USING A MOBILE PHONE TO CONTROL MOVABLE LEGO ROBOT SUPPORTED BY SIMPLE ROBOTIC ARM

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Abstract

Technology becomes more and more advanced in all areas. Smart phones technology and assistant robots can be devoted to help us and improve our life. According to the World Health Organization (June 2011) [1] over a billion people live with some form of disability. This corresponds to about 15% of the world's population. Between 110-190 million people have very significant difficulties in functioning. According to this statistics it is important to think and attempt to use the technology of robots to assist them, and to make them feel that they can live in a normal way and feel comfortable in their environment. In this paper, we have decided to help disabled people with movement difficulties by combining the technology of smart phones and mobile robots to provide them with a system that can control an assistant robot supported by arm using an Android mobile phone. This will increase their self-confidence because it will allow them to bring things from the surrounding environment without any other help from other persons.

Keywords - Lego MINDSTORMS, Robots, Motor Disabled, Mobile Controlling Robot.

1 INTRODUCTION

Robots are smart machines that can be programmed and used in many areas such as industry, manufacturing, production lines, or health, etc [10,11]. These robots perform hard, dangerous, and accurate work to facilitate our life and to increase the production because they can work 24 hours without rest , and can do works like human but more precisely and with less time. Assistive mobile robots that perform different kinds of work over everyday activities in many areas such as industry, manufacturing, production lines, or health, etc. are very commonly used to improve our life. The idea of this research is to exploit robotics usage on healthcare field to help mobility disabled people.

A smartphone is a mobile phone built on a mobile computing platform, with more advanced computing ability and connectivity than a feature phone. Smartphones are a more affordable and efficient hand held devices which can be used to support collaborative activities in a community. It is a result of a huge advancement in mobile phones technology [2].

This research combines the capabilities of robots (using 3 Lego MINDSTORMS kits to construct a prototype) with the Android mobile phone platform via Bluetooth connection offered by Android mobile phones and Lego NXT 'Brick'. This provides an interactive system by which disabled people can control an assistant robot with simple touches on user friendly interface, within the range of Bluetooth signals (10 meters) to get objects from the surrounding area. The user will be able to control the movement of the robot and perform actions of catching different kinds of objects.

We aim to develop a mobile phone application to control a robot regardless of its capabilities (e.g. robot with wheels and arm). As a proof of concept we built a robot model using Lego MINDSTORMS in order to test our proposed robot controller. The developed Android mobile application can run on any Bluetooth enabled android device which operates on API level 10 and more.

2 BACKGROUND

This section takes a brief look at Android smart phones and its features, Lego MINDSTORMS Robots, how smart Phones will help to develop a community in the environment it is used in. Hardware, software and communication protocols are evaluated for their suitability to this application. Finally, we take a brief look on existing systems.

2.1 Android Platform

Android devices are powerful mobile computers and they become more and more popular smart phones used worldwide. They becomes more and more popular for software developers because of its powerful capabilities and open architecture, also it's based on the java programming language. Because Android uses the Java programming language getting started with the Android API is easy; the API is open and allows easy access to the hardware components. Android devices provide numerous communication interfaces like USB, Wi-Fi and Bluetooth, that can be used to connect to the robot. We think it is a great platform for a robotic system control, because it's much cheaper than any other ARM-based processing unit. We use android platform because it is the widest used in the word and runs the largest number of smartphones worldwide [3,4].

2.2 Lego MINDSTORMS

The Lego MINDSTORMS NXT series of kits contain software and hardware to create small, customizable and programmable robots. The Lego MINDSTORMS NXT system becomes very popular in universities [13,14] because is cheap compared to other advanced robots platforms, the NXT kit is very flexible to construct because it consists of hundreds of mechanical building units, gears. Also, it contains motors and sensors that can be used to build many models of robots, the main kit component is the CPU NXT 'Brick' computer that acts as the heart of the robot. This 'Brick' can be connected to 3 servo motors and four sensors (ultrasonic range sensor, light sensor and two touch sensors) via RJ11 wires and will take care of the processing, USB or Bluetooth communications to make control over robot actions. The robot motors are flexible and powerful enough to move the robot, and can move a robotic arm within the accuracy of one degree [5,6,12].

2.3 Connectivity and Communication

This section discusses the communication protocols available and how they are used by the system.

Lego MINDSTORMS NXT Communication Protocol: The Lego MINDSTORMS NXT product includes the communication possibilities that will enable higher communication speed and wireless communication.

The Lego MINDSTORMS NXT includes the following communication possibilities:

- Bluetooth Communication, V2.0 with EDR.
- USB Communication V2 [7].

