Designing Arms for Lil'Flo, a Socially Assistive Rehabilitation Robot

Michael J Sobrepera[1], Michelle J Johnson, PhD[1-3]
[1]Mechanical Engineering and Applied Mechanics, [2]Bioengineering, [3]Physical Medicine and Rehabilitation, University of Pennsylvania; Philadelphia, PA

Introduction:

Affecting children at an incidence of 2 to 2.5 per 1000 live births, cerebral palsy (CP) is one of the leading causes of disability in children worldwide. Children with CP often have motor impairments affecting upper limb range of motion and function on activities of daily living (ADLs). Providing ongoing therapy and/or accurate assessment of arm function as a child grows with disability is difficult and costly, requiring a child to either visit a therapist or be brought to a clinical facility housing a complex motion capture lab. Accessing therapists and human motion capture labs is not always possible, especially for children in rural and developing settings. The use of social robots as vehicles for therapy has been demonstrated, with many studies using the Softbank NAO robot. The NAO, while well designed with a complete programming environment, is costly and resistant to users fully customizing the robot's form. This limits our ability to study how a robot's form and movement can impact therapy interactions with children. To address these challenges, we have been working to design Lil'Flo (Fig 1), a small socially assistive rehab robot. Lil'Flo is stripped down to the essentials of what is needed in an upper extremity rehab focused robot, to decrease cost, and is designed so that components can be added and removed to study how they impact interactions. Our design objectives were to create the robot with arm movements that approximate human shoulder and elbow motions. Here we present our work to add arms to Lil'Flo which are critical for demonstrating reaching actions in ADLs.

Materials and Methods: Lil'Flo uses motors, a control board, and the chest of the XYZRobot Bolide robot, a commercially available, affordable, edutainment robotics platform. The Bolide's motors are serially controlled and can provide digital feedback. The Bolide is however not appropriate for upper extremity rehab in its native form, lacking appropriate placement of degrees of freedom and having an exposed skeleton. To rectify this, we have developed a custom skeleton for Lil'Flo. The skeleton is an exoskeleton with an exterior which is meant to be visually pleasing. It is designed to minimize weight and assembly steps. Each arm segment is composed of two exoskeleton components and each joint is composed of one component. The small number of components, enabled by the melding of the skeleton and shell, minimizes assembly steps and allows easy maintenance and experimentation on the robot's form. The motors are fully encased and pinch points are minimized. The hard exterior makes it possible to wipe down the robot, but it is not sealed to fluids or dust. The system of motors is controlled by custom software, exposing it to the robot operating system (ROS). This allows the arm's movement to be captured, visualized, and controlled in ROS. To understand the viability of the new arm design, the range of motion of the robot' joints were measured using the encoder built into the motors. The arm motions were compared to standard human joint range of motions for the shoulder and elbow. We evaluated the ease of control, workspace extent, ease of maintenance, and ease of modification for the system.

Figure 1: A picture of Lil'Flo with the arms attached. The arms still require paint but are mechanically complete.

Results and Discussion: Measurements from the constructed robot of range of motion show shoulder flexion: 3.6 radians, shoulder extension: 3.9 radians, shoulder abduction: 3.0 radians, shoulder adduction: 0.1 radians, shoulder internal rotation: 2.4 radians, shoulder external rotation: 3.2 radians, elbow flexion: 1.5 radians, elbow extension: .68 radians. The limits are imposed by both physical contact between components and length limits on the wires connecting the motors. These yield coverage of human range of motion except for shoulder adduction and elbow flexion. Elbow supination and pronation are not present in the design, nor are any wrist motions. The shoulder internal/external rotation is done near the elbow joint, instead of near the shoulder. The motors which are currently being used cannot simultaneously move and provide position information to the high-level controller.

Conclusions: The arms of Lil'Flo have sufficient coverage of human range of motion to demonstrate many ADLs, improving the elbow flexion is a target for future work. The easy to fabricate, modular, low cost design will allow rapid iteration on the robot, allowing different features to be tested on the arms to motivate attention and engagement in rehab activities. Our future plan is to upgrade to Dynamixel motors to improve controllability.