The Helpless Soft Robot - Stimulating Human Collaboration through Robotic Movement

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ABSTRACT

Soft robotics have a set of unique traits, such as excelling at grabbing fragile objects which stem from the highly compliant materials used to produce them. However, very little research has so far focused on the interplay of the different interaction partners in a human - soft-robot collaboration. In this paper, we present the results of our investigation of the influence of two movement patterns on the willingness of random passersby to assist a soft robot in completing a task.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; • **Computer systems organization** → Robotics;

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KEYWORDS

Human-robot interaction; soft robotics; collaboration

Figure 1: The setup of the Helpless Soft Robot: The robot trying to grab the ball using the "Grabbing" motion where all three parts of the actuator are inflated lightly.

[1]https://www.festo.com/group/en/cms/12745.htm

INTRODUCTION & BACKGROUND

Soft robotics – meaning robots that are built from highly compliant materials inspired by living organisms – have a set of unique features that enable them to be employed in a variety of use cases. They have been successfully employed in industry applications in the past, and a variety of other applications have already been proposed such as medical surgery, rescue operations, and especially collaborative robots [8]. One particular well suited application case is to act as a robotic gripper[1]. Their softness lets them excel at grabbing objects that are fragile, compared to conventional rigid robots. Nevertheless, if the soft robot fails in completing its task and cannot self-correct its behavior, a human may be needed to assist it or in general might collaborate with the soft robot. Human robot collaboration is currently an important research topic in Human Robot Interaction (HRI) [2]. A particular challenge from an HRI perspective is the complex multi-modal interplay of different interaction partners with asymmetric communication capabilities. Robot motion is essential for conveying important information and supporting interaction, especially for non-humanoid robots or more diverse robot morphologies. The design of nonverbal signaling behaviors for conventional robots has been explored in [1, 3]. To our knowledge, no such studies yet exist for signaling behaviors for soft robots.

To estimate the robot's intention in a collaborative setting, the human first needs to interpret the motion of the soft robot. Given their smooth and organic appeal and motion [11] this might be problematic [9]. Especially compared to e.g. a rigid robotic arm this might represent a much more complex scenario [5, 6, 10]. Therefore investigating human perception and interpretation of soft robot actions is necessary for facilitating human-soft-robot collaboration.

To investigate this area, we present in this paper an initial in-the-wild study using a simple soft robotic gripper. To simulate the aforementioned situation where a human is supposed to collaborate with a soft robot in finishing a task, we staged the gripper below a ball dangling from a spring (compare Figure 1), as if the robot were tasked to grip the ball. To simulate the robot's failure we designed two different movement patterns, one very articulate and one rather basic, that imply that the robot is trying to grab the ball. The results of our in-the-wild study suggest however, that both of these motions only were successful in combination with another cue (a sign in our case) to trigger passersby to support the robot.

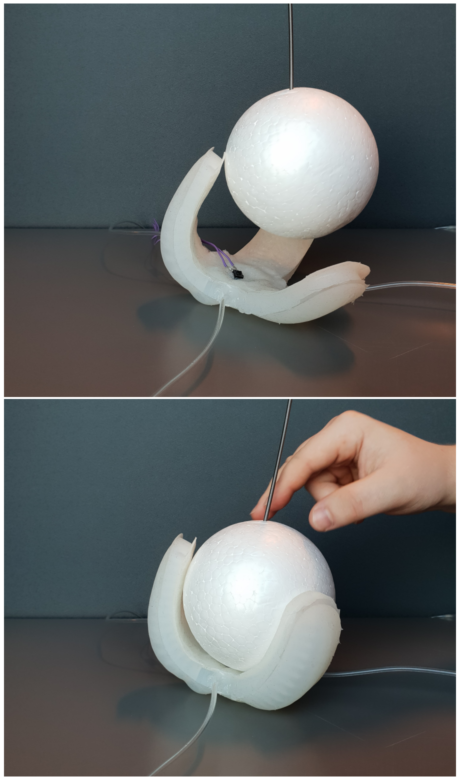

Figure 2: *Top*: The "Reaching" movement, where one arm would be strongly actuated, resembling a human stretching herself when reaching for a high object *Bottom*: The robot acknowledges the help and grabs the ball after a human pushed it down.

DESIGN & IMPLEMENTATION

The purpose of this investigation is to explore the area of human-soft-robot collaboration specifically whether movements of a soft-robot alone can provide enough cues to engage a human in collaboration. For this we decided to use a simple soft-robotic gripper as soft-robots excel at grabbing fragile objects due to their compliant materials. Furthermore the goal was to simulate a collaborative situation in which a human has to support the robot, therefore we staged a task where a robot is trying to grip a ball that is beyond its reach and therefore requires human support to complete the task (compare Figure 2).

One of the main inspirations for this project is the Helpless robot installation by Norman White, which was exhibited periodically from 1987-2002 [7, 12]. This artistic robot cannot move on the floor without being pushed by viewers. To achieve movement, the robot senses the environment; its own position and that of other participants in the space. It compares this data in relation to past situations and thereafter utters 1 of 512 possible spoken sentences in order to get participants to push it around. Similarly, the soft robot in this experiment is not capable of achieving the task on its own, and requires human assistance.

Prototype

The robot consists of a custom made three-chambered grabber actuator, cast in uncolored ecoFlex silicone. The mold was designed from scratch based on the PneuNets principle [4]; specifically the lamellar shape of the air chamber which ensures good air distribution. A 3D modeling program was used to design the mold, and it was then printed using a UltiMaker 2+ 3D printer. The robot is pneumatically actuated by two Mitsumi air pumps and a valve is attached to each motor to release air from the chambers to deflate the robot. The motors and valves are controlled by an Arduino Uno with a motor shield.

