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Review of Anthropomorphic Robotic Arm with Force Sensor

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Abstract-This paper details the design of Anthropomorphic Robotic Arm, works on teleoperation using bilateral master-slave methodology. Anthropomorphic arm is similar to a human arm with respect to the number and position of the joints. Most attention has been given on Force Feedback technique. The device makes use of WiFi technology as its wireless communication medium. The unit is small, light, and easy to transport. It is usable in any orientation and is inexpensive. Master rig is fitted to the user's arm it is possible to easily control an anthropomorphic robotic arm. The force being exerted by the arm is measured and fed back to the user who is operating the master. The Wireless Communications and Control Module (WCCM) of robot controller need to design with project portability in mind. The methodology is, Use of Wireless Master Slave Controller Technology. Use of Web enable service. Use of Force Feedback Technique. The robotic arm mimics the dexterity of the human hand, wrist, and fingers. The proposed master control unit is cost effective and will have wide-ranging applications in the fields of medicine, manufacturing, security, extreme environment, entertainment, and remotely operated vehicle teleoperation in undersea recovery or extraterrestrial exploration vehicle.

Index Term-Anthropomorphic Robotic Arm; bilateral master-slave; Force Feedback; Master rig; Web enable service.

1. INTRODUCTION

Teleoperation has an important role in manipulating remote objects interactively using robotic manipulators, especially in hostile environments [2]. Robotic arms are now extensively used in medical surgery [3-4]. It has been shown that a dedicated robotic arm, holding a real ultrasonic probe can be remotely controlled from an expert site with fictive probe, and reproduces on the real probe all the movements of the expert hand [5] remote manipulation of objects in hazardous environments [6], weaponry for warfare [7] and industrial automation [8]. Service robots and personal care robots will become more prevalent at home in near future and will be very useful in assistive operations for human care [9].

Remote control of these robots by human beings poses several significant challenges such as the ease of operation, which depends greatly on the interface available to the user to control the robot. Another challenging issue is that of haptic sensing – some sort of feedback of touch feeling or forces exerted by a robotic arm on the object being manipulated is required for dexterous operations.

The design of a wireless bilateral master-slave controller was introduced in [10]. The block diagram is shown Fig. 1. The master unit is a "wearable jig" and greatly simplifies the user interface for the control of the slave which is a 6-DOF robotic arm.

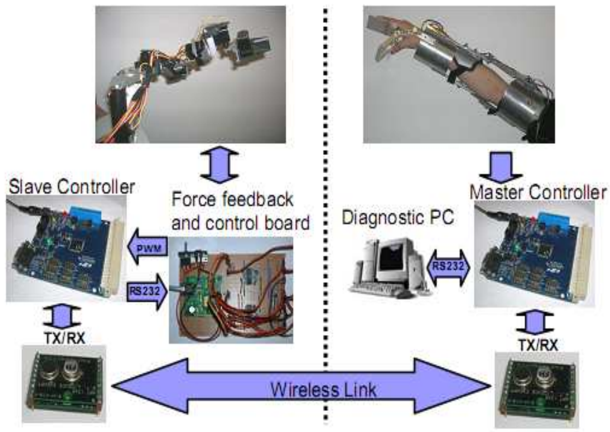

Fig. 1. Functional block diagram of a wireless master-slave controller.

The analogue voltages from the master unit are measured by the Master Controller and transmitted over the wireless link to the Slave Controller. The Slave Controller generates the position commands for the slave unit servos and sends them, over a serial communication wired link, to the Servo Control Board.

2. TELEOPEERATION

The idea of teleoperation [11] has been around since the 1970s, a time when it was totally unfeasible to program adaptive robots, instead it was decided that it would be easier to allow human beings to control the robots from afar [12].

The main advantage of this is that human beings are adaptive and so are better able to deal with unstructured environments. The main disadvantage is that it can be difficult to use this type of system if the interface is not designed properly.

3. FORCE FEEDBACK

Master-slave control is not enough to allow the user to work productively with the robot. The movements of the robot joints are easy to control but the user would have to be very careful not to exert too much force on the objects that the arm is manipulating as this could damage either the object or the arm.

A good example of this would be if the user needed to lift and move an egg using the arm. If the user exerted too much force on the egg then it would crack and if they used too little force then the arm would not be able to grip the egg and the arm would drop it.

