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Human-Robot Shared Control for Split-Site Interaction and Disabled Assistance

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INTRODUCTION

The context where the robot will be used leads to understanding the interaction requirement among the robots and between the human and robot. This includes the number of humans and robots to be used, the task to be solved, and in several cases, the human is expected to assist the robot in overcoming the limitation in robot performance [1]. Numerous factors are nominated for the robot to be successful, such as the repetition to reach regular quality, the speed and the force of manufacturing robots, reduction of the task hazards, decrease of the force required and flexibility in programming [2].

The estimated number of multi-task robots around the world is about 1,664,000 as reported by the International Federation of Robotics (IFR) statistical analysis [3]. The industrial robots continue to develop in both safety and productivity; moreover, while they have evolved in their functionality, safety is a hugely significant concern [2].

Since the risk of injury is the most crucial factor for the human-robot interaction, the soft robotics technologies provide significant alternatives for rigid robots. The soft actuators that made as a human-like muscle such as the pneumatic muscle actuators (PMA) are used to design such type of robots. The main advantages of the PMA are the high force in comparison of its weight, multiple degrees of freedom (DOF) without joints, small workspace required and it is safe for human-robot collaboration [4].

MATERIALS AND METHODS

In this paper, the self-bending contraction actuator (SBCA) by Al-Ibadi, et al. [5] is used to design a single actuator continuum robot arm. The specifications for this actuator are listed in Table 1. The small size of the SBCA is used to develop a 4-fingers soft gripper, and it is mounted to the end of the soft robot arm.

Table 1. The specifications of the bending PMA

L_0 (m)	*Rubber thickness (m)*	*Braided thickness (m)*	*Rubber diameter (m)*
0.6	1.1 x 10^{-3}	0.5 x 10^{-3}	26.5 x 10^{-3}
Rubber stiffness(N/m)	**Rod length (m)**	**Rod thickness (m)**	**Rod width (m)**
545	0.6	0.003	0.025

L_0 is the length of the SBCA at relaxed condition (no pressure). Fig. 1.a-c shows the design and the implementation for the continuum arm and the gripper respectively.

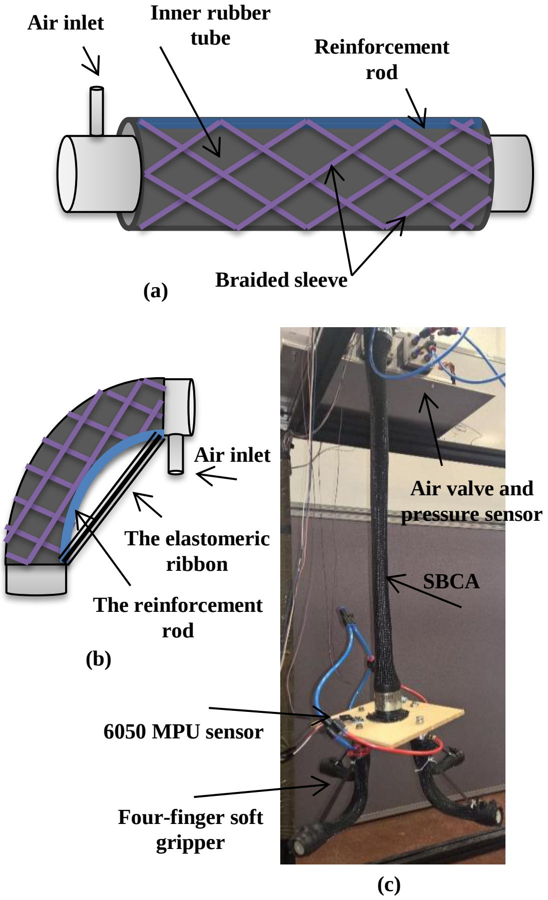

Figure 1. The bending continuum arm. (a) The structure of the SBCA. (b) The design of the soft finger. (c) The entire soft arm with soft gripper and

In order to control the grasping force and the bending angle of the proposed continuum arm by a split-site or disabled human arm, four sensors are used in both the human and the soft robot arms. Two 6-axis motion tracking (MPU 6050) sensors, an air pressure sensor and flex sensor and they are mounted as shown in Fig. 1.c and Fig. 2.