The main Lego MINDSTORMS NXT Communication Protocol contains a sub-protocol specifically designed for direct commands which make it possible to control the NXT brick from outside devices. These outside devices may be other NXT bricks, a PC, or any other Bluetooth capable device. the main intent behind including this sub-protocol is to provide simple interface for this outside devices to utilize basic brick functionality (i.e. Motor control, sensor reading , and power management), without the need to write or run specialized remote control programs on the brick.

All the communication that occurs between the robot and the mobile application are subject to the Lego MINDSTORMS NXT Direct Commands Communication Protocol.

Bluetooth: Bluetooth is a wireless communications protocol running at 2.4 GHz, with client-server architecture, suitable for forming personal area networks. It is designed for low power devices such as mobile phones [8].

Bluetooth now comes as standard on the majority of mobile phones, and desktop computers. It can be easily fitted with a module to allow Bluetooth communication. Bluetooth is the only appropriate communications protocol for this system because the NXT brick supports only Bluetooth wireless communication. We use Bluetooth to connect and send direct commands from the mobile phone to control the robot based on Lego MINDSTORMS NXT Direct Commands Communication Protocol.

2.4 Software

This section discusses programming languages and software that used for the development of the NXT mobile controller application.

NXT Firmware

The Lego MINDSTORMS provides a programming environment called NXT-G. It is a graphical programming language which is suitable for simple robotic programs the NXT Brick operates on this firmware by default. The NXT-G support simple functionality such as accepting Bluetooth connections, receiving LCP messages, process and execute LCP Direct commands, and move motors or read input from sensors. There's a wide range of alternative firmwares, development environments and libraries for various languages (C, Assembler, Java, Matlab...). We use NXT-G firmware because we used LCP Direct commands to control the robot actions [5,6,7].

Android SDK

Android is a software stack for mobile devices that includes an operating system, middleware, and key applications. The Android SDK provides the tools and libraries necessary to begin developing applications that run on Android-powered devices [3,4].

Android SDK environment for developing GUIs is very suitable for developing the Front end of the application, Android application is a set of Activities pending to each other and each activity has its own UI, the most common way to define a UI is with an XML layout file saved in the application resources. This way, you can maintain the design of your user interface separately from the source code that defines the activity's behavior. The front end of the application is the interface by which users interact with the application. This section discusses the suitability of Android SDK to the development of the Front end.

3 DESIGN

This section introduces the system requirement, system architecture, the design of the front end interfaces, and the robot model that is constructed.

3.1 Requirements

Table 1 lists the requirements for the overall application.

ID	DESCRIPTION
R1	The System shall run on any Bluetooth enabled android device that operates on API level 10 or more.
R2	The System shall store the MAC address and robot configuration for the current connected robot.

R3	The System shall allow the user to connect and control a pre connected robot directly.
R4	The System shall allow the user to start scanning for new robots and make a new connection to any found robot.
R5	The System shall prevent the user to navigate from the main interface to the robot controlling interfaces if the Bluetooth is not enabled.
R6	The System shall allow the user to control the power of the robot motors.
R7	The System shall provide a list of common objects that the user may frequently need that will set the catching speed to the appropriate value for the selected object.

Table 1. System Requirements

3.2 System Architecture

Fig. 1 shows the overall architecture of the system, and with which components the different types of users will interact.

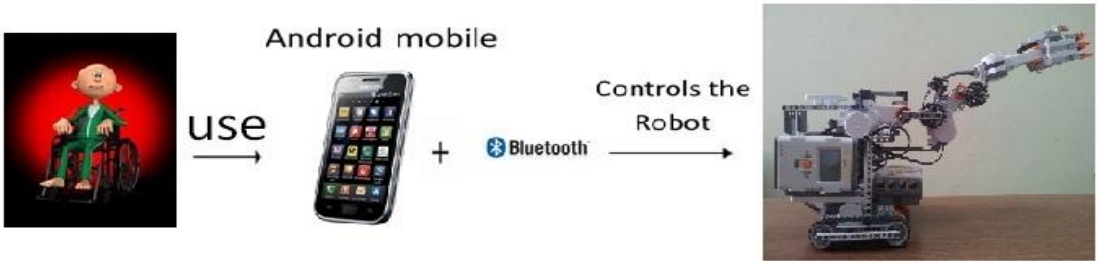

Fig. 1. SYSTEM ARCHITECTURE

3.3 Robot Model Construction

The construction of the robot accomplished using 3 Lego MINDSTORMS Kits [9]; the model is built using 3 kits because each kit contains only three servo motors and one brick and the proposed model (Fig. 2) needs seven servo motors that also need 3 bricks to control them because each brick can control at most three servo motors.

