Tele-presence Based Patient Monitoring Robot

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Abstract

Tele-presence is a vast terminology incorporating techniques, methods and ways to make someone present at a location virtually to achieve a specific goal. Tele-presence systems can take many forms ranging from a simple software to a complex artificial intelligence based robots. In this paper, we develop a simple and cost effective tele-presence and multi-purpose robot controlled by both Wi-Fi and through web. Furthermore, the developed system supports live video streaming from any location as well as the video and audio transmission. The robot is tested for patient monitoring and a complete system is designed for this purpose.

Keywords: *Tele-presence, Micro-controller, Video streaming, Patient monitoring, 3-Tier Architecture*

1. Introduction

In today's era of distance control and autonomous vehicles, the concept of tele-presence plays an important role in many applications where presence of human being is not possible. Such applications include but not limited to rescue missions extreme terrains and environmental conditions using intelligent and human being controlled robots [1], Tele-surgery [2], industrial and security inspections [3] and Unmanned Arial Vehicles (UAVs) for 3D modeling [4]. Furthermore, tele-presence technology can provide users with solutions for advanced mobile video conferencing communication and remote navigation. A virtual presence environment can be provided by such robots. The robots are equipped with a screen displaying smiling mug to co-workers, as well as a camera that beams a feed straight to the computer screen. Tele-presence robot requires that the senses of the user, or users, be provided with such stimuli as to give the feeling of being in that other location. Additionally, the users may be given the ability to affect the remote location. In this case, the user's position, movements, actions, voice, etc. may be sensed, transmitted and duplicated in the remote location to bring about this effect. Therefore information may be traveling in both directions between the user and the remote location with automatic operation. Although robots have the programming logic to do the desired task but the decision power lies in the hand of the controller (human) handling the robot.

As an example of an existing robot under the tele-presence category is a patent work by Wang et al. which was assigned to InTouch Technologies Inc. [5]. It discloses a robotic

system that includes a primary remote control station and one or more secondary control stations that are all linked to a tele-presence robot. The system allows the secondary stations to observe the video/audio feed provided by the robot. This allows the users of the secondary station to be trained through the robot and primary station.

In most of the tele-presence applications both the remote station and the controlled station (e.g. robot) have cameras, monitors, speakers and microphones to allow for two-way video/audio communication. The controlled entity's camera provides video images to a screen at the remote station so that the user can view the robot's surroundings and move the robot accordingly. In addition most of the communication between the two entities takes place through a wireless communication infrastructure [6]. Mediums of communication can vary according to application and distance Satellite, microwave, sonar and many more channels can be used for remote control and communication. In addition it would be desirable to modify such systems to have two way communication or to transfer robot control from one robot station to another.

Now in order to develop a tele-presence robot, and looking at the present demands of robots especially in developing countries, appropriate development of robots in a cost effective manner is required. This development helps many industries, workplaces and research development centers to utilize robots in place of humans. In our work, we have developed a generalized multipurpose tele-presence robot which is controlled by either a wireless device or through the web with minimal affordable cost. Rest of the paper is organized as follows: in section 2 a brief system design and architecture is discussed. Section 3 gives details regarding the components used in our work. Section 4 describes some use cases along with cost analysis of the system. Conclusion and future enhancements are presented in section 5.

2. Overview of the Proposed System

The objective of our work was to develop a cost effective robot which can be controlled through a wireless communication medium (in this case Wi-Fi connectivity is used) and through internet. The movement of the robot is controlled by pressing appropriate buttons on the designed website. In addition a bidirectional audio and video link provision is there which can aid a user in navigation. The overall system block diagram of our system is shown in Figure 1. The system can be broken into two parts, the first one is at the robot side and contains various hardwares for movement control along with camera and a receiver for video streaming and instruction reception from the control station respectively. The second one at the remote station end is software in the form of web application for issuing movement instructions and for displaying the streaming video. The link between the transducers at both ends is wireless (ZigBee, Wi-Fi, infrared or blue tooth). In our experiments, we have used Wi-Fi connectivity.

In addition, we can view the system as a client and server. The state diagram at both ends is shown in Figure 2 and Figure 3 respectively. At the client side, only movement control and monitoring takes place while at the server side, various signal level processing takes place along with mechanical processing. The developed robot can but you specifically in a hospital environment where doctors who would like to monitor a patient or a room within a hospital can access the robot through an online web system. Registration of authentic doctors and

other authentic persons who are permissible to interact with the robot is done through the website initially. A simple log in and some other sample forms are shown in Figure 4. Once an authentic log in is achieved, a control navigation buttons appear which directly controls the tele-presence robot along with a display window to monitor the movement of the robot as it is evident in Figure 4(b). It is obvious that a transmitting Wi-Fi device is used with the PC terminal hosting the web application. Similarly at the robot end, we have used a laptop supporting Wi-Fi connectivity and which itself connected to the robot through a serial connection. Multiple view of our developed robot is shown in Figure 5. A housing box is used to incorporate the PC terminal (laptop, microcontroller with other hardware accessories). In the next section, a complete list of hardware components along with their descriptions and functionality is given.

