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Design of Force Feedback System for Haptic

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ABSTRACT

In this paper the design of force feedback system is proposed for haptic perception. The proposed system consists of manipulation mechanism as well as the force feedback mechanism to get sense of touch. The system uses one sensor plus actuator pair for manipulation and another sensor plus actuator pair for feedback. In manipulation system the finger movement of operator is detected by rotary potentiometer. The output of this potentiometer is processed by controller to generate Pulse Width Modulation (PWM) cycles, which is used to drive servomotor of robotic griper. When robotic griper grasps or touches any object then back-force is experienced by the robotic griper. This back-force is detected by sensor located on griper and is processed to convert into displacement by feedback servomotor at operator end. The proposed system is experimentally verified.

Keywords

Haptic system, force feedback, robotic griper, experimentation

1. INTRODUCTION

The robots are greatly used into an industrialized manufacturing, outer space, military, medical surgeries etc. Typically the applications uses articulated arms particularly created for applications like, material handling, painting, welding and others. For operator being it is difficult to work in the hazardous environment, in such situations the robotic systems are used. The robots can be manipulated by the operator, but operator is not able to feel the real forces experienced by the robot, only by visual feedback.

Until now different approaches are reported in the literature on the implementation of systems or algorithms such that those are able to react with environment appropriately by exerting forces, and measuring effect by force/pressure sensors. One of study has been done to identify the different textures [1]. The discrimination of textures is done by rubbing the fabricated module against surface whose texture has to be determined. Similar work is been carried to classify the rigid and deformable objects by tactile sensing, could be referred as haptic [2]. The design consists of a novel tactile array sensor based on flexible piezo-resistive rubber. A robotic gripper with two sensors mounted on its fingers performs a palpation procedure on a set of objects. Keehoon Kim et. al. [3] developed three different versions of a multifunction haptic device that can display touch, pressure, vibration, shear force, and temperature to the skin of an upper extremity amputee, especially the one who has undergone targeted nerve reinnervation surgery. Work proposed by Michela Borghetti et. al. [4] is focused on studying and implementing a system for measuring the finger position of one hand with the aim of giving feedback to the rehabilitation system. Similar work in rehabilitation is done for the stroke patients to give training of gait motion[5]. The stable grasping of the object by robotic hand requires the tactile feedback, tactile feedback allows to know the grasp is stable or not. The studies has been done on stable grasping [6],[7],[8] by developing various algorithm depending upon tactile sensor's feedback. In all above mentioned systems, the robotic griper itself feel that object but no any feedback is given to the operator hand. The studies has been done which represents different actuators which gives the feedback to the operator hand. In such case force feedback is necessary which are provided by the electromagnetic motors (EMM) [9]. The

advancement of this is presented in system [10]. The a hybrid actuator system is developed by combining an EMM with an ultrasonic motor (USM) and a piezoelectric clutch/brake (piezo-clutch/brake). Similarly, system presented by Gonenc and Gurocak [11] uses actuator as servomotor with magnetorheo-logical brake. Another application area of haptics is the invasive surgeries. Haptic feedback is given to the human hand by pneumatic feedback[12]. Different approaches are found out by [13],[14] which reduces the dependency on surgeon's skill. Also, the surgical procedure from a distant location is possible now-a-days, the office based surgeries are done[15].

In this paper the main objective is to get force feedback experienced by robotic griper. The force feedback mechanism along with manipulation is designed. The force experienced by robotic griper is processed and fed back to the feedback servomotor. The displacement of servomotor is converted into a force by a simple spring mechanism. The performance of the proposed system is found to be better.

The rest of the paper is organized as follows: In section 2 description of proposed system is presented. The system design is explained in section 3. Experimentation and results are discussed in section 4. Conclusion is mentioned in section 5.

2. SYSTEM DESCRIPTION

The system is designed in two parts: manipulation system and feedback system. The manipulation system allows to move robotic griper in accordance with the operator finger. The feedback system allows the operator finger to stop whenever robotic griper stops. Fig 1 shows the block diagram of proposed system. The system includes two sensor actuator pairs. One pair is used for transmitting the signal from operator finger to the robotic griper and another pair is used for transmitting the signal is from robotic griper to the operator finger. The movement of operator finger is given to the sensor: potentiometer. The analog output of the sensor is converted into the digital form in the micro-controller, which is used to generate the pulse width modulation (PWM) cycles. These PWM cycles are used to drive the servomotor of robotic griper.

