Force Control based Soft-stuffed Robot Interaction

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Abstract : This study explores how a soft-stuffed robot interact with a human based on impedance control of the robot arms. This impedance control is realized with external forces which are imposed on robot arms and detected by a photoreflector based force sensor. In this proposal, two photoreflector installed in individual aluminium cases constitute the force-detection equipment. These cased photreflectors can detect the external forces with 2 degrees of freedom. If there are some external forces coming from human detected on robot arms, the robot will move its arms to reply these forces; giving the appearance that the robot can react as a living creature.

1. Introduction

Many researchers have developed various human-robot interaction systems in the fields of therapy, entertainment, training, facial expression, voice recognition and sensor of sight. Now days, these technologies are used in human-robot interaction widely. But in this paper, a special kind of interaction system will be realized based on force control. The proposed interaction in this system, happens when the user grabs the robot's arms and move them in the same rhythm of his, then the robot will also move its arms depending on the external force provided by the user.

There are two conclusions about this interaction. The first one happens when the user external force is very strong, this will cause the robot to refuse to the movement, and then it will move the arms in the opposite direction. In the second one, if the external force is appropriate, the robot will move following the users movements. In daily life, this interaction is similar to when parents dandle with their child and catch child arms to wave together for conveying their love. But sometimes, if child feel any pain on his arms, he will refuse to move them.

Harry F.Harlow implement a experiment about the nature of love[1]. His experiment used newborn monkeys and proved that newborn monkey prefer to touch cloth mother than wire mother. Therefore, in this interaction a soft-stuffed robot, as shown in the Figure 1, whose movable parts are soft is used as the experiment subject; instead of other robots whose movable parts are hard. Furthermore, compliance is needed to create following motion, also compliance is easy to show with soft mechanisms in this interaction because haptic information can be greatly influenced by the robot movement at every moment [2]. It is more difficult to present compliances with a hard arm robot instead of soft arm robot.

Fig. 1 Soft-stuffed Robot

2. Relevant Research

Almost of the robots are produced accordingly to the appearance of some real creatures, which can interact with human beings; although the materials, the design and the function of the robots are different. A humanoid robot called CB^2(Child-robot with Biomimetic Body)[3] is developed so that establish and maintain a long-term social interaction. The most significant features of CB^2 are a whole-body soft skin (silicon surface with many tactile

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sensors underneath) and flexible joints (51 pneumatic actuators). But the robot needs a air compressor because of pneumatic actuators, this is not convenient. And the robot is a bit scary because the robot was designed as human keeping joints and soft skin.

M.Siina and T.Ishikawa proposed a soft-stuffed robot using strings to control moveable parts without any machinery for tactile sense[4][5]. Y.Yamashita studied on soft-stuffed robot interaction based on impedance control and an outside camera[Kinect][7]. There were three strings on one arm and leg, and six strings on head to control robot movements for keeping the softness of robot.

The soft-stuffed robot was evaluated by an experiment on its actions and structure, in the experiment the soft-stuffed robot was compared with the recent Robot-PHONE[7]. The result indicates that the familiarity with the soft-stuffed robot is better, and users prefer to communicate with the soft robot though touching or catching the arms the robot. Therefore, this paper propose a new method to interact with soft-stuffed robot through force control, which can be accurately feedback with the external force coming from users.

In the previous research[7], the impedance control based on estimated force from tension sensor was developed. So the external force is calculated by tension of strings and resilience force coming from materials of arm. But there was an inaccuracy in measuring tension and resilience force, because the friction between string and materials caused hysteresis; so the impedance control could not be realized correctly.

3. Methodology

3.1 System Structure

Figure 2 shows the force control system structure. When external force interacts in the arm, the system start to work depending on force control. In order to achieve an accurate interaction between human and soft-stuffed robot, the external force should be detected precisely at first by force sensor. The microprocessor (RENESAS SH7239) and the FPGA (EP3C10E144), are main part of the robot's control board. Then the control board is used to control the RE-10 maxon motors to pull the robot's arms.

