Gripper Telemanipulation System for the PR2 Robot

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Abstract

The most common method of teleoperation has an operator using a joystick to drive a robot, but also having to manipulate each joint of a robotic arm plus its end effecter. But while this is a working solution at the moment, it is inefficient and makes controlling the robot difficult without extensive training. Our goal was to create a telemanipulation device that would mimic a robot's end effecter, in this case the PR2. This device will also provide haptic feedback, track the hand pose of the operator, and simultaneously control the arm joints regardless of the operator's skill level. All of this was accomplished by using a combination of electrical hardware, mechanical engineering and software. And even though this device was developed for the PR2 robot, this device can serve as a template to develop controllers for any robot design.

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1 INTRODUCTION

The goal of telerobotics is to operate in inhospitable environments or perform dangerous tasks through the use of a robot. Some examples include removal of hazardous waste, space exploration, or bomb disposal. Teleoperation interfaces often suffer from the lack of haptic feedback to the user. It can also be difficult to control multiple aspects of the robot simultaneously with just one controller. This project attempts to address these weaknesses by creating a full teleoperation system. We have used the PR2 robot as the platform for developing this teleoperation system.

Work on the teleoperation system began several years earlier with designing a system to telemanipulate the head of the PR2. The first method used the Vicon motion capture system to track markers placed around the operators head. This system proved to be highly accurate, but the Vicon system is very expensive and not very portable. The following year, this method was improved upon by replacing the motion capture system with accelerometers that measure the yaw and the pitch of the operators head. The accelerometers contain the same amount of accuracy with a much lower cost and fit on a circuit the size of a quarter. This is the current method of telemanipulation for the PR2's head.

With a way to telemanipulate the head established, we then focused on improving the current method of controlling the arms and the grippers of the PR2. Before our work, an Xbox Kinect was used to track the operator's body posture. These postures were then mapped onto the PR2 causing the robot to mimic the movement of the operator. The grippers were controlled by Wii controllers by taking advantage of their buttons and accelerometers. These were used to control the grip aperture and track the orientation of the hand. While the Kinect could track the body posture of the operator, it was highly unreliable and could not read the operator's hand postures. The Wii controllers did solve the problem of reading the hand postures, but failed to give the user the necessary haptic feedback we were looking for.

2 BACKGROUND

2.1 Telerobotics

Often the words; teleoperation and telemanipulation will appear to be interchangeable throughout this document, but they have two distinct meanings. Teleoperation deals with the operation of a task [1], like in the picking up of an object or moving down a hallway. Telemanipulation is the manipulation of an object [1], like in the moving of the robot's arm or opening and closing the robot's gripper. Telerobotics is the generic term for the human control of a robot [1] and encompasses both teleoperation and telemanipulation. Figure [1] shows a diagram of a standard teleoperation system.

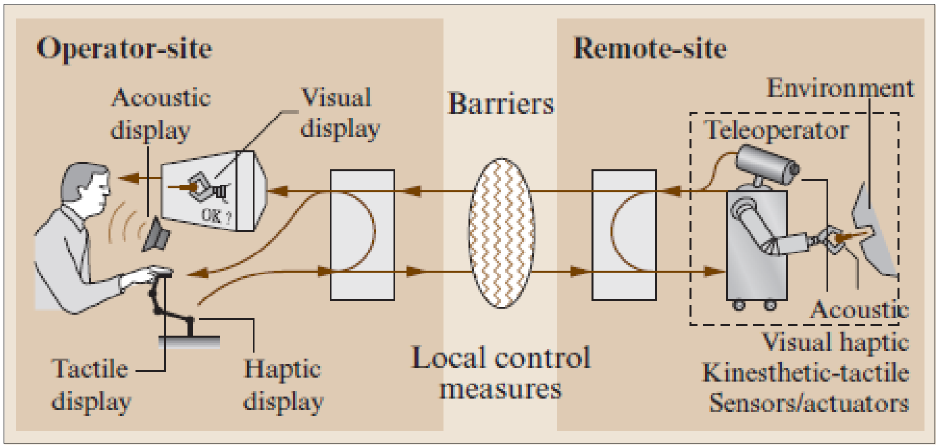

Fig [1], Diagram of Standard Telerobotics System [2]

2.2 Haptics

With the aid of mechanics, haptics allow a user to perceive the properties of everyday objects virtually. These properties are felt through force feedback, generated by computer-controlled mechanical systems called Haptic Interfaces (HIs) [3]. For this project, a DC motor controlled by a micro-controller will be our HI and will receive its stimulus from the items held by the PR2's gripper.