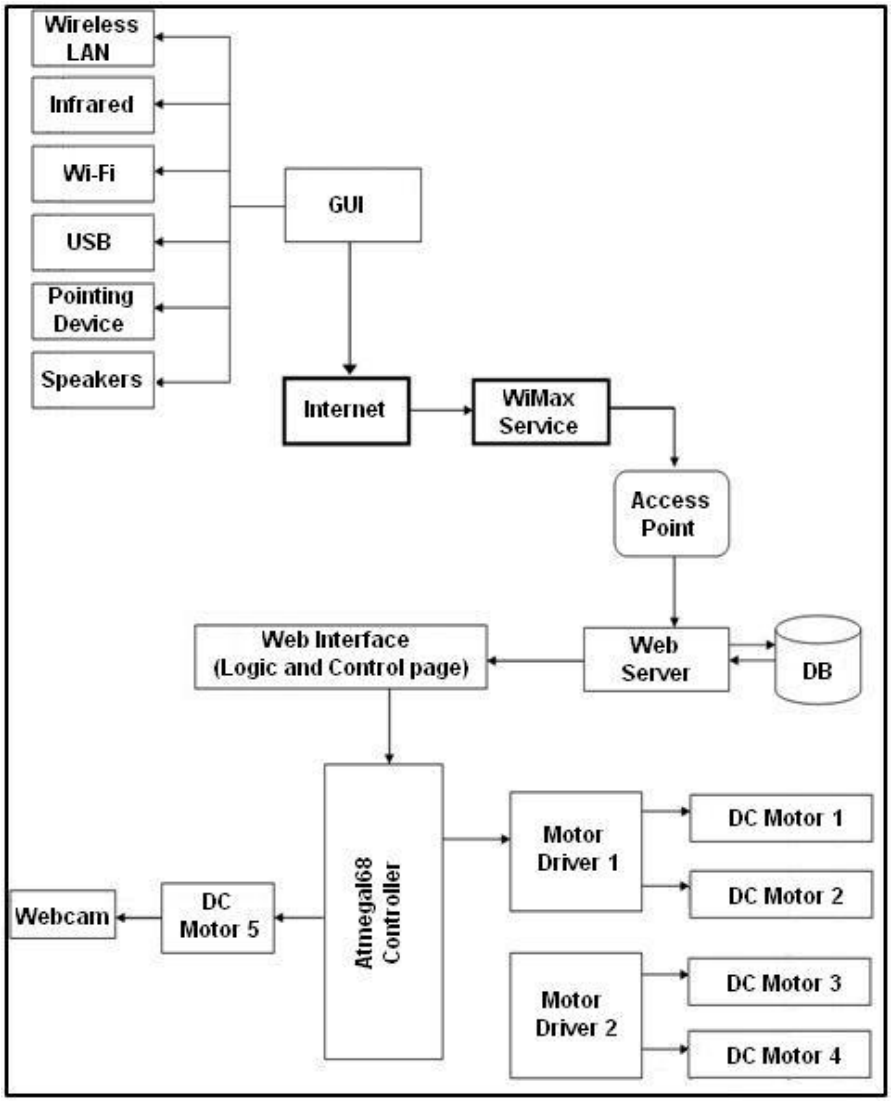

Figure 1. The Proposed System Block Diagram

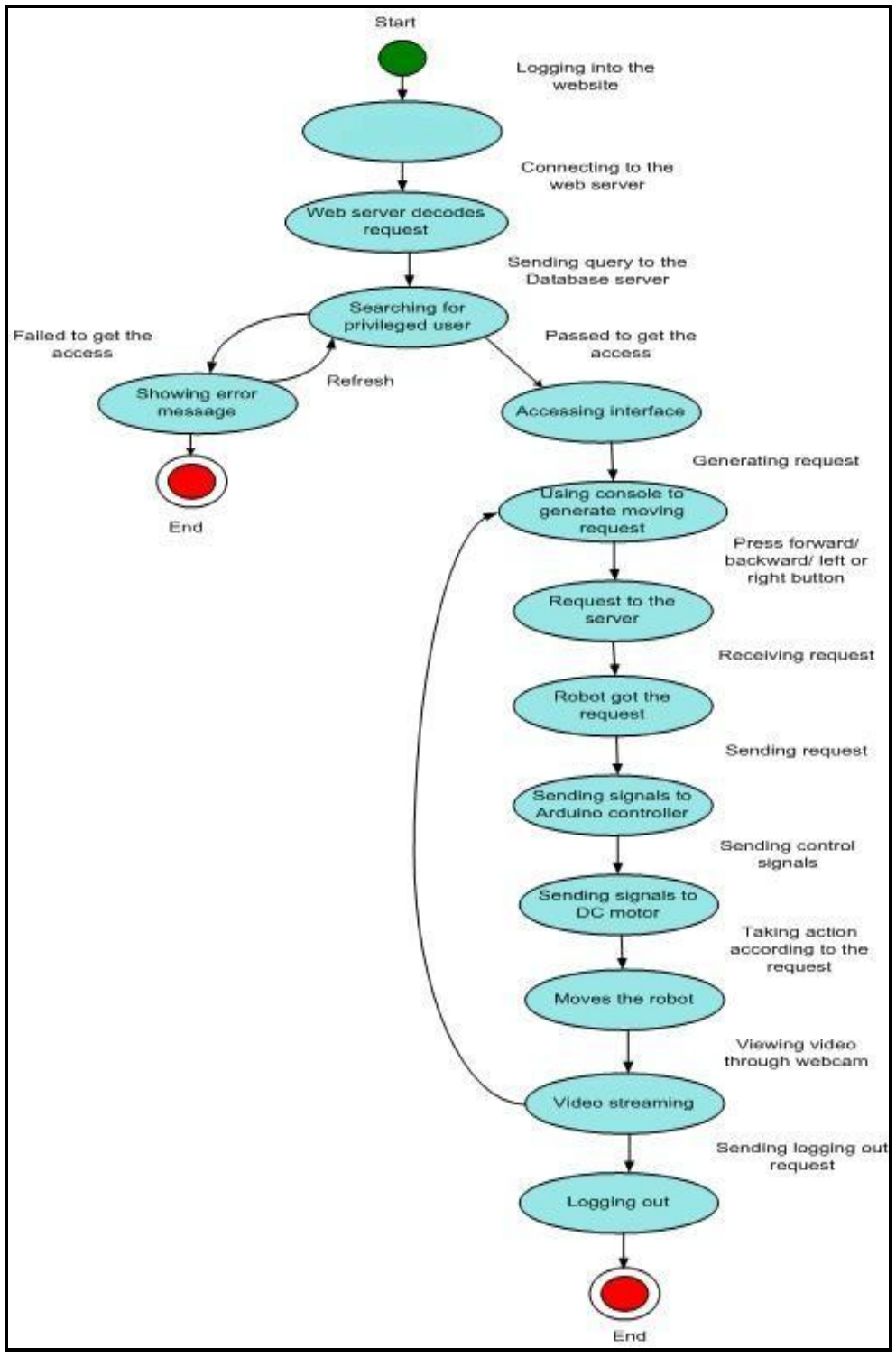

Figure 2. State Diagram of the Proposed System at the Client Side

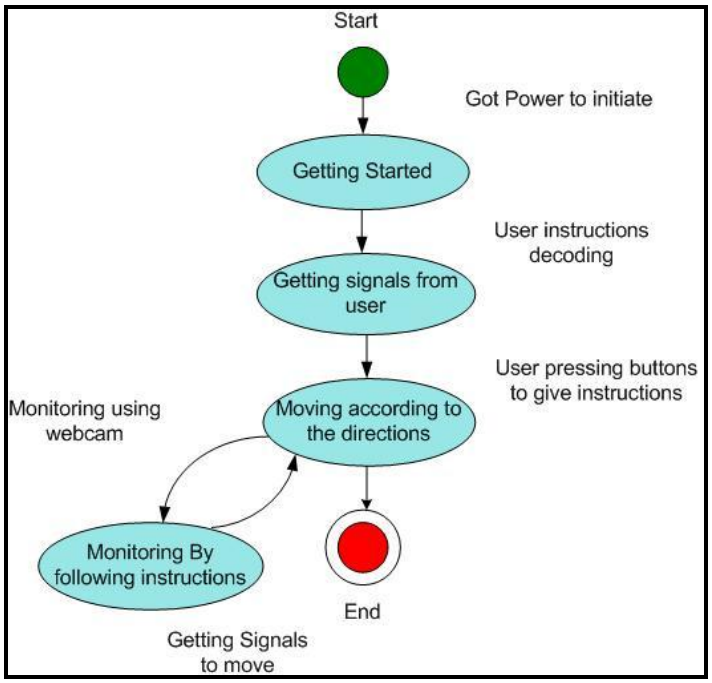

Figure 3. State Diagram of the Proposed System at the Server Side

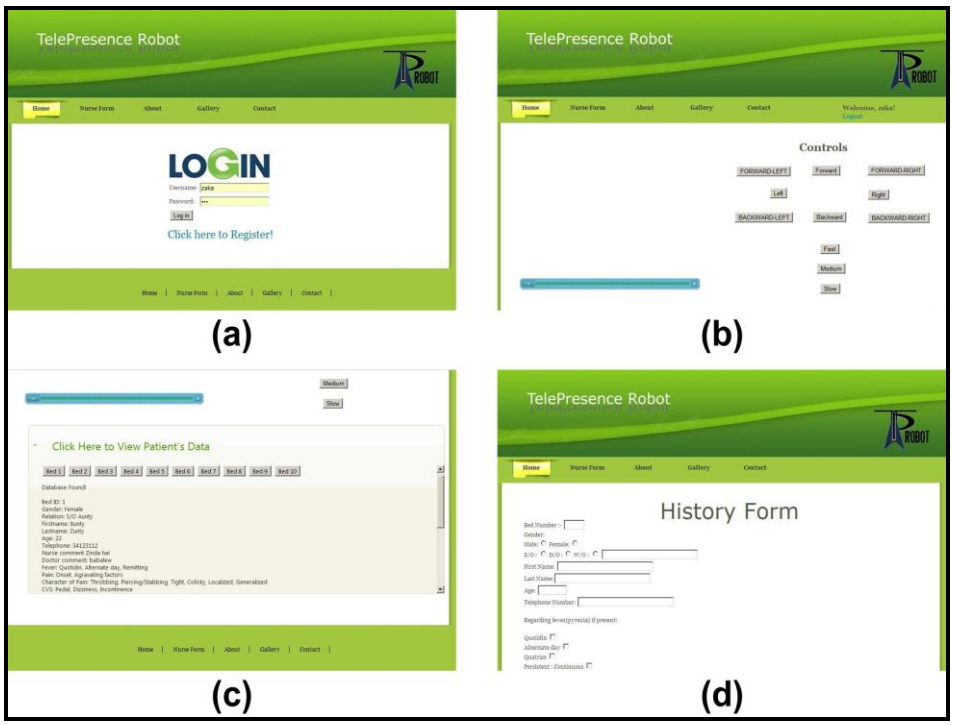

Figure 4. Sample forms at the client end: (a) Log in form (b) Robot navigation and display page (c) Patients data sheet (d) Patients history form

Figure 5. Snapshots of the Developed Robot

3. Various Component Descriptions

Number of cost effective and efficient hardware components is used at the robot side and at the interfacing level between the server and the robot. The details of these components and their functionalities are given below along with some software tools:

3.1. AT Mega 168 Controller

It is an ideal new and powerful main controller for complex applications [7]. This unit is both compact and powerful with high speed operation making which