So, the question is: how does the user gauge how much force they are commanding the arm to apply to an object? Possibly the best solution would be to give the user a physical sense of how much force the arm is exerting by applying to the joints of the master unit a force that is proportional to the force that is being exerted by the slave. This process has been called ‘force feedback’ and is currently used in video games to give the player a better sensation of what is going on in the game.

There are three main ways of measuring the force that the slave unit is exerting; each of these is briefly described in the following subsections.

3.1. *Current Sensing*

In this method the force fed back to the user is made proportional to the current that is being drawn by each of the joint motors. The current drawn by a motor is proportional to the torque that it is exerting; therefore it can be used as a measure of force since torque is simply force of rotation.

This method would be the best as it is based on actual force measurement and does not require extra force sensors to be added to the arm.

3.2. *Force Sensors*

In this method force sensors would be mounted on the material between the joints. These sensors would measure the amount of strain placed on each of these joints, the higher the strain the greater the amount of force that the joint must be exerting.

The advantage of this system would be that it is measuring actual forces and that the measuring of the force would not interfere with the operation of the joints themselves. The disadvantage would be that most force sensors are difficult to mount on the arm with no preload on the sensor.

3.3. *Positional Error*

In this method the force that is fed back to the user is made proportional to the difference in positions of the master and the slave units. If the positions are very different it is assumed that the arm is under strain and unable to reach the master’s position therefore a force should be applied to the master unit.

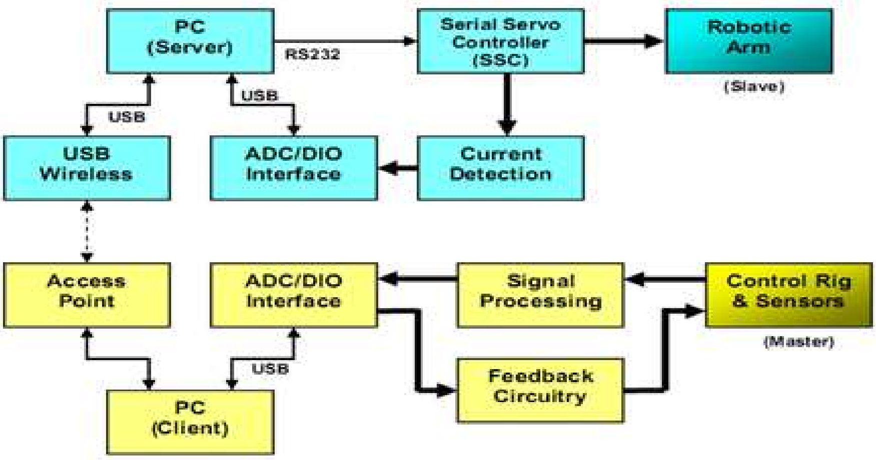

Fig. 2. Functional block diagram of the web-enbled robotic arm

This method has the advantage that it does not require any extra sensors to be added to the slave unit. All the calculations can be done by the coordinator program. The disadvantages of this method are that it does not work with actual measured force values and the assumption stated above may not be appropriate.

4. SYSTEM OVERVIEW

The functional block diagram of the proposed web-enabled anthropomorphic robotic arm, with force feedback, is shown in Fig. 2. The entire system can be thought to start with the control rig, otherwise known as the master unit. This is a glove-like device that the user will wear, augmented by flex and tilt sensors to measure the required degrees of freedom. These sensors (and associated circuitry) pass analogue voltage values on to an Analogue-to-Digital Converter (ADC), connected to a client computer through the Universal Serial Bus (USB).

The client computer runs a Visual Basic 6 (VB6) program that reads these analogue values and converts them into digital positional and speed values which it then sends to the server computer via Windows' wireless networking.

The server computer, running a VB6 program, receives the data and forwards it to the Serial Servo Controller (SSC) by way of an RS232 connection. The SSC takes an index, position, and speed value, and controls the corresponding servo on the Lynxmotion Robotic Arm (the slave unit). The current through each servo is measured as a voltage level, and then passed through a USB ADC connected to the server computer, which in turn passes it back to the client computer for processing.