The system was staged in a way that the soft robotic actuator was lying flat on a table, placed to allow the arms to rise from the table, and curl above the robot. One pump and valve were attached to one chamber in the actuator in a closed system, and another pump and valve was attached to the remaining two chambers likewise in a separate closed system. Silicone tubing was used to connect the actuators chambers with the pumps and valves. Above the system, a styrofoam ball was hanging from a spring attached to a wooden scaffolding (compare Figure 1). A button connected to one of the Arduino's analog pins was placed in the "palm" of the robot. This allows the robot to detect when an object is placed in its grasp and would trigger a holding motion once a user places the ball on it.

The intent of this design of the soft robot was to allow the robot to reach for an object placed above it by utilizing its multi-chambered actuator. This was done to signal the robot's intention to grasp the object placed above. We combined this motion with the robot reaching for a ball that has the perceived affordance of being graspable.

Movement

Based on this prototype we designed two different movement patterns, which the soft-robot would repeat to indicate the intention of grabbing the ball. The first one, called ”Grabbing”, simply resembles a failed grab attempt of the robot. All three chambers of the gripper would be actuated at the same time and with the same, rather low, strength (compare Figure 1). As the ball would hang too high the robot would simply grab air. The second pattern called ”Reaching” was meant to signify the struggle of the robot more and maybe create more empathy in the potential collaborator. In this pattern only one arm would be strongly actuated, to resemble the way a human might overreach or extend one limb when grasping for an out-of-reach object (compare Figure 2).

PRELIMINARY USER EVALUATION

To evaluate the potential of our soft robot movements to trigger human collaboration, we carried out an observational in-the-wild study in the foyer of our university building. The robot was placed on a table in a highly frequented spot. The robot was left by itself and not attended by anybody. A camera was set up above the robotic platform, that would record the surrounding and all interactions with the robot. We compared the two different movement patterns as well as for each of the patterns we tested a situation with a sign that stated "Help me!" placed next to the robot and without the sign. This resulted in four different conditions which each was tested for 30 minutes. We deliberately chose to use a sign instead of an auditory cue (such as the Helpless Robot [12]) as the robot was placed in a very noisy environment.

The video recordings were analyzed according to a coding schema that would allow us to detect to which degree people progressed towards direct interactions with the robot, and how many would continue onto giving the robot the object that it reaches for.

The coding schema was created with the following progression:

- Passersby: These are all people recorded in the video
- Stopping and watching: These are all people who stop moving and turn their head to watch the robot for any amount of time, but who do not engage it physically in any way.
- Interaction: These are all people who physically interact with the robot or object.
- Helping interaction: These are all the participants who place the object upon the grabber, making the hand close.

	Reaching		Grabbing	
	no sign	sign	no sign	sign
Total Passersby	135 (100%)	139 (100%)	245 (100%)	171 (100%)
Stop & Watch	9 (6.6%)	13 (9.3%)	16 (6.5%)	14 (8.1%)
Interaction	1 (0.7%)	8 (5.7%)	2 (0.8%)	6 (3.1%)
Helping Interaction	0 (0%)	8 (5.7%)	1 (0.4%)	4 (2.3%)

Table 1: Results of the coding of the video recordings.

Results

Over all conditions we recorded 690 passersby from which only 17 (2.5%) interacted with the robot. As can be seen in Table 1 the two movement patterns had comparable ratios between interaction states when no sign was present. Very few passersby interacted, and fewer completed the helping interaction. When presented with a sign, people were much more inclined to help the robot. When the sign was up, we see a difference between the movement patterns emerge. The data suggests that people were more inclined to help the ”reaching” robot, as 5.7% of the total did so, while the numbers for the ”grabbing” robot was only 2.3%. The conversion rate numbers from interaction to helpful interaction were comparable, with 8/8 for the reaching robot and 4/6 for the grabbing one, suggesting that if you chose to engage with the robot, you were inclined to help it.

DISCUSSION

It is important to note here that the sign did state ”Help me!” which gives the audience a clear signal towards the robots ineptitude and communicates that the audience are expected to interact-and-help the robot. This cue in conjunction with the button may have signified how the robot should be helped - by pressing the button. This very likely explains the drastic increase in correctly executed helping interactions. However, as mentioned before, human robot collaboration is often a complex multi-modal interplay that often uses more cues besides motion, which makes us believe that our early investigation shows the potential impact of movement patterns.

While we did see a difference between the two tested movement patterns on the participants, we realize that the difference in appearance and function between the two is not significant. Nevertheless, the "reaching" pattern which was meant to highlight the struggle of the robot to a higher degree was more successful. The asymetrical reaching motion might have been interpreted as a more clear sign of "struggle" and signaled the need for help. As this was only a preliminary experiment that is supposed to open up the discussion around the influence of movement on the likeliness of human collaboration, the rather small number of passersby that interacted with the robot is acceptable. However, we would propose that our findings support to a certain degree our hypothesis; a more articulate soft robotic actuator would increase the willingness of participants to assist it the task. However, this only worked with a second modality supporting the movement.

CONCLUSION & FUTURE WORK

In this paper we present the design and preliminary evaluation of an investigation method for studying nonverbal signaling methods for soft robots. We measured this by the willingness of passerby to collaborate on an unspecified task both with and without a written cue. While we found a difference in how the participants reacted to the soft robots movement, more investigation is needed. Further experiments would be several laboratory- and in-the-wild studies isolating the impact of individual characteristics of robot, such as its texture, the anthropomorphic characteristics, or its movement patterns. Movement patterns based on human movement and signaling, especially movements of the human hand, proved essential for nonverbal communication of a soft robot.

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