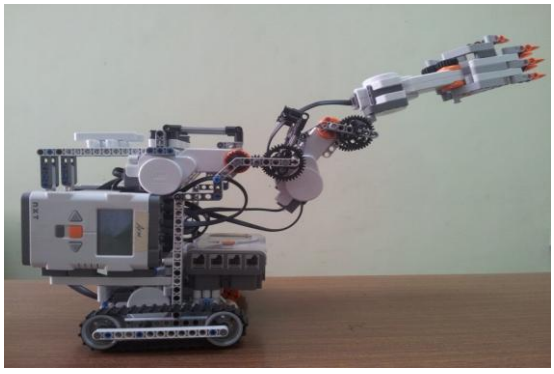

Fig. 2. ROBOT ARCHITECTURE

Based on the functionalities that the system shall provide; the robot model must contain three parts; wheels, arm, and hand, each of these components will contain motor(s) that is responsible for the movements that each part of the robot shall support, also each part will have an independent brick to control these motor(s).

4. IMPLEMENTATION

This section documents the implementation of the system using the criteria set out in the previous section. This section is divided into several sections, one for each component of the system.

4.1 System's Sequence of Events

Fig. 3 shows the typical sequence of events when a user runs the application. This sequence diagram assumes the user already has the software on his phone and the robot and it represents an abstract level of the interaction between the system components (mobile application and the robot).

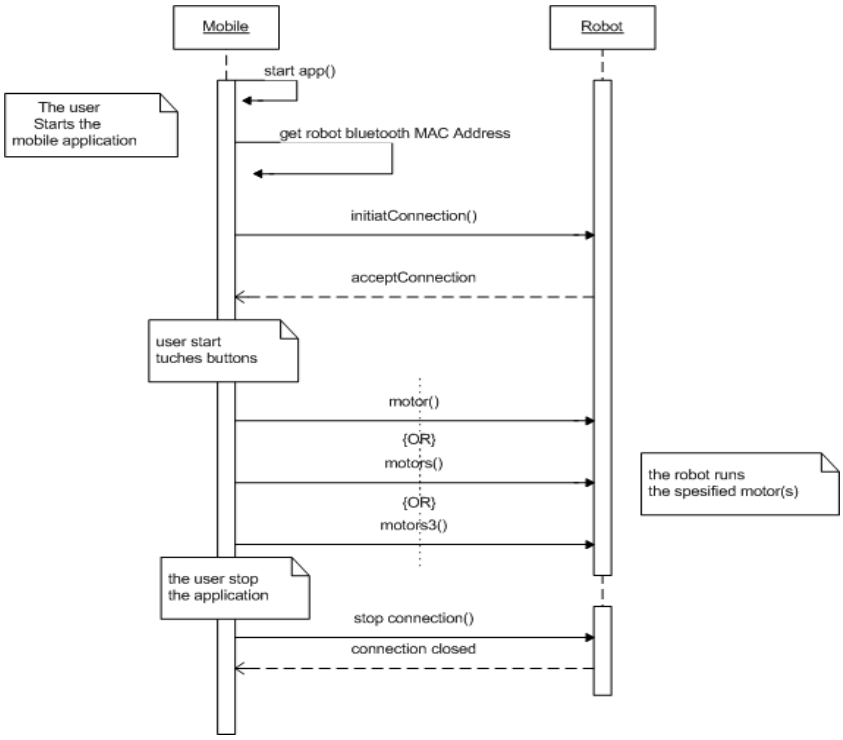

Fig. 3. SYSTEM SEQUENCE DIAGRAM

4.2 Mobile Application

The mobile application consists of many User Interfaces connected to each other, each interface specialized to control a specific functionality on the robot side, each button will send different command to the NXT Brick that will process and execute the command. Fig. 4 shows one of the screens of the mobile application.

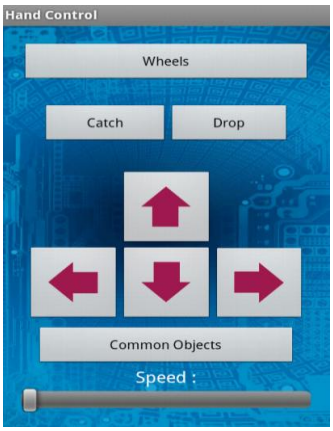

Fig. 4. User Interface

5. SYSTEM OPERATION

This section is a walkthrough of a typical scenario of using the NXT Mobile Controller system. This walkthrough assumes that the user runs the application for the first time.

5.1. Setting up a Connection

The first step to start using the system it's necessary to set up a connection between the two components, Fig. 5 shows a sequence diagram that demonstrates how to set up a connection.