With the current measurement from each servo, the client computer calculates the appropriate force being exerted on each servo. It then sends this information through the USB ADC (which incidentally has digital I/O as well) to the feedback circuitry which in turn controls the haptic elements of the master unit.

4.1. Master Slave Control

Methods for controlling master-slave robot systems may be divided into two categories - unilateral control system and a bilateral control system [13]. In a unilateral control system, shown in Fig. 3(a), no force feedback is available from the slave unit. The only form of feed to the master unit operator is in the form of vision data. Such a system has the merit of having a simple controller and mechanism; however dexterous manipulation is difficult. Fig. 3(b) shows a bilateral control system in which force feedback signal, usually electrical, is available from the slave to the master control unit. Although the controller and other mechanisms.

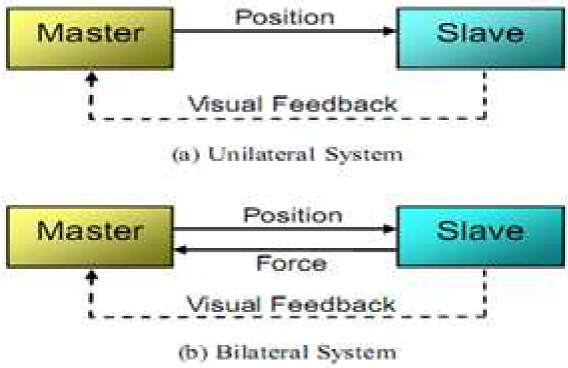

Fig. 3. Master-Slave control system

become more complex, dexterous manipulation is possible using the bilateral system.

4.1.1 *Control Rig*

The control rig is a glove-like device that covers the length of the arm. It measures six degrees of freedom amongst four joints: between thumb and forefinger, wrist, elbow, and shoulder. The majority of the movements are translated into digital signals using flex sensors while tilt sensors or accelerometers are used for measurement of rotation.

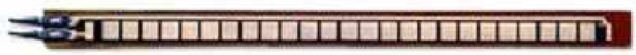

Fig. 4. A flex sensor

A flex sensor, shown in Fig. 4, is a lightweight component that increases resistance when bent In order to convert the deflection measured into a voltage signal usable by the computer, a simple voltage dividing circuit, shown in Fig. 5, has been used.

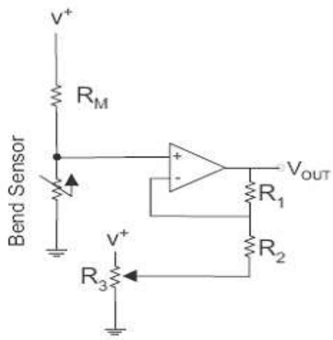

Fig. 5. Amplifier for measuring bend

4.1.2. *USB ADC/DIO Interface*

In order to get the analogue voltage signals into the computer program, a ADC Kit 8/8/8 board has been used. This board has 8 analogue inputs, 8 digital inputs, and 8 digital outputs, and comes supplied with an application programming interfaces (APIs) for various programming languages, of which VB6 is one.

4.1.3. *Client PC*

Standard PC running Microsoft Windows XP SP2 connected to an 802.11b/g Wireless Access Point, with Windows networking enabled.

4.1.4. *Server PC*

The server PC is a PCM-3375 single board computer (96mm long x 90mm wide), running a 533MHz VIA Mark CPU, 256MB RAM, 4GB solid state hard drive, with among other things, RS232 and USB connectivity. It has a wireless 802.11b/g USB adapter, and is running Microsoft Windows XP SP2 with Windows networking as well.

4.1.5. *Servo Controller*

The Serial Servo Controller (SSC) has 12 ports for controlling 12 servos, and communicates with the PC through RS232 at 9600 baud. It accepts a 3-byte serial command, consisting of a sync marker (255), servo number (0-11), and position (1-254). A four-bit speed factor is tucked into the upper four bits of the servo number byte. Speed is expressed in 1/2 unit per frame with a frame rate of 50 frames per second, with a value of 0 causing the servo to rotate as fast as possible, 0.5 unit/frame taking 10.16s for full range rotation, and 7.5 unit/frame taking 0.68s for full range rotation.

