Embracing Comfort: Soft Socially Assistive Robot for Early Emotional Interventions in Primary School

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***Abstract*—Social workers are often overworked and need to care for more students than they can handle. To address this issue, we propose a soft inflatable social robot that can be used to aid overworked social workers. Its soft body assists in its primary function to provide emotional support to primary school students in the form of comforting hugs. Our robot uses an RGB-D camera and pressure sensors to detect student posture and contact, and the robot will respond accordingly by adjusting hug timing and magnitude in real time. This robot can be used to comfort students during stressful moments and frees social workers to focus on higher-priority interventions.**

I. Introduction

In the United States, there is a persistent shortage of social workers available to aid elementary school students. According to the National School Social Worker Census, there are zero states in the United States that meet the recommended student-to-social-worker ratio of 250:1 [1]. A social robot can help by offering support when human social workers are overwhelmed. Most state-of-the-art social robots are focused on verbal interaction, and lack the functions necessary for physical interaction. Despite the widely documented benefits of positive physical contact [2], there are a lack of robots that focus on offering comfort in that manner. In psychologist Harry Harlow's experiment on development, it is shown that infant monkeys preferred a comfortable cloth mother even when it didn't provide any food [3], suggesting a powerful preference for comforting contact over purely utilitarian caretaking. Therefore, this project focuses on offering a comforting sensation similar to that of the "cloth mother" through a soft robot that can deliver controlled, comforting hug to provide reassurance and comfort to struggling children.

The size of soft social robots can vary via inflation, with most being relatively small, such as Kaspar who measures approximately 46 cm tall [4]. A larger soft robot could approximate an enveloping embrace while remaining safe contact to produce a sensation that is more similar to being fully embraced by an adult. Our design centers on soft pneumatic actuation and on-device sensing, with educators or social workers initiating and supervising interactions.

II. Methods

We proposed a two-layer, pneumatically actuated soft robot with distributed hugging pressure sensing and RGB-D perception, coordinated by a compact control box, to deliver safe, adjustable "hug" gestures suitable for primary-school settings. As sketched in Fig. 1, the robot is designed with two layers. The inner layer consists of a fully inflated pressurized balloon, which provides the robot structural support. A compliant, outer layer fully envelopes this balloon and is soft when touched due to its lower internal pressure. At joints of the robot (shoulder, elbow, and wrist), there is a segment that can be inflated or deflated by the controller, allowing the robot to move and support its limbs and interact with the user. Joint segments include the shoulder, elbow, and wrist segments for a total of 6 degrees of freedom. Limb motion will also be guided with the inflatable actuators for further support.

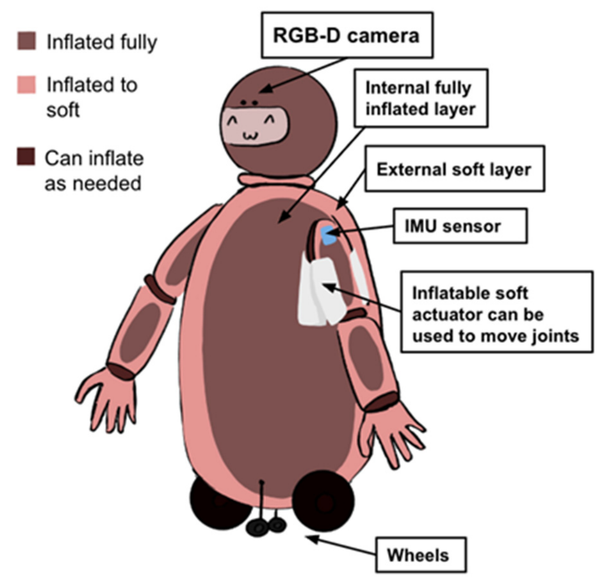

Fig. 1. Concept sketch of the social hugging robot, showing the fully inflated internal layer, soft external layer, inflatable joint actuators, camera, and wheels.