2.3 Micro-Controller

Our project will make use of a micro-controller with an ATmega32u4 processor. The features of this processor include a 16 MHz clock and 32K of flash memory [4]. This micro-controller is also programmed through a mini USB cable using open source development software. The micro-controller is used to generate a pulse width modulation (PWM) signal that controls the DC motor. The micro-controller also processes the data signals from the PR2 gripper to allow for haptic feedback.

2.4 Operational Amplifier and Low Pass Filter

Two electrical components needed for the telemanipulation device is the operational amplifier (op-amp) and the low pass filter (LPF). The purpose of the op-amp is to prevent the amperage created by the DC motor from feeding back into the micro-controller. This prevents the pins or the micro-controller itself from short circuiting. The LPF fits into the circuit by converting the PWM into an attenuated DC voltage. This voltage becomes the input for the op-amp and is variable based on the percentage of the PWM's duty cycle.

2.5 Brushed DC Motor

Another main component for our telemanipulation device is a brushed DC motor. It provides the haptic response from the PR2 robot to the person manipulating the gripper. When there is a rise in current to the DC motor the amount of torque generated is increased. This increase in torque provides a sensation, to the controller, of a hard object being grasped by the PR2. The torque, measured in milliNewton meters (mNm), can be increase by attaching a planetary gear head to the shaft of the motor without adding to the current necessary to operate the motor. There is also a binary optical encoder attached to the end of the motor to count the number of rotations made by the motor's shaft.

3 MATERIALS AND METHODS

Work on developing a telemanipulation device for the PR2 began with discussions on how to approach the different aspects of the device. These aspects consisted of mechanical operation, electrical components and software implementation. Each was addressed by members of our group whose majors were in mechanical engineering, electrical engineering, and computer science. With all assignments made, our group set about on implementing each part of the project. Below, in figure [2], a diagram outlines the different components that make up the telemanipulation system to control the PR2 gripper.

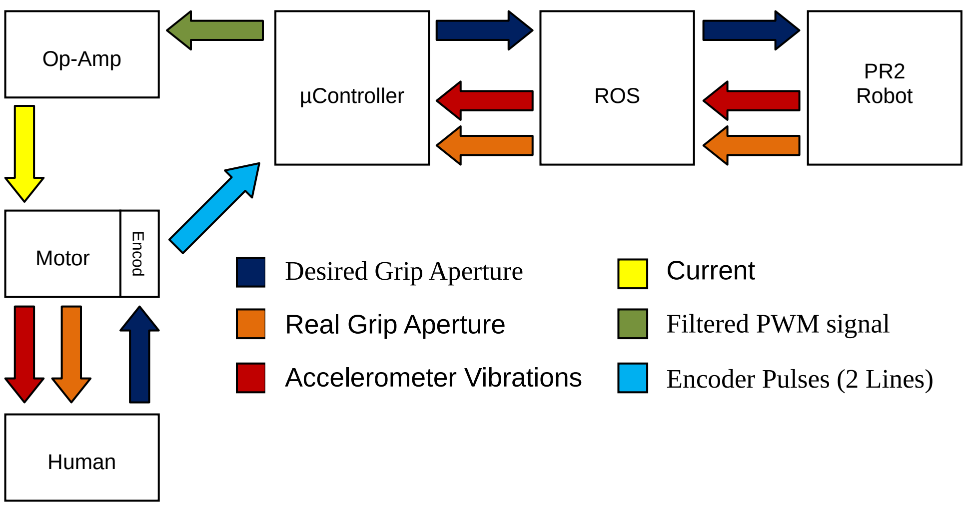

Fig. [2], Flow diagram of telemanipulation gripper controller

3.1 Mechanical Operation

The mechanical aspects of this project consisted of the design of the controller's I/O device and how it interacted with the hand. The look of the human interface of the I/O device began with creating cardboard mock-ups of the telemanipulation device before making the device. Creating these early mock-ups was useful to the process since they allowed for the testing of different hand grips and motor positions. The final design puts the user's hand in a position that mimics the gripper of the PR2. Once the desired hand grip and motor position of the input device was found using the cardboard mock-ups, work began on drawing the I/O device inside a CAM program.