3.2 External Force Detection

Two photoreflector(SG-105) installed in individual aluminium cases constitute the force-detection equipment, show in the Figure 4, this force-detection equipment is

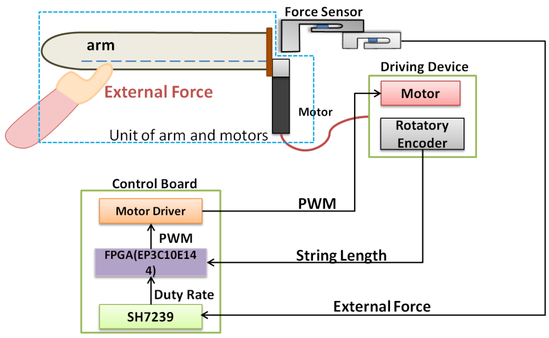

Fig. 2 System Structure

used to detect the external force with 2 DOF. The Part A can measure external force F_1 on horizontal direction; Part B can measure external force F_2 on vertical direction. When force is applied into the force sensors, the aluminium cases deform and then the groove width become wider than before3. So the distance between photoreflector and surface of aluminium case changes because the external forces; then the external force can be quantified measuring the distance between the photoreflector an the aluminium case. The Figure 4 shows the real force sensor equipment used at external force detection.

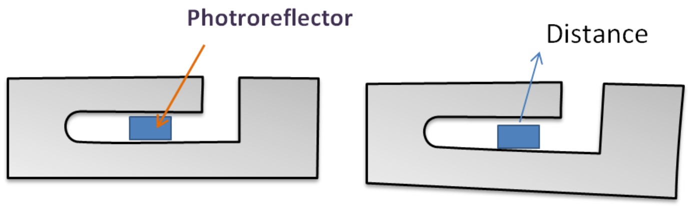

Fig. 3 Force Sensor Deformation Before and After

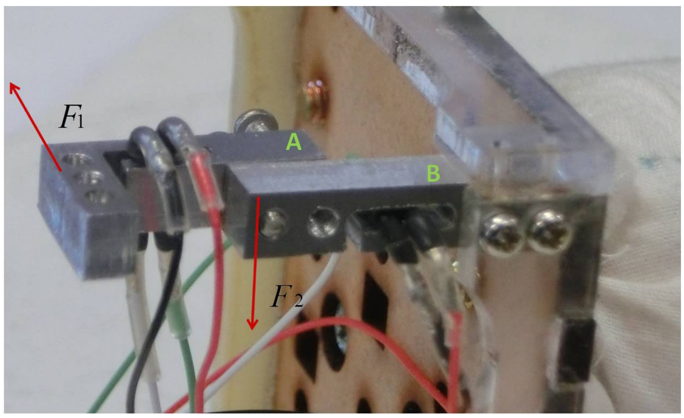

Fig. 4 Force Sensor Equipment

3.3 Impedance Control Equation

After the control board obtains the external force from force sensor, the increment length of strings will be calculated by the Equation 1 [2]. In the Equation

1,$(1 - Ab_{in})\,\Delta x_{tgt}(t)$ part is damper influence on strings; $k_{in}(x_{cur} - x_{in})$ part is resilience force coming from materials of arm. The external force F_e will be more and more weak over time; the calculation happens many times depending the control board clock frequency Δt.

$$\Delta x_{tgt}(t + \Delta t) = A\,(F_e - k_{in}(x_{cur} - x_{in})) + (1 - Ab_{in})\,\Delta x_{tgt}(t) \quad (1)$$

Δx_{tgt} : Increment of target string length for local motor controller

F_e : Measured external force

A : Constant to adjust sensitivity of impedance control

k_{in} : Desired spring constant

b_{in} : Desired damper coefficient

Δt : Control period(cycle)

x_{cur} : Actual string length

x_{in} : Desired string length

3.4 Behaviour Control

As mentioned before, robot would try to follow the external force or resist the external force. There are two modes during the interaction controlled by k_{in} of the Equation 1.

The first mode is when the robot wants to communicate with user. In this mode, value of k_{in} is a little small, and there are many goals of x_{in} depend on emotions of robot. Although at the beginning of the interaction, user would feel robot arms heavily because robot just starts to follow him, but the arms will be more and more light under communication. This interaction processing can be realized by changing x_{in} in the Equation 1. Therefore, it is important to predict the value of x_{in} which is key point to target position of robot arms.

The second mode is when the robot refuse to move the arms. This mode needs large value in k_{in} enough to offset the external force coming from user.

4. Future

In this interaction mentioned before, it is extremely important to predict the value of x_{in}. In other words, the prediction relates goal positions of robot arms what decide the "emotions" of robot. For this reason, a prediction program should be built first in order to achieve a natural dandle between the user and the soft-stuffed robot; as a baby by waving arms. In the future, soft-stuffed robot can give proper feedback to human as living beings what is significant in resolution of some social problems, such as population ageing, solitariness. However, this proposal is still on examination. It needs more time to do experiments on force sensor.

About the demonstration, the soft-stuffed robot will show its interaction skills based on outside camera(Kinect) and impedance control. Therefore, not only face to face interaction, but also there will be a touching interaction by impedance control.

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