The flex sensor is mounted on the index finger as illustrated in Fig. 2 and it is connected to the pressure sensor to control the grasping process via Arduino Mega 2560 and a neural network (NN).

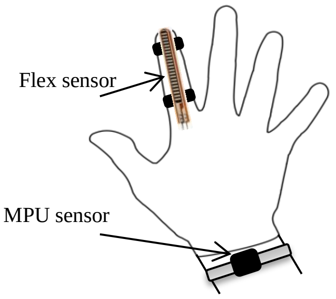

Figure 2. The sensor layout on human

The NARMA-L2 NN-controller by Matlab R2016a is used of 9-neurons in one hidden layer, 3-delayed plant inputs, 2-delayed plants outputs and it is trained by (trainlm) for 100 Epochs. The mean square error (MSE) for the training, testing and validating data is about 10^{-7}. The NN is trained by the relationship between the resistance of the flex sensor and the pressure of the soft gripper. A no grasping state (zero pressure) is assumed at the relaxed condition for the index finger and 300 kPa air pressure in each finger in the soft gripper at fully closed of the human hand.

One MPU sensor is mounted on the top of the soft gripper and the second MPU is worn as a bracelet closed to the wrist. Bending the human arm send a reference bending angle to control the bending angle of the soft robot arm. Fig. 3 illustrates the flow chart for the human-controller-robot system (HCRS).

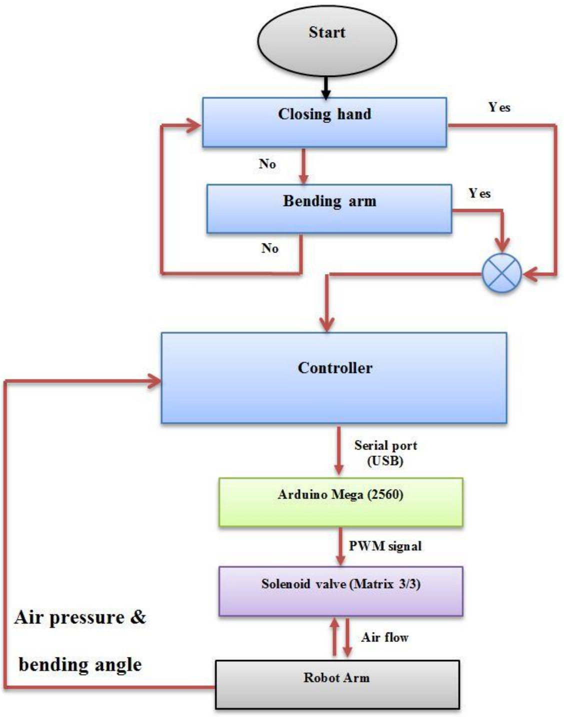

Figure 3. The flowchart of the human-controller-robot system.

RESULTS

Fig. 4 shows the step response at 0.25 Hz at root mean square error equal to 0.2°.

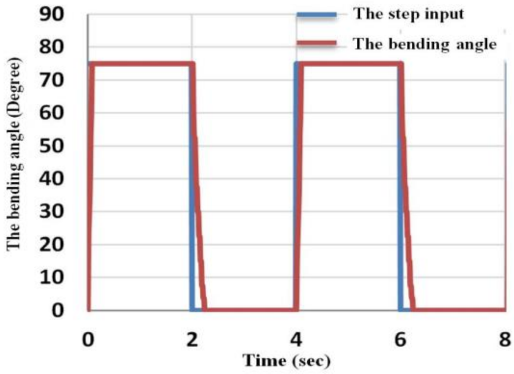

Figure 4. The step response at 0.25 Hz.

Fig. 4 shows the robustness of the controller to send the commands from the human arm to the robot to grasp and bend.

The proposed system is used either to control the robot arm which is not in the safe area for a human being or to assist an elderly/disable person to grasp and move objects by a safe robot arm. The disability is restricted by the ability to close the hand partially and bend the forearm in small degrees. The HCRS transfer these movements to full grasping and bending.

CONCLUSION AND DISCUSSION

Using the soft robot arm close to human is safe due to the softness and the light weight of its material.

The proposed human-controller-robot system (HCRS) provides a full controlled operation to move the continuum arm by an operator by wearing the flex and the MPU sensors. As well as help the person has difficulties to grasp and move the objects.

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