A pneumatic control box has been designed to manage the inflation of the joint actuator (Fig. 2), consisting of an air pump, printed circuit board with a Teensy microcontroller, pressure sensors, pressurized air accumulator, and solenoid valves to control the air flow.

The accumulator is attached to the actuator through tubing, and the air flow is controlled by the solenoid valves. Soft pressure sensors are applied to the inner side of the outer layer in order to detect the pressure that is being applied by the hug, and to adjust hug intensity and duration.

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The “face” is made of a screen on the head displaying various pixel kaomojis. The simple pixelated kaomojis are designed to convey approachable expressions while avoiding uncanny-valley effects associated with realistic faces. This helps the robot be perceived as cute rather than potentially scary. An RGB-D camera mounted above the face tracks proximity and body posture and supports basic affect-related cues without requiring physical identifiers.

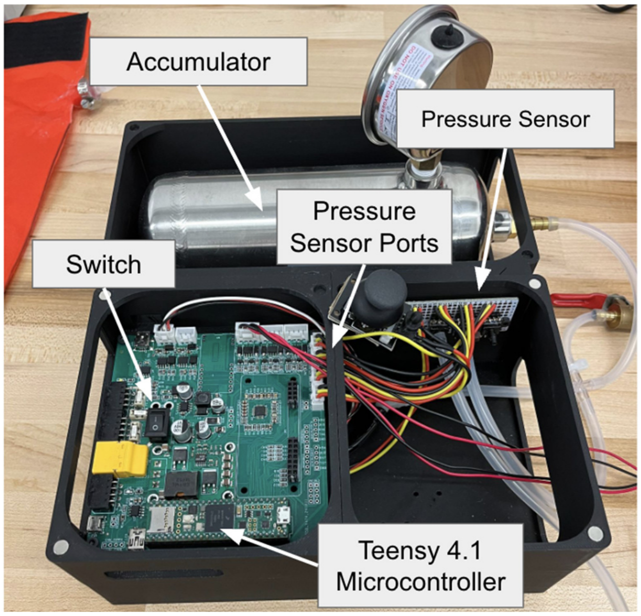

Fig. 2. The parts used in inflating the actuator: a circuit board with a Teensy 4.1 Microcontroller and pressure sensor ports, a pressure sensor connecting to tubing and valves that regulate air flow from the accumulator to the actuator, and an accumulator that accumulated pressurized air from a pump below the circuit board.

III. Experimental Results

We evaluated whether the pneumatic rotary actuator can raise the robot’s arms to a hug posture while maintaining compliant contact. As a proof of concept, we tested on a shoulder model (shown in Fig. 3), and recorded shoulder angle, actuator pressure, and accumulator pressure under low and high pressure setpoints (Fig. 4). The actuator was able to assist in the robot lifting its arms to a desired angle for hugging and inflate to offer support up to 0.45 bar of air pressure.

Fig. 3. A deflated (left) and inflated (right) actuator. The inflated actuator is stiffer to provide support.

As seen in Fig. 4, at low actuator pressure, the actuator is softer and more malleable and as a result, the shoulder is at a lower angle. At high actuator pressure, it becomes solid and the arm is propped up higher.

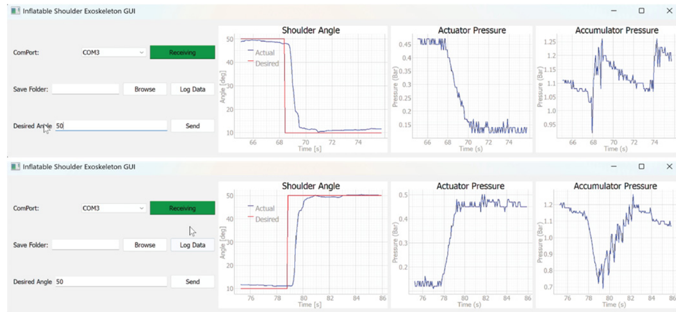

Fig. 4. Plotted results showing shoulder angle, actuator pressure, and accumulator pressure of the actuator-accumulator system on a shoulder model at low and high actuator pressure.

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