If robotic griper touches any object it experiences the back-force. If the same force is transmitted to the operator finger then the objective of sense of touch can be accomplished. In the Fig.2 the force feedback is sensed by force sensor (load cell), which is mounted on the robotic griper. The signal conditioning of load cell is done to get output compatible to micro-controller. The micro-controller processes the signal to drive the feedback servomotor at manipulator end.

3. SYSTEM DESIGN

The first part is the manipulation system, by which the robotic griper will replicate the movement of operator finger. For this the potentiometer is used to detect the movement of operator finger. When the finger of hand moves the shaft of potentiometer rotates accordingly. As shaft rotates the value of resistance changes which is measured in between fixed and variable end. The potentiometer used here is of 10KΩ.

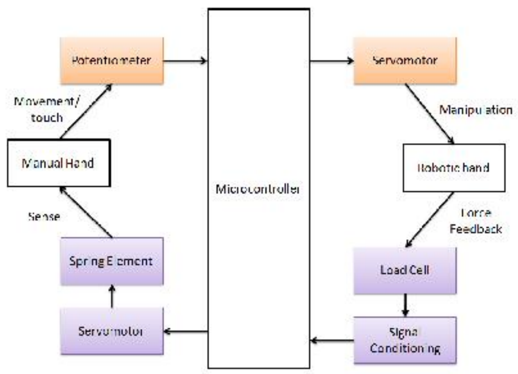

Fig 1:Block Diagram of System

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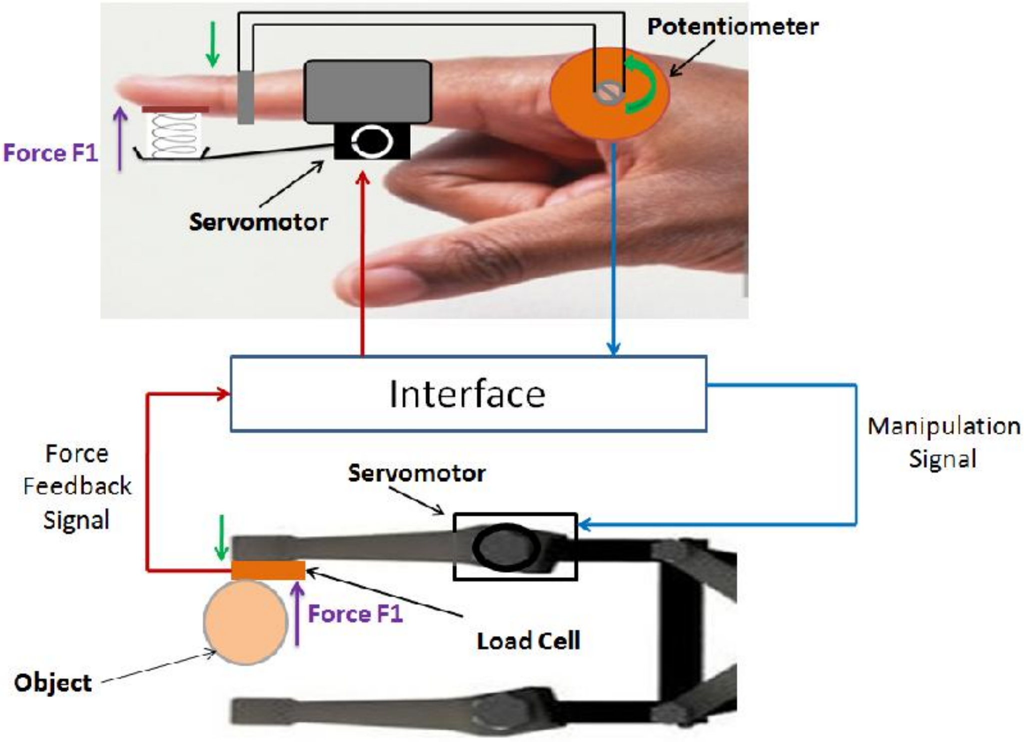

Fig. 2: Schematic Representation of System

To make signal compatible to controller, it should be converted into voltage signal of range 0-5 V. Whenever the operator finger moves from 0^o position to 90^0 position, the output changes from 0-2.5 V, and the mechanism is as shown in Fig.3.