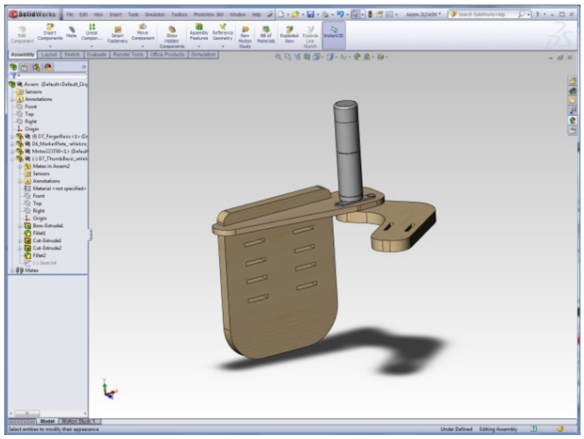

Fig. [3], SolidWorks Drawing of I/O device created by Elizabeth Fedalei

With the I/O device drawn out in SolidWorks it is ready to be sent to the laser cutter to be cut out of a combination of acrylic and pressed wood. Looking at figure [3], the motor is connected firmly to the fore finger guard. This connection acts as a pivot point for the shaft of the motor which is connected to the thumb guard. There is also a rectangular plane connected to the finger guard that will hold the markers used in the motion tracking. Velcro straps allow the operator to hold onto the I/O device. Figure [4] below, shows the I/O device completed.

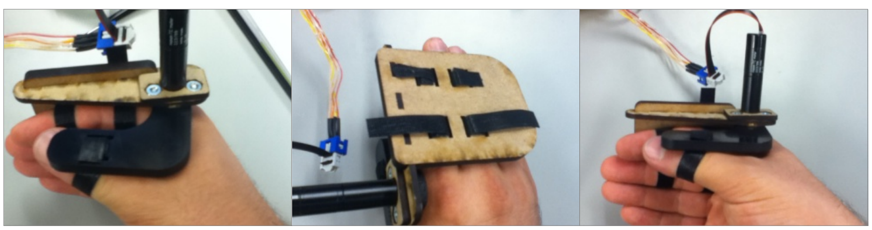

Fig. [4], Top, Back, and Front views of the I/O device

3.2 Electrical Components

To power the motor, a DC voltage source was needed along with the necessary current in order to properly operate the I/O device. This voltage and current are supplied by the micro-controller. The amperage generated by the micro-controller is too small to properly drive the motor. We have solved this deficiency by adding an operational amplifier into the electrical circuit. This op-amp prevents the amperage, high enough to provide sufficient torque to the motor, from shorting out the micro-controller. The following figure shows the completed circuit used in the gripper controller system.

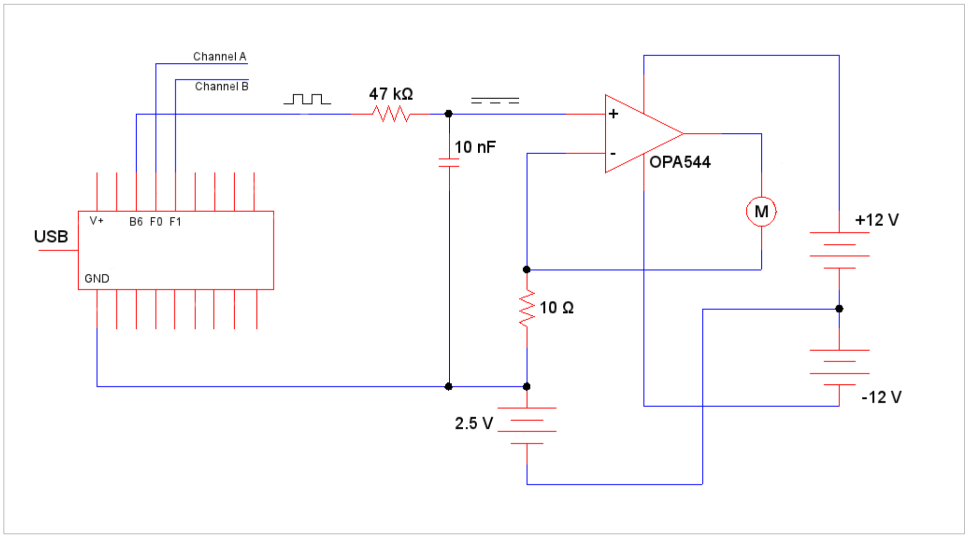

Fig. [5], Circuit diagram for gripper controller system

This circuit operates by first having the micro-controller generate a pulse width modulation (PMW) signal. This PMW has a frequency of 16 kHz and is sent through a low pass filter with a cut off frequency of approximately 330 Hz. It is necessary for there to be a large difference between the PMW and cut off frequency in order to attenuate the resulting output. The value of the output, measured in voltage, depends on the PWM's duty cycle. This voltage ranging from 0V to 5V is then feed to the positive terminal of the op-amp.