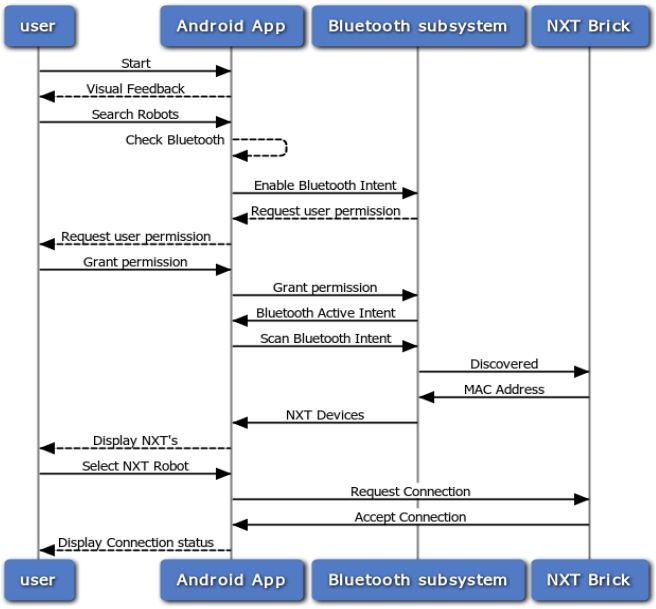

Fig. 5. SETTING UP A CONNECTION SEQUENCE DIAGRAM

5.2 Start Controlling the Robot

After setting up the connection the user will start controlling the robot using the direction buttons in the application UI; when pressing a direction (controlling) button, an LCP Direct Command will be sent from the mobile to the robot. Fig. 6 show the sequence of actions that occurs in the communication between the application and the NXT.

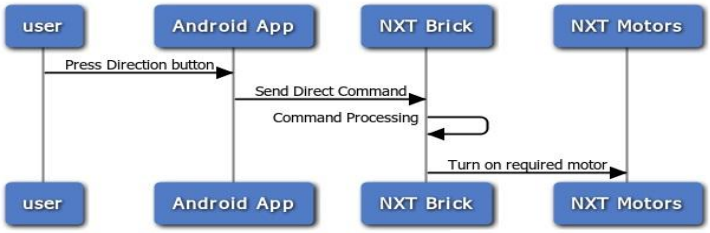

Fig. 6. CONTROLLING MOTORS SEQUENCE DIAGRAM

6 TESTING & EVALUATION

This section describes and discusses the real-world testing for the system and gives an evaluation of the functionality and user interface of the system.

6.1 Procedure

To test the system in a real-world environment, we went into a practical session consisting of some bottles, end-user, and some reviewers that monitor the application work , robot response and construction, where we record a video that describe the testing.
The session began with a brief presentation introducing how to use the mobile application and how to control the robot, after the testing finished we have collected the feedback notes and questions. We have recorded these feedback notes and questions and we have worked to change the system according to it.

All participants were asked to record their questions and feedback and answering some questions about system usability and reliability.

6.2 Results

From the system evaluation we note from user feedback, questions and answer some alteration in the mobile application and in the robot, where, end-user may need many steps to move arm, make (Catch, Drop) operations and return to control arm, wheels of robot.

Another comments like user-interface need some alteration like remove some buttons, add some buttons that move user from hand controlling to wheels controlling without need to return in sequence way.

Robot arm construction like add three motors to provide more power and ability to carry the object, made robot more fixed and balanced.

7. CONCLUSION & FUTURE WORK

This paper presents a robot model with an arm that is fully controlled by a mobile phone using a Bluetooth signals. We used Lego MINDSTORMS NXT to construct the robot model because of its low-cost with powerful and extensible features that satisfies our goal. The purpose of such system is to help people with motor disabilities in controlling different widgets in daily life using mobile phone. The proposed idea can be expanded to control almost any device with Bluetooth receiver.

The usability and functionality of the system has been proved through real-world testing that has been carried out with many participants. The evaluation results show that participants enjoyed their experience with the system, and agree that there is a need for this type of systems in the health care field.

In the future we plan to use more powerful robot that can hold any object that the human may need from the house such as a book, TV remote control, medicine bottle, a cup of water, etc. The following points list some ways in which this system could be extended in the future:

- Improve the mobile application to receive voice commands to control the robot. This will enable blind people to use such a system.
- Improve the robot ability to move larger objects by extending its size, or using more powerful robots.
- Increase the robot intelligence through enhancing object detection and collision detection algorithms.
- Extend the robot capabilities to be used for other purposes (e.g., using the robot for environments that cannot be accessed by human).

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