makes it suitable for many real time applications including robotics, remote sensing and machine control. Various features of this unit are listed below:

- Powerful Atmel ATMega128 Microcontroller with 128kb Internal Flash Program Memory
- Operating Speed at 16MHz with up to 16 MIPS throughput
- In-Circuit Programming via ET-AVR ISP
- LCD Connector with Contrast Adjustment
- 8 Channel 10-bit A/D Convertor
- 4kbyte EEPROM
- Power LED
- Reset Button
- Ideal as an Interchangeable Controller for Real-Time Systems

3.2. DC Motors

These motors are used to vary the speed-torque relationship in any direction of rotation. Continuous operation of dc motors is commonly available over a speed range of 8:1. Infinite range (smooth control down to zero speed) for short durations or reduced load is also common [8].

3.3. Arduino IDE

T It is used as a supporting tool for our hardware components. The Arduino IDE is a cross-platform application written in Java. It is capable of compiling and uploading programs to the board with a single click. There is no need to run programs on the command line using this tool.

3.4. Wi-Fi Routers

It is used for building wireless connection between robot and the user accessing the robot providing access to network devices in public locations.

3.5. Computer Terminals

Two processing systems are required, one at the client and the other at the server side.

3.6. 1L293 Based Motor Driver Circuit

Four D.C motors are used for the horizontal motion of the robot. This task is accomplished by using a single circuit employing a L293 to drive the four D.C motors. L293 is a quadruple half-H bridge IC primarily meant for motor driving applications with a high current handling capacity of up to two amperes peak current as required.

3.7. Atmega168 Controller

Atmel's ATMega168 8-Bit Processor in 28 pin DIP package. 16K of program space, .23 I/O lines, 6 of which are channels for the 10-bit ADC. It runs up to 20MHz with external crystal. Package can be re-programmed in circuit.