4.1.6. *Robotic Arm*

The robotic arm is a Lynxmotion servo controlled arm, utilising four Hitec HS-475 servo motors for the arm, an HS-422 for the base, an HS-85 for the wrist, and an HS-81 for the gripper. Servos have been used as they are simple to control, cheap, and lightweight. Each servo has a maximum rotation of 180°, and given the 256 positions available from the SSC, results in a resolution of 0.7° for each servo.

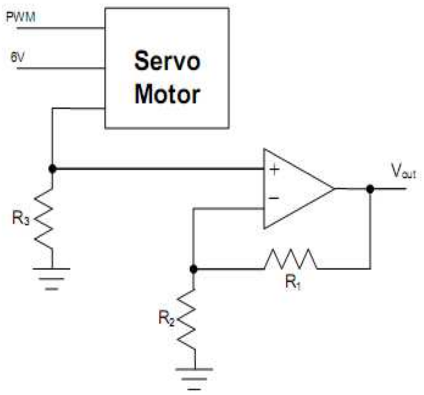

Fig. 6. Measuring motor current for force feedback

4.1.7. *Current Detection*

Given the fact that the applied torque of a motor is directly proportional to the current it draws, the easiest solution is to simply measure the current each servo draws, convert it to an analogue voltage, and then pass it through the USB ADC back to the program. This can be achieved using the circuit shown in Fig. 6.

5. WEB CONTROL BASED

A more widespread need for a web-enabled device is shown by various similar developments that have been undertaken. Published designs have made use of the GSM (cellular phone) network [11]. Using this carrier is excellent if coverage is a prime concern, however if large amounts of data need to be transmitted or operation over a long time is required, data transfer cost can be prohibitively large. A web enabled service robot, which works as a tour guide, has been reported in [12]. The Web interface consists of modules concerned with displaying information such as images and the robot's position. Web tools which enable efficient and robust teleoperation of a robot in unknown and unstructured environments are detailed in [13]. The paper presents a system design for safe and reliable Web-based vehicle teleoperation and describes an active dynamic user interface. [14] details a robot dog which is wireless, highly mobile and may be controlled over vast distance via the Internet using a common Java-enabled browser.

Two wireless standards are in common use- IEEE 802.11a/b/g or WiFi, and IEEE 802.15 Bluetooth. These methods are somewhat similar but have a few points of difference that make them suitable for different applications. Bluetooth has low power consumption, relatively short range and is quite cheap. However it is designed to act as a communications link directly between two devices, and does not lend itself easily to use within a network infrastructure.

5.1. *Software*

A PC for the server was chosen because it allows greater flexibility in programming; the possibility of internet control; and wireless communication has already been well established.

The program for this project is written in Visual Basic 6, and has the same program running on both the server and client computers; however one must select if the computer is the server or client in the program before anything will happen. On the server side, one just has to choose a port to listen on and then wait for a connection from a client. The client needs the IP address of the server and the port number it is listening to, and then can establish a link. The wireless communications are handled by TCP/IP through the Winsock protocol.

6. Prototype And Working

It allows manual control of the robotic arm in two different ways. When a position slider (scroll bar) is changed (on the server side), the program immediately sends the required 3-byte command to the SSC containing sync byte, servo number, speed, and position via RS232 communications. At the speed the program runs at, coupled with 9600 baud for the SSC, the movement is essentially simultaneous, even when multiple servos are to be moved.

On the client side, the user must press the "Send" button after establishing a communications link (as previously described) and setting the slider bars. This causes the program to poll the values of the sliders, which it compiles into a string together with a start and end of transmission character, and then sends to the server 5 times a second.

On receipt of the data, the server inspects the string for the start and end characters, and then picks out the correct servo number, speed, and position values for that data block. It then moves the sliders into the associated positions, which triggers communication with the SSC. The reasoning behind sending each data stream as a set 'block' is that the data arrival event, which is triggered on the server upon receipt of data from the client, is inconsistent in the frequency at which it is triggered and in the amount of data each transmission packet contains. Because the robotic arm has two servos controlling the same axis of the shoulder joint, ports 4 and 5 must always have identical values.

7. Discussion

In this paper author have presented force feedback technique with current sensing circuitry for design of a web-enabled anthropomorphic robotic arm. Initial testing of the slave, using software sliders, has been completed. The remote control, using the WiFi connection has also been successfully implemented. The wearable master rig is still under development. Control rig can be modified using capacitive sensor.

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