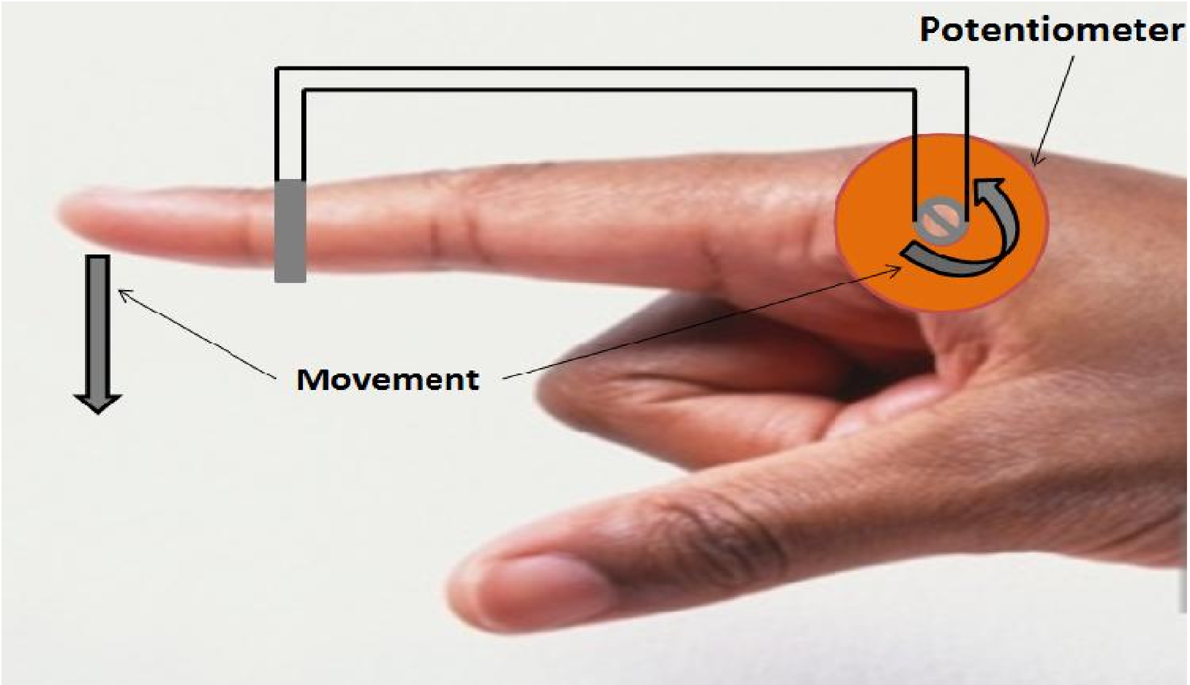

Fig. 3: Manipulation Mechanism

While replicating the operator finger movement if any object comes in contact with the robotic griper then the force is sensed by the load cell. The mechanism for griper arrangement is as shown in Fig. 4.

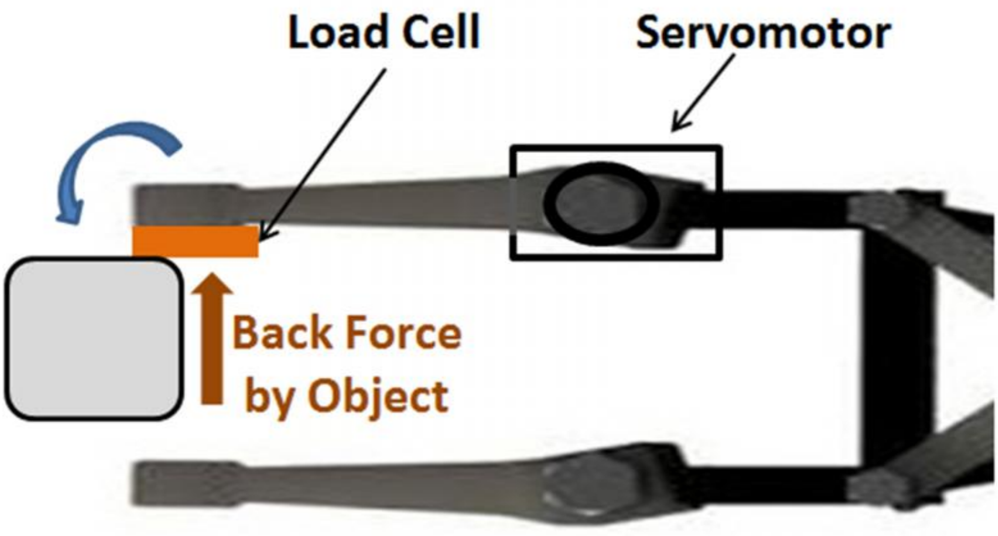

Fig. 4: Detection of Force at Robotic Griper

The signal of load cell is in mV so it required to be bring in the range which is compatible for micro-controller. This signal is processed and fed to drive the feedback servomotor through PWM generator. The servomotor gives the angular displacement which need to be converted into force. The displacement is converted into force by using spring element. This force conversion is based on Eq. (1).