3.8. Distributed Power Supply

The distributed power supply provides secondary sources of power of different voltage levels required by the various electronic modules while using a single 12V7AH sealed lead acid battery as the primary source of power.

3.9. Flash Media Server

Streaming video with Flash Media Server provides many advantages over embedded and progressively downloaded video. Video playback starts sooner than it does using other methods of incorporating video. In addition, streaming uses less of the client's memory and disk space, because the clients do not need to download the entire file [9]. Also Flash Media Server enables multi way and multiuser streaming for video chat, video messaging, and video conferencing applications.

3.10. Apache Web Server

Apache offers various features including implementation of the latest protocols customizable, extensible, and efficient. It runs on a wide variety of operating systems, including all variants of UNIX.

3.11. WAMP Server

It is a wonderful package for PHP developers. Version of WAMP Server contains - Apache 2.2.6, MySQL 5.0.45 and PHP 5.2.5 in one package.

3.12. PHP

There are some indisputable great reasons to work with PHP. We used PHP because it has many disadvantage over other web development languages. It Works great with HTML and both are interchangeable within a web page. PHP allows users to interact with visitors in ways HTML alone cannot. We have used PHP as a scripting language that can manipulate information held in a database and generate web pages dynamically each time content is requested by a browser. It also provides a graphical user interface called php MyAdmin 3.2.0.1 for the MySQL database manager.

3.13. Database

At the base of an application is the database tier, consisting of the database management system that manages the database. In our work MySQL database server is used which provides excellent scalability and high performance. Its unique storage-engine architecture allows dynamic configuration of the database server. Specifically for some applications such as Web and Data Warehouse, it provides robust high-traffic web sites because of its high-performance query engine and specialized web functions. In terms of database authentication, MySQL provides powerful mechanisms for ensuring only authorized users have entry to the database server.

As it is evident from these components, our model follows a 3-tier architecture. Built on top of the database tier is the complex middle tier, which contains most of the application logic and communicates data between the other tiers. On top of the hierarchy comes the client tier. Usually web browser software that interacts with the application is an example of an application in this tier. A typical 3-Tier model is shown in Figure 6. All selected tools are used to provide feasibility and ease to use the prototype in a very effective manner. Furthermore, hardware connectivity is shown in Figure 7. Navigation commands issued by the user are received by the computer server after which these instructions are passed to the micro-controller. The Arduino IDE provides a platform for interpretation of these instructions. Both the webcam and the L293B driver circuit responsible for controlling the motors are connected to this micro-controller board.

4. A Use Case and Cost Analysis of the System

In designing the robot, various requirements, constraints and limits were taken under consideration. For instance, in dimensional requirements, the area required by the different parts to be placed e.g. laptops, battery, and camera were considered when designing the

housing box on top. Similarly for weight considerations, the total weight of the robot is around 8 Kg. Therefore the DC motors chosen for driving the robot are powerful enough to carry the weight without locking while turning. Figure 8(a) shows the connectivity of the Arduino controller, Figure 8(b) shows the connectivity of motors and Figure 8(c) shows the motor driver connectivity.

