HugBot: A soft robot designed to give human-like hugs

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ABSTRACT

As robots increasingly enter our daily lives, there is a need to understand how to design robots capable of emotional interaction with humans, especially children, due to their sensitivity and vulnerability. For example, robots that provide children with social and emotional support might be more effective at also helping children develop cognitive abilities, rather than designing robots that focus solely on helping children acquire cognitive skill. In this paper, we examine the design of robots that can provide human-like hugs as a particular form of social and emotional support. We first discuss the need to design robots that can interact emotionally with children. Then, we present the development of a shirt augmented with pressure sensors used to collect data on how humans hug each other. Finally, we detail the design of "Hugbot", a soft robot that could use this data to give human-like hugs, and discuss our planned future work on this system.

CCS CONCEPTS

• **Computer systems organization** → **Robotics**; • **Human-centered computing** → *Interaction design*; Collaborative interaction.

KEYWORDS

Soft robots; Human-like hugs; Social robots; Child-robot interaction

INTRODUCTION

The rise in technologies, especially in the area of robotics, is leading to a rise in affordable robots for families, such as Roomba and Sphero robots. Moreover, there is a trend in developing social home robots to assist children in a variety of tasks such as developing and improving motor skills, verbal skills, creativity, etc. Most existing work involving social robots focusew only on the task e.g., ways to help a child through storytelling [9], act as a companion to learn English as a second language [8], or even as informants for young children [3]. These efforts are valuable by themselves but we believe children may learn better if they can emotionally connect to their tutor or companion. Research shows that teachers with social-emotional skills have better influence on their students' learning [7] but when there is still much to be explored on how robots with such skills impact children's behavior or learning. The lack of knowledge in this area is due to the relatively new body of research that looks at ways to develop robots that can effectively provide social and emotional support. One such area is the interaction of robots and humans through hugs.

Hugs are a natural and intuitive way of expressing affection and giving a hug is an expression that comes almost instinctively for some people, while others feel uncomfortable in giving hugs because of the complex series of interactions involved. First, a "good" hug involves proper positioning of the arms and hands and torso, then one must be aware of the appropriate amount of force to use, and finally understand when is the right moment to let go [2]. It is a two-way interaction between huggee and hugger. Researchers have studied how robots could engage in giving hugs, from using a robot-like design called the "Hug" to give "tele-hugs" [5], to acting as a companion inspired by animal therapy to promote the overall health of an individual [11], or even using personal robots to give hugs to adults for emotional support [2]. However, most previous research focuses on the robots instead of the users i.e., the robot initiates the hugs and opens and closes its arms to give a hug, lacking a consideration of when the user wants to let go or if the hug is sufficient for providing emotional support. More research

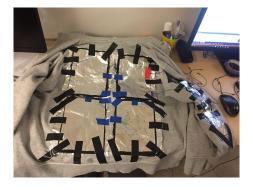**Figure 1: A child getting hugged by the HugBot**

Figure 2: Design of sensory shirt: contains a shirt with 8 pressure sensors that uses velostat to measure the pressure and aluminium foil to make the sensors conductive

is needed to explore ways to train a robot to understand these challenges and provide emotional support to children. Children are sensitive to hugs and by learning how to give a good hug they might learn an important social skill from a robot and be more socially engaged with their parents and peers [12]. Bearing in mind the process of a "good" hug, we designed HugBot: a soft-robot that can give human-like hugs to users, especially children. In this paper, we describe background research and our approach for designing the HugBot. First, we lay out the steps to design a custom sensory t-shirt to measure how humans hug each other, e.g., how to initiate hug, attachment-detachment time, etc. Then, we discuss the design of HugBot (see Figure 1), and finally, we share our findings and elaborate our future plans to collect data to train the HugBot to give human-like hugs.

RELATED WORK

We designed the HugBot in consideration of prior work in two research areas: robots as social agents and the need for designing soft robots to provide more human-like interactions.

Robots as social agents

Research has shown that children tend to perceive robots as life-like characters and with extended interaction the relationship evolves to the point that children see robots as their peers [6]. As a result, researchers have suggested the need to create robots that are engaging and interact continuously with humans. In the case of children, robots serve as tutors, therapeutic assistants, or toys [6]. In exploring these use cases, researchers have developed robots that express emotions in a variety of ways, for example through eye gaze or gestures [3]. Although different social-emotional interactions of robots have been studied, comparatively less work has explored the impact of the robot on children's learning to actively engage in such interactions. Researchers have postulated that this could advance the field of child-robot interaction [1]. In this work, we are interested in supporting children's learning of social and emotional skills, such as giving and receiving hugs, and ways to use this learning in other aspects of day-to-day interactions.

Soft robots to support human-like interactions

Interactive robots are being used in providing physical, educational and therapeutic assistance in schools, homes, and hospitals [5]. Robots with animal-like appearances, such as the robotic dog AIBO, can be an important factor in providing tangible interactions and developing a sense of emotional attachment [13]. PARO, a robotic baby harp seal, has been used to help reduce agitation and improve mood states in people with dementia [4]. Others have designed soft robots that react to touch, like the Huggable [11], which can motivate children, or like the HuggieBot [2], which can engage adults in affectionate behavior such as cuddling or hugging. Additionally, Disney plush toys or stuffed animals are being used by researchers to study the amount of pressure children can exert while giving hugs,

Figure 3: Prototype of a 3D printed arm with 3 joints and a fixed part on which the other joints rest

Figure 4: Design of HugBot's arm using foam sponge and strings

in order to design interactive robots [10]. Our work contributes to this area through the design of a human-size soft robot that supports opportunities for social and emotional skill enhancement.

