# A Soft Inflatable Elbow-Assistive Robot for Children with Cerebral Palsy

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## Introduction

- Background
  - Cerebral palsy (CP) – neuro-developmental disorder – could happen before, during the after the child is born
  - CP could be caused by damage to the brain before birth, brain infection (such as meningitis) after birth, stroke and other reasons [2].
  - Cerebral palsy can severely impair children's motor function and leading to permanent disability.
  - Around 50% of children with CP suffer from an arm-hand dysfunction, especially upper elbow flexion deformity – leading to pain and loss of motion.
  - Compared to adults, children are more vulnerable and susceptible to external harm.
  - Elbow is a complex joint consisting of three bones and two joints, allowing for two DoFs – flexion/extension and pronation/supination, respectively [3].
  - Conventional treatments are labour-intensive, and the existing adult-oriented wearable assistive robots are unsuitable for children.
- Target, requirement and idea
  - Novel soft inflatable robot that can aid children in elbow movement whilst minimising the risk of harm.
  - Thermoplastic Polyurethane (TPU) and pneumatic actuation were used in developing the soft robot.
  - Maximum bending angle ≥ Range of moment of arms **(130°)** [2]
  - Maximum force generated by the actuator should fulfill the force required to accomplish ADL **(0.97 Nm)** [4]

## Method

***Mechanical Design:*** Design criteria are as follows:

- The robot must **not restrict wearers when not in use.**
- The system must be **low cost or cost-effective.**
- The bending profile of robots must **conform to the elbows.**
- The range of motion **(RoM) of robots > RoM of elbows.**
- **Soft and flexible.**

**Design strategy**

- Segment the robot into multiple inflatable chambers with narrow and longitudinal air slits in the middle, see Fig.1.

***Bending Experiments:***

- The robot bends towards one direction as it is inflated.
- Eight pressures – 0, 0.2, 0.5, 1, 1.2 bar were applied, and their corresponding coordinates of each joint was recorded

***Force Experiments:***

- Under different pressures, the maximum payload that the soft actuator could lift is also recorded.

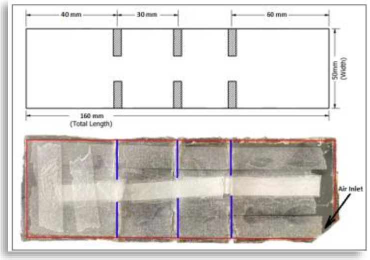


**Figure 1** – Mechanical design and the fabrication of the soft robot

## Results

***Bending experiment result:***

- Computational visualisation – Fig.2(left) – bending profile under various pressures.
- Quantify the bending, the bending angles are plotted, see Fig.2(middle).
- The maximum bending angle of the design is about 142.2°, which meets the requirement – 130°

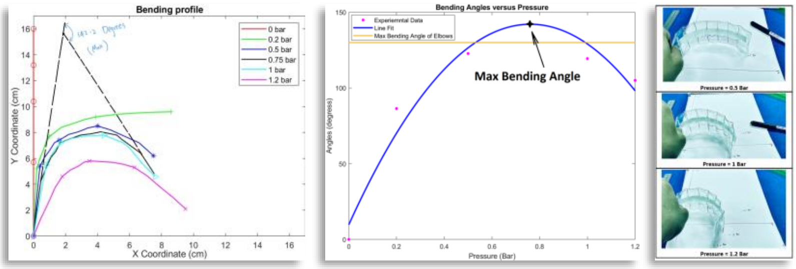
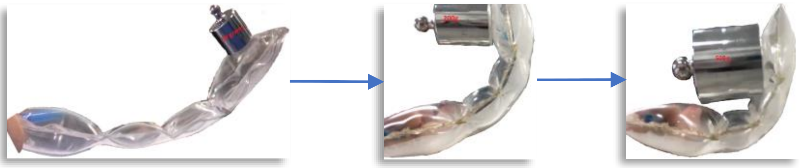


**Figure 2 -** (Left) Bending profile; (Middle ) Bending angles & polynomial regression fit; (Right) Bending Experiments

***Force experiment result:***

- Pressure = 1.2 bar, the maximum payload the design could support is 500g (4.9N).
- The total length of the robot is 16cm, the total moment –
  *Moment = 4.9N * 0.16m = 0.784 Nm – 80.8% of the required value – 0.97 Nm.*
- Further improvements are required – ***1. Fibre reinforcement; 2. Multiple layers***

***Visualisation of robot lifting different weights – 50 grams → 200 grams → 500 grams***



## Discussion

***Current stage:***

- The proposed target was partially achieved – lightweight, provide ***enough bending angles*** **and** ***80.8% of bending moment*** required to carry out ADL.
- Flexible when not in use so would not obstruct a user in any way. Small pressure only – safe for children.
- Cheap and easy to manufacture and meet the functional requirements – promising and make it particularly suitable for children who grow quite fast.
- Different ways for force improvements – fibre reinforcement, multiple layers .
- The applications of the robot could be extended to a hand or knee exosuit.

***Next step of the project:***

- Different materials, i.e., fabrics, fibre, etc. shall be tested to understand which material will provide the greatest lifting force under given pressures whilst maintaining the level of bending that was found in the experiments.
- Scaled-down versions that would fit a child's hand should also be trailed to see if they have any effects of the movements that can be achieved.
- Human trails to understand if they are comfortable and to what degree of support they can provide.
- Intention detection using multiple sensors (EMG, IMU, etc.)
- Sensor fusion with the aid of computer vision will be applied to find out the implicit relevance between the bio-signals extracted from sensors and the intentions of wearers.

## References

[1] Yulin Wang and Benny Lo. "A Soft Inflatable Elbow-Assistive Robot for Children with Cerebral Palsy". In:2021 IEEE 17th International Conference on Wearable and Implantable Body Sensor Networks (BSN) (IEEE BSN 2021). Athens, Greece, July 2021.
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