$$F = Kx \quad (1)$$

Where

F= Force

K= spring constant

x= displacement

4. EXPERIMENTATION AND RESULTS

While carrying out experimentation the sensor is mounted on the operator hand. The signal from sensor is processed and calibration is done such that the servo rotates by the same degree as the potentiometer. The robotic griper is connected to the servomotor, so this replicates the operator finger movement. The next part is of force feedback. The load cell is mounted on the robotic griper, so whenever robotic griper touches or rests on any object the force is experienced by the load cell. The force feedback to the manual hand must be same that of the force experienced by the load cell mounted on the robotic griper. For this calibration of force feedback is performed.

4.1 CALIBRATION AND VALIDATION

The calibration is done in such a way that the operator finger should experience the force as per the force experienced at robotic griper. For this experimental set-up is designed and is as shown in Fig. 5. In this case to measure the force feedback at operator end, the finger of operator is replaced by the another load cell. Here, load cell on robotic griper is represented as the load cell 1 and to measure force feedback at the operator side the load cell is represented as load cell 2.

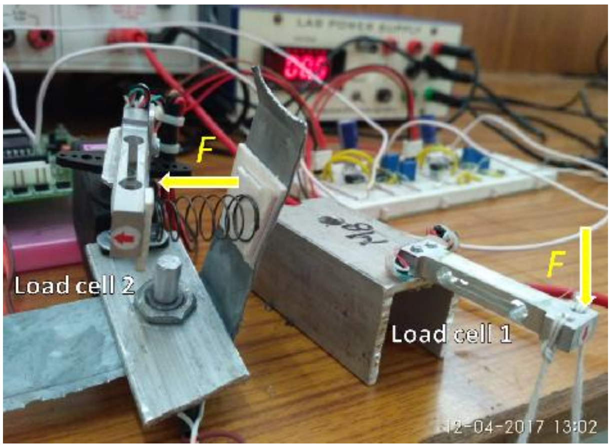

Figure 5: Experimental set-up for calibration and validation

The known weights of different values are placed on load cell 1 and the corresponding weight readings of load cell 2 are noted and as given in Table.1. The weight is calculated at load cell 2 side from the relation: Weight = Observed voltage X 125.

Table 1. Results of Validation

Sr. No	Weight Applied in gm	Observed Output Voltage of Load Cell 2 in V	Calculated Weight on Load Cell 2 in gm
1	50	0.52	65
2	70	0.96	120
3	75	1.04	130
4	80	1.22	152.5
5	85	1.28	160
6	90	1.46	182.5
7	95	1.6	200
8	100	1.72	215

The corresponding relationship is as shown in the Fig.6. The results shows that the force on the operator finger side is same as the force on the robotic griper side. So the system is validated by the experimentation.

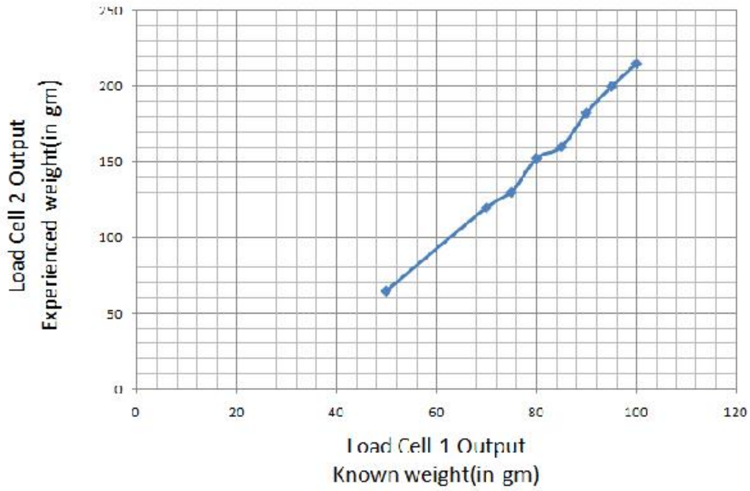

Fig. 6: Result of Validation

5. CONCLUSION

The force feedback system for sense of touch along with the manipulation system has been designed. The robotic griper replicates the operator finger movement. In the case of force feedback, the force experienced by the robotic griper is transmitted at the operator finger. The force on operator finger is same as that of the robotic griper. Validation of this force feedback is done by applying the known force on robotic griper side and measuring the force at operator side. The results shows the both applied forces and measured forces on operator finger side are same.

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