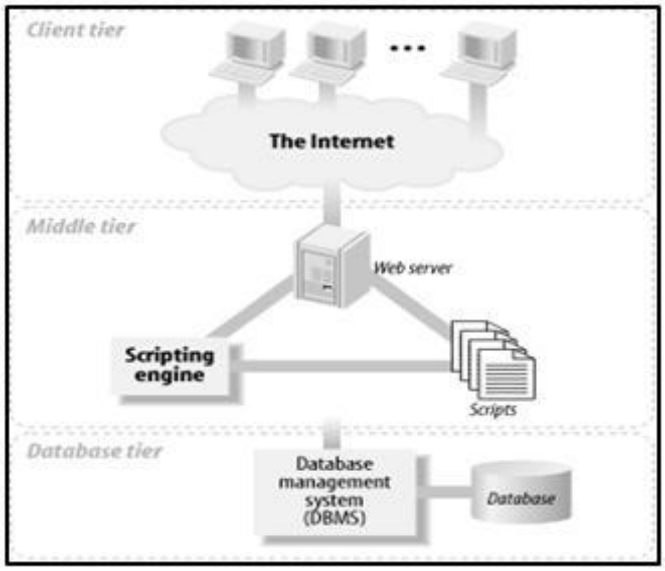

Figure 6. General 3-Tier Architecture of a Web Application System

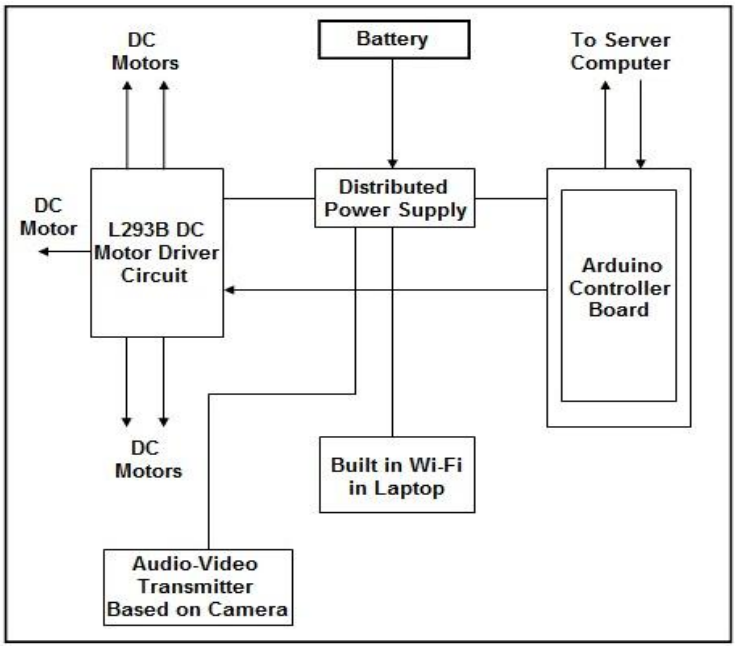

Figure 7. Electronic Module Connectivity and Distribution of the Proposed System

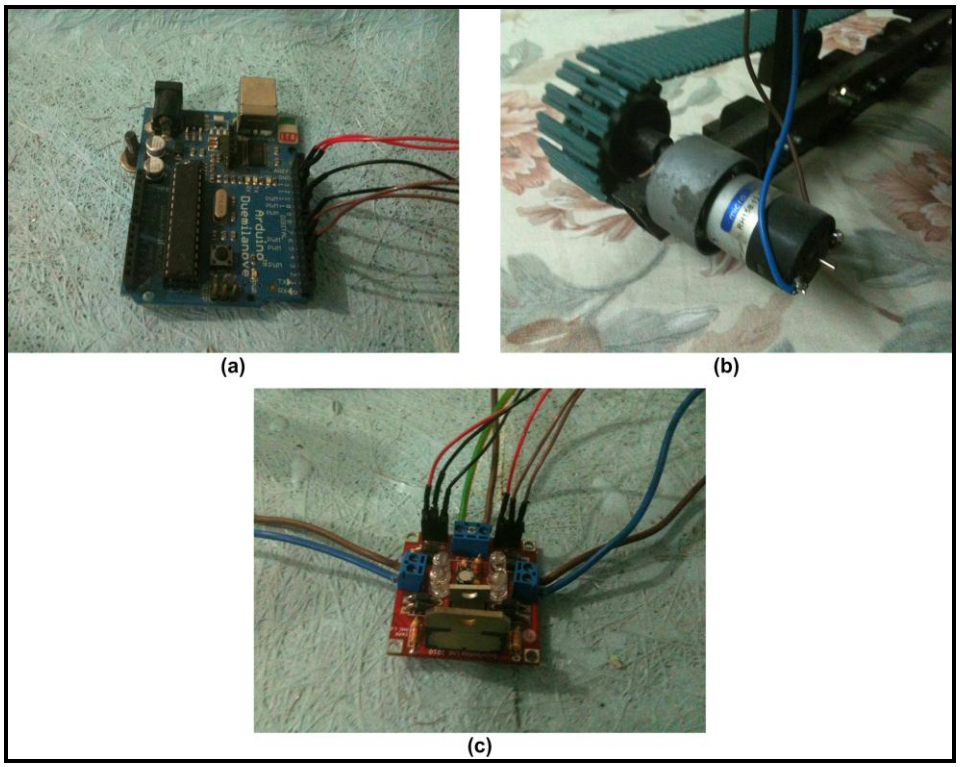

Figure 8. Connected Components: (a) Connectivity of the Arduino Controller (b) Connectivity of Motors(c) Motor Driver Connectivity

Now an approximate cost of the components along with additional costs is shown in Table 1. The total cost of the system apart from software cost is around 899 US Dollars which a very cost effective tele-presence robot especially for under developed countries.

Finally to illustrate the working of our work a simple use case scenario is provided describing the steps through which our software works. A use case diagram for patient monitoring is shown in Figure 9 and can be divided as shown below:

a) Use case name: **Website interface interaction**

Summary: Website interface interaction process requires Doctor/Consultant to interact and submit personal information to be stored in the database or to authenticate the valid person. System will allow Doctor/Consultant to perform desired task either use console or monitor the patient.

Actors: Doctor/Consultant.

Preconditions: Doctor/Consultant can access the interface.