With this set-up of the op-amp and assuming that the output of the op-amp has a normal feedback loop like in figure [5], the motor would only rotate in the clockwise (CW) direction. For this project, though, we need the motor to rotate in both directions. In order to achieve this, the relative ground of the op-amp feedback is replaced with a 2.5V source. This 2.5V source is supplied by the V+ output of the micro-controller that goes through a voltage divider. The motor now can rotate in a counterclockwise (CCW) direction when the duty cycle of the PWM goes below 50%.

3.3 Software Implementation

Now that our group has successfully created both the mechanical device and electrical component, work began on communication between the PR2 robot and the micro-controller. This communication is handled primarily in a program called robot operating system (ROS). The vast repository of ROS and the fact that it is open source allows for the integration of multiple peripherals to be used at once.

One useful library in ROS is called “cereal_port”. Cereal_port allows for communication between the micro-controller and the PR2. This is accomplished by allowing the program to be written for the micro-controller but adding the necessary libraries to the code the enable USB communication. This gives us the ability to provide tactile and grip-aperture data of the PR2 gripper to the controller. It also sends the requested aperture of the controller to the PR2.

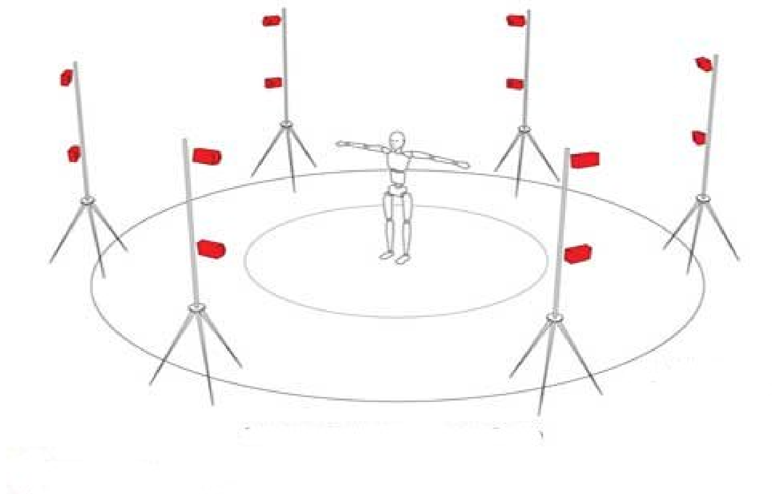

Fig. [6], Diagram of Motion Capture System [5]

While not the Vicon motion capture system, figure [6] above shows what a motion capture system generally looks like. The Vicon system is used to track the arm and hand postures of the operator. This adds a high degree of dexterity to manipulating the PR2 gripper and gives the controller a better sense of actually being in the robot's environment.

4 DISCUSSION AND RESULTS

Weekly meetings with our group kept the project constantly moving forward. Because of this, we were able to build a working prototype of a telemanipulation system for the PR2. At the end of this project, we meet the objectives of creating a device that completed the following:

- Create a I/O device that opens and closes the gripper of the PR2
- Use tactile data from the PR2 gripper to provide haptic feedback through the I/O device
- Track arm and hand postures of the operator through the Vicon system

5 FUTURE WORK

Most of the goals set at the beginning of this project were meet for our prototype device. For future work, we would also like to add haptic feedback from the accelerometers located in the PR2's wrist. These accelerometers measure vibrations caused by objects the gripper holds bumping into the robot's environment. This tactile data would be realized by the operator as corresponding vibrations made by the DC motor.

Besides this telemanipulation device being used solely for the PR2 robot, we believe that it could be utilized for other robots as well. With the PR2 having end effectors, our telemanipulation system could be used as a template for other robots that have similar end effectors. Such robots that this could be used with are bomb detection robots, unmanned underwater vehicles, and repair robots in Earth's orbit. Lastly, we see our telemanipulation device used in a way that could help train the PR2 learn complex kinematic chains in order to serve as an assistant for the elderly or disabled.

6 ACKNOWLEDGEMENTS

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