SYSTEM DESIGN

Our system consists of 3 components: 1) a sensory shirt to study hugs, 2) robotic arms to manipulate the hug, and 3) a panda-like stuffed animal, which hosts all the sensors and actuators.

Design of a sensory shirt

To execute a realistic hug, it is necessary to study how people give and get hugs. It is also important to describe a hug by features or attributes so that it can measured and emulated. We identify two features to describe a hug. First, "*engaged body parts*", a vector of n bits where n is the number of sensors, and each bit represents whether the relevant sensor is sensing pressure. Second, "*duration*", is the total attachment-detachment time, starting when one of the sensors show a number more than the threshold (e.g. in our application it is 0.12) and ending when all the "*engaged body parts*" vectors are less than the same threshold. We designed a custom sensor shirt, consisting of 8 pressure sensors (4 on the chest and 2 on each arm) that can record the amount of pressure exerted to different parts of the chest and arm, the attachment-detachment time, and which parts of body are involved during the hug (see Figure 2). A preliminary study with volunteers provided an initial understanding of the data. We used these data to control and actuate the robotic arm to imitate a hug. In the future, we plan to collaborate with local primary schools to complete a formal user study with children. We used the gathered data in two ways, first for classifying the different type of hugs, and second for reinforcement learning, to control the robot arm so that it can give realistic hugs.

Design of a soft-robotic arm

To design a proof-of-concept arm, we used cardboard to develop arms with different degrees of freedom (DOF) to determine a design that supports a flexible arm that can bend freely around an object. These parts are still being developed and we need more data to accurately classify hugs.The robotic arm should be able to completely grasp the chest and back with an adjustable pressure similar to human arms when humans hug each other. After several iterations, we found that an arm with 3 joints provides a suitable trade-off between arm complexity and flexibility. Next, we 3D printed a variety of joints for the arms to test possible shapes (see Figure 3). Through this process, we determined that each joint should have a curvature of at least 30 degrees. From the 3D printed joints we observed that for safety, it was essential to make the material for the arms softer, as we did not want HugBot to exert an uncomfortable amount of pressure on the person it was hugging. In the final design, the arms were made using foam sponge. As shown in Figure 4, it consisted of 6 identical pieces roughly quarter-circle shape (15cm x 10cm x 5cm). Strings were used to keep the arms straight, with one end

Figure 5: The T-shape structure used for making the backbone of HugBot

Figure 6: A panda shaped stuffed toy we used for creating the HugBot

fixed to the end of the arm, while the other side was connected to a servo motor. Rubber bands were used to keep the arms open by default. The arms were attached to a T-shaped wooden structure, which acted as a backbone for the robot (Figure 5). The actuation of the arms were such that the entire arms bend on the pulling and releasing of two strings attached to a pulley that go all the way through both the arms. To automate this process, a stepper motor was added to the T-shape structure and it completed majority of the Hugbot design.

Choice of soft robot

There are multiple challenges to choose the right robot body for this project. It is essential that the appearance of the robot be acceptable to children. No matter how well the hugging part of the robot works, if the robot itself is not appealing (e.g., scary, too big, etc.), children will not use it. We opted for a zoomorphic appearance, rather than a humanoid morphology to avoid uncanny valley effects. As we wanted to put the arm and actuators inside the body, the choice of using a stuffed animal was promising. We decided to use a panda stuffed animal that is visually appealing and mimics the common notion of a stuffed bear with which many children are familiar (Figure 6). As elementary school children are the main target of this research, we decided to use a stuffed animal with 1 meter height, roughly mimicking the height of the children.

DESIGN IMPLICATIONS AND FUTURE WORK

This paper presents ongoing work on HugBot, a hugging robot that gives human-like hugs. The aim of designing such a robot is to teach social skills to children through emotional interactions like hugs. To test the feasibility of our design we pilot tested it with different users. The sensor-shirt was tested by members from our research group and we noted changes necessary in order to effectively collect data, such as increasing the surface area of the 8 pressure points and making the pressure points more continuous instead of separating them from one another. We presented our work at a research expo where child visitors interacted with the HugBot (see Figure 1). From our observations we saw that robots with zoomorphic appearance keep children more engaged, and that HugBot could be used as a means to teach social skills to children. Our system design and initial tests suggest that there are different types of hugs (e.g., between two friends, or between a parent and a child). To design a robust system that mimics these types of human hugs, intensive user studies need to be conducted with children to train the robot. As part of our future work, we will test the sensor-shirt and the robotic arms with children and their parents and peers, and record types of hugs. Using these data, we plan on implementing machine learning techniques to train the robot to give different hugs and enable more social interaction with children. Thus, we envision all the parts of our system to be integrated into a HugBot design that can help children learn about social skills like hugs and it comfortable for them to interact with family and peers.

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