Post conditions: Doctor/Consultant has successfully entered into the monitoring system.

Flow of Events:

1. Doctor/Consultant enters the HTTP request for the monitoring system website and clicks on “Login” or “Register”

2. System prompts Doctor/Consultant to enter personal information including name, password and email address into the empty fields.
3. Doctor/Consultant can find the information related to the system by clicking on tabs.

b) Use case name: **Registration**

Summary: Registration process requires Consultant to enter and submit personal information to be stored in the database. System will respond to warn user for any correct or incorrect entered data. Correct email will be verified via email and password will be set up accordingly.

Actor: Consultant

Preconditions: Consultant has an email account.

Post conditions: Consultant has successfully registered with patient monitoring system.

Flow of Events:

1. Consultant opens the System website and clicks on "Register."
2. System prompts Consultant to enter personal information including full name, email address into the empty fields. The user will also choose a password, entering it twice for confirmation.
3. Consultant enters all the information needed, and clicks "Submit" button.
4. System validates form data, then saves the information in database and informs the Consultant.

c) Use case name: **Getting Authentication**

Summary: Doctor/Consultant enters the login name and password and the system validates the entered information with the information stored in the database. System will respond to warn user for any correct or incorrect entered data.

Actors: Doctor/Consultant

Preconditions: Doctor/Consultant is logged into the System.

Post conditions: Doctor/Consultant has successfully edited his profile

Flow of Events:

1. Doctor/Consultant clicks on "Login"
2. System validates form data.
3. Displays message that profile has been loaded.

d) Use case name: **Make Appointment**

Summary: Doctor checks his or her appointments and monitors the patient according to the information or record made by the nurse. System allows Doctor to change the record with respect to the current situation. Any feedback from the nurse can be accepted by voice.

Actor: Doctor

Preconditions: Doctor is logged into the System.

Post conditions: Doctor validates the record by monitoring patient.
Flow of Events:

1. Doctor clicks on "Record"
2. System prompts for the "Bed No".
3. Doctor confirms the monitored information.
4. System updates the record according to Doctor's opinion.

Extensions:

3a. Doctor can reject the record and can update it.
3a.1. System returns to entering record.

e) Use case name: **Using Console for Robot's movement**
Summary: The doctor enters into the system by logging in and enters the validation password to get right to control the movement of robot by using console which can send the directions to the robot to move forward, backward, left and right.
Actor: Doctor.
Preconditions: Doctor has logged in and entered password.
Post conditions: Give directions to control the robot.
Flow of Events:

1. Doctor log on to the website.
2. System prompts for validation password for the console.
3. Doctor enters password and clicks "Get control".
4. System shows the console for controlling robot's movement.
5. Doctor give instructions to robot for movement by clicking on buttons "Forward", "Backward", "Left" and "Right".

Extensions:

2a. Password for using console does not match.
2a.1. System displays "Invalid Password".

f) Use case name: **Manage Patient's Record**
Summary: A Nurse manages and maintains every patient record so that doctor can access it and can have knowledge about the patients.
Actor: Nurse
Preconditions: Nurse has right to update the records.
Post conditions: Nurse has successfully enters records.
Flow of Events:

1. Nurse clicks on "patient records"
2. System shows the forms for entering history about the patient
3. Nurse fills up the form after diagnoses

g) Use case name: **Store Patient's Record**
Summary: For each patient nurse enters the information related to the diagnosis for that patient and stores it in the database.
Actor: Nurse
Preconditions: Nurse accesses the forms for patient's record.
Post conditions: Nurse stores the information into the database.
Flow of events:

1. Nurse accesses the forms.
2. System shows forms for entering record.

3. Nurse enters information.
4. Stores information into the database.

h) Use case name: **Attended by the doctor**
Summary: Patient is attended by the doctor according to the Bed No.
Actor: Patient.

i) Use case name: **Notified symptoms**
Summary: Nurse notifies the symptoms of the patient which the patient has.
Actors: Nurse and Patient.

j) Use case name: **Moving Robot According to the instructions**
Summary: The Robot moves according to the instructions given by the doctor maintaining speed. The robot can move in any direction given by the doctor.
Actor: Robot
Preconditions: Robot follows the instructions.
Post conditions: Robot is moved.
Flow of Events:

1. Doctor clicks on "Forward", "Backward", "Left" or "Right".
2. Robot moves.
3. Doctor can maintain speed of the moving robot.

k) Use case name: **Patient monitoring**
Summary: The Robot monitors the patient by controlling doctor being at any place and doctor can give prescription according to the symptoms or the diagnosed disease.
Actor: Robot
Preconditions: Robot follows the instructions.
Post conditions: Robot is moved.
Flow of Events:

