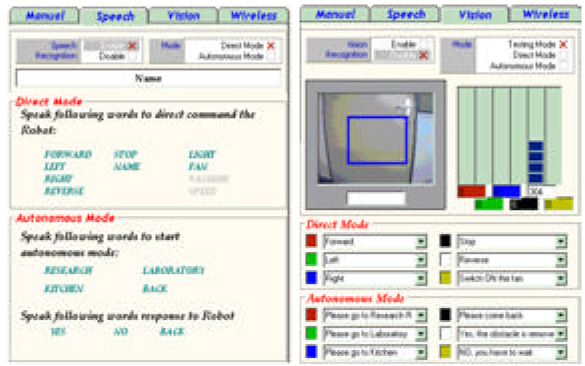


Fig 10: Speech Interaction (Left) and Vision Interaction.

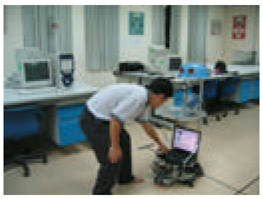
### 3.4 Portable Device Interaction

Portable device interaction is achieved through the software module to interface with BeMR wirelessly using Bluetooth. Visual Basic 6 is used to write the module for PC and Visual Basic.NET is used to write the software module for PDA. The module is implemented with two communication channels namely TCP server for data exchange and FTP server for video streaming. Figure 11 shows the GUI on PDA and Computer.

Fig 11: GUI on PDA (left) and a computer.

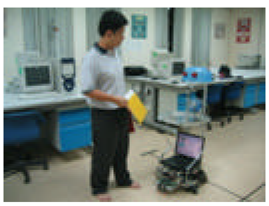
## 4. Experimental result

Several experiments were carried out to test the performance of the four types of human robot interface. The ultimate objectives of the experiments are to investigate the possibility of using portable device for communication between human and robot and to evaluate its performance compared to other known methods of HRI based on different factors. These factors are distance, noise, lighting, task complexity and ease of use. Figure 12 shows the four HRIs.

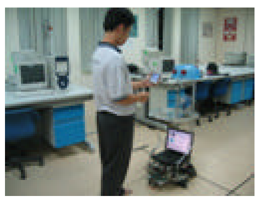


a. Manual

b. Speech



c. Vision



d. Portable device

Fig 12: Manual, Speech, Vision and Portable Device Interaction.

Table 1 shows the HRI's interaction performance based on different factors. Distance factor affected all HRI methods except the portable device interaction. It is impossible for a user to control a robot manually if the user is in a remote location. A user has to shout at the robot if the robot uses voice recognition and this is not practical.

Table 1 HRI's interaction performance based on different factors.

| **FACTORS** | **HUMAN ROBOT INTERFACE** | | | |
|---|---|---|---|---|
| | **MANUAL** | **SPEECH** | **VISION** | **PDA** |
| **Distance** | AFFECTED | AFFECTED | AFFECTED | *Not affected* |
| **Noise** | *Not affected* | AFFECTED | *Not affected* | *Not affected* |
| **Lighting** | *Not affected* | *Not affected* | AFFECTED | *Not affected* |
| **Task Complexity** | AFFECTED | AFFECTED | AFFECTED | *Not affected* |
| **Ease of use** | *Not affected* | AFFECTED | AFFECTED | *Not affected* |

With noise factor, speech interaction is affected tremendously. Imagine giving a voice command to a robot in a very noisy railway station. Meanwhile, vision interaction is affected by lighting. It is not possible for a robot to see in a dark environment. The object position was another influencing factor in vision interaction. This was proven when the color board was put at the same distance but at a different angle. The result was unpredictable because light reflected at different angles from the board affected the color as seen by the camera (Figure 13).

Fig 13: Different angles and different distance give different result in vision interaction.

To evaluate the system based on task complexity, users were asked to perform a several tasks using the four HRIs (Figure 14). All the HRI methods, except portable device interaction, gave poor outcome in terms of task completion.

Fig 14: Some of the users testing the HRIs.

It is important that the HRI is easy to use. Portable device and manual interaction were voted as the HRI which is easiest to use. This is mainly because they only have to click on the GUI. Furthermore, the GUI is found to be easy to understand and user-friendly. New user had no trouble using both methods mentioned above to control the BeMR as they only have to click on the screen with lots of information and explanation.

## 5. Conclusions

The main objective of this work is to develop and evaluate various types of Human Robot Interface to be used on mobile service robots, namely manual, speech, vision and teleoperation. Manual interaction required the user to manually control BeMR through hardware input (keyboard and mouse) attached physically to the BeMR. It is not suitable for mobile robots that will always move around. Speech interaction performs poorly in noisy environment and meanwhile, vision interaction performs poorly in different lighting conditions. In the experiments, portable device interaction performs impressively under all tested conditions. It can be concluded that HRI using wireless communication via portable device is more convenient and reliable compared to manual, speech and vision interactions.

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