1. Robot follows doctor's instructions.
2. Robot moves.

5. Conclusions

In our work we have developed a simple and cost effective robot which is multi-purpose tele-present in nature. Mainly it is designed for hospital environments but can be extended to other applicable areas such as security, industrial inspection, etc…. It has an effective architecture while being cost effective especially in under developed countries. It provides a video streaming capability and can be controlled remotely through Wi-Fi and through the web. A web application is also developed for this robot and it has navigation options to control the robot remotely. As future enhancement, the robot can also be navigated through iPhone. In addition, a single control can be extended to multiple clients controlling the robot simultaneously. Finally, further intelligent processing can be incorporated inside the robot to assist manual control. Such techniques include image processing for scene analysis and computer vision, neural network and fuzzy systems.

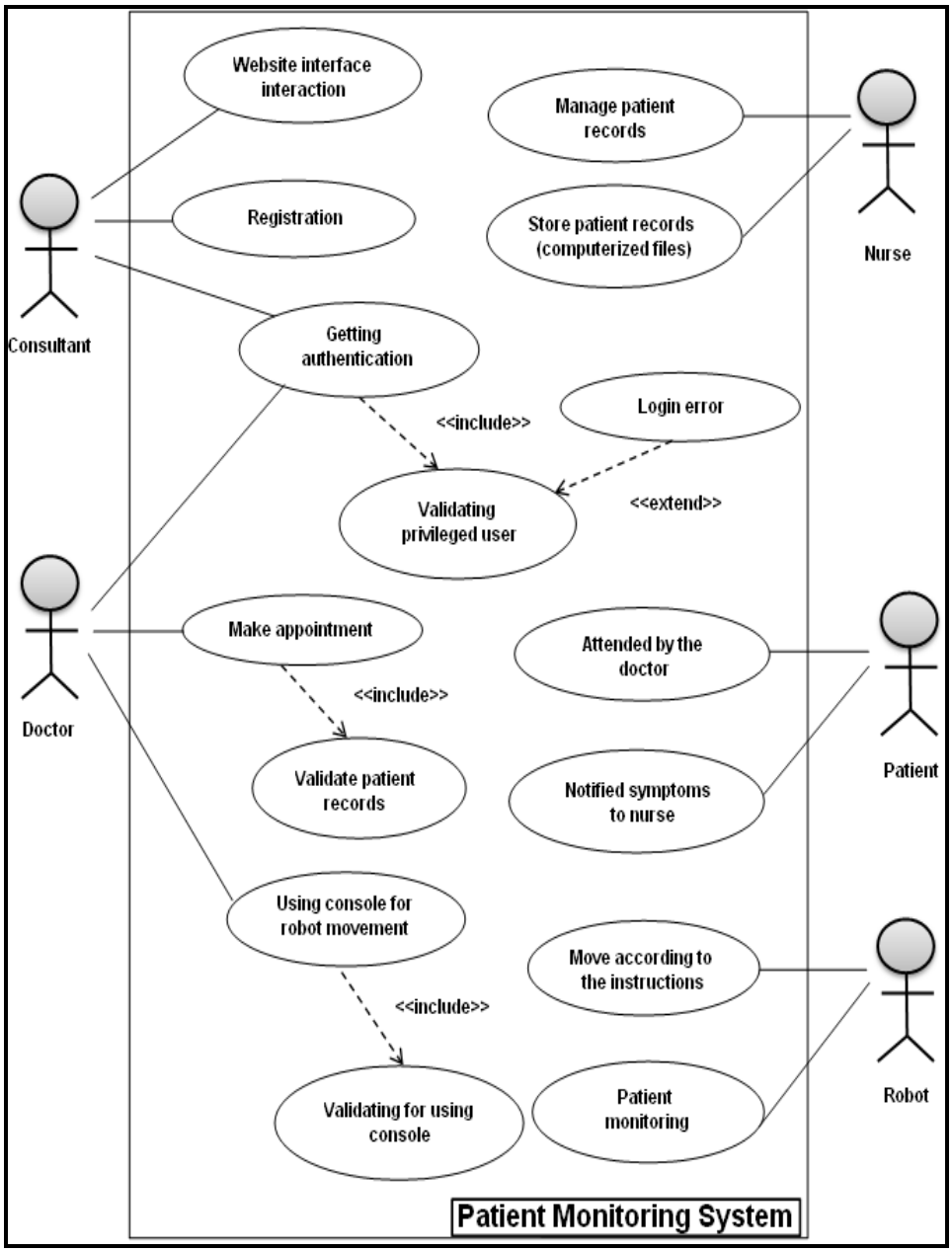

Figure 9. Use Case Diagram for our Patient Monitoring System

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