Modelling and Control for Chamber-reinforced Soft Robots with Dimension Scalability

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ROBOTICS

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1. Introduction and Background

- **Soft continuum robots made of highly deformable elastomers** are inherently **compliant and safe**, with a high **flexibility and versatility.**
- **Elastomer-based soft robots exhibit nonlinear kinematic properties, which further complicate its kinematic control.**
- **With scalable dimensions, the robots can be applied in various applications, e.g., .Minimally invasive surgery (MIS) . MIS** a procedure inserting thin instruments through **small incisions (3-15 mm)** in the abdominal area, which has the advantages of, e.g., **less postoperative pain**, better **therapeutic outcome**.

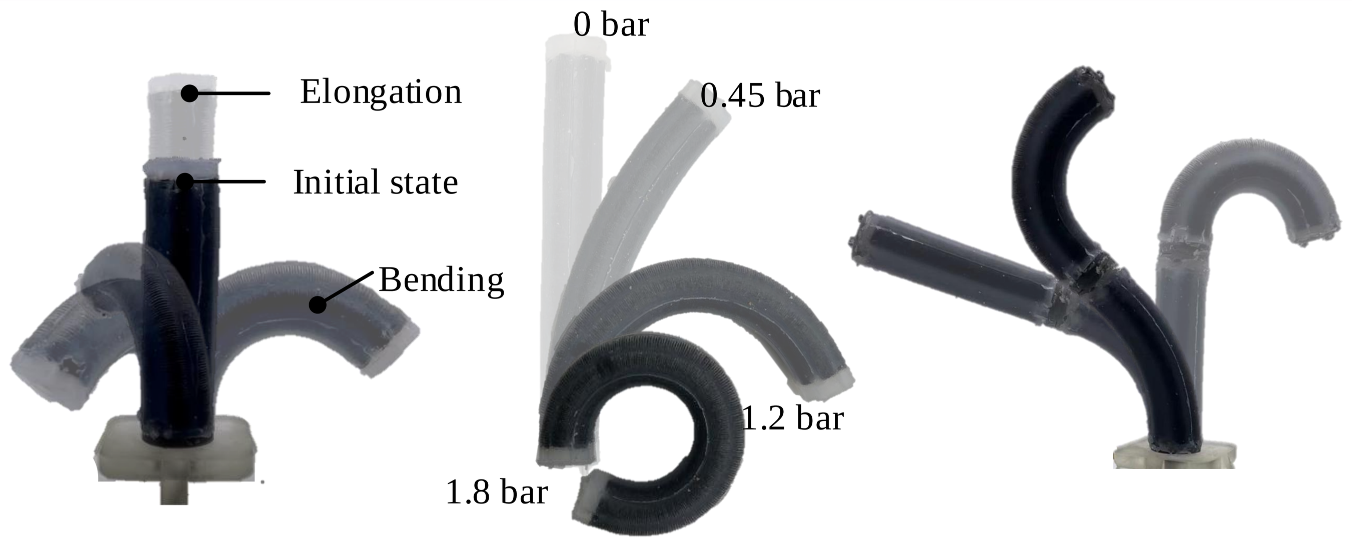


Fig. 1 Pneumatically driven, high flexible and dexterous soft continuum robot with full chamber reinforcement. The robot has a diameter of 10 mm.

2. Aim and Objectives

Aim of this work

Developing a **design, modelling and control framework** for **chamber-reinforced soft robots** and exploring relevant **medical applications**.

Objectives:

- The soft robots should have **satisfactory manoeuvrability, flexibility, reliability and predictability.**
- To establish a **kinematic modelling and control methodology** to understanding and manipulator the soft robots.
- To create soft robots having miniaturised diameters (feasibly ≤ 15 mm, **ideally ≤ 12mm**), e.g., to fit medical requirements.

3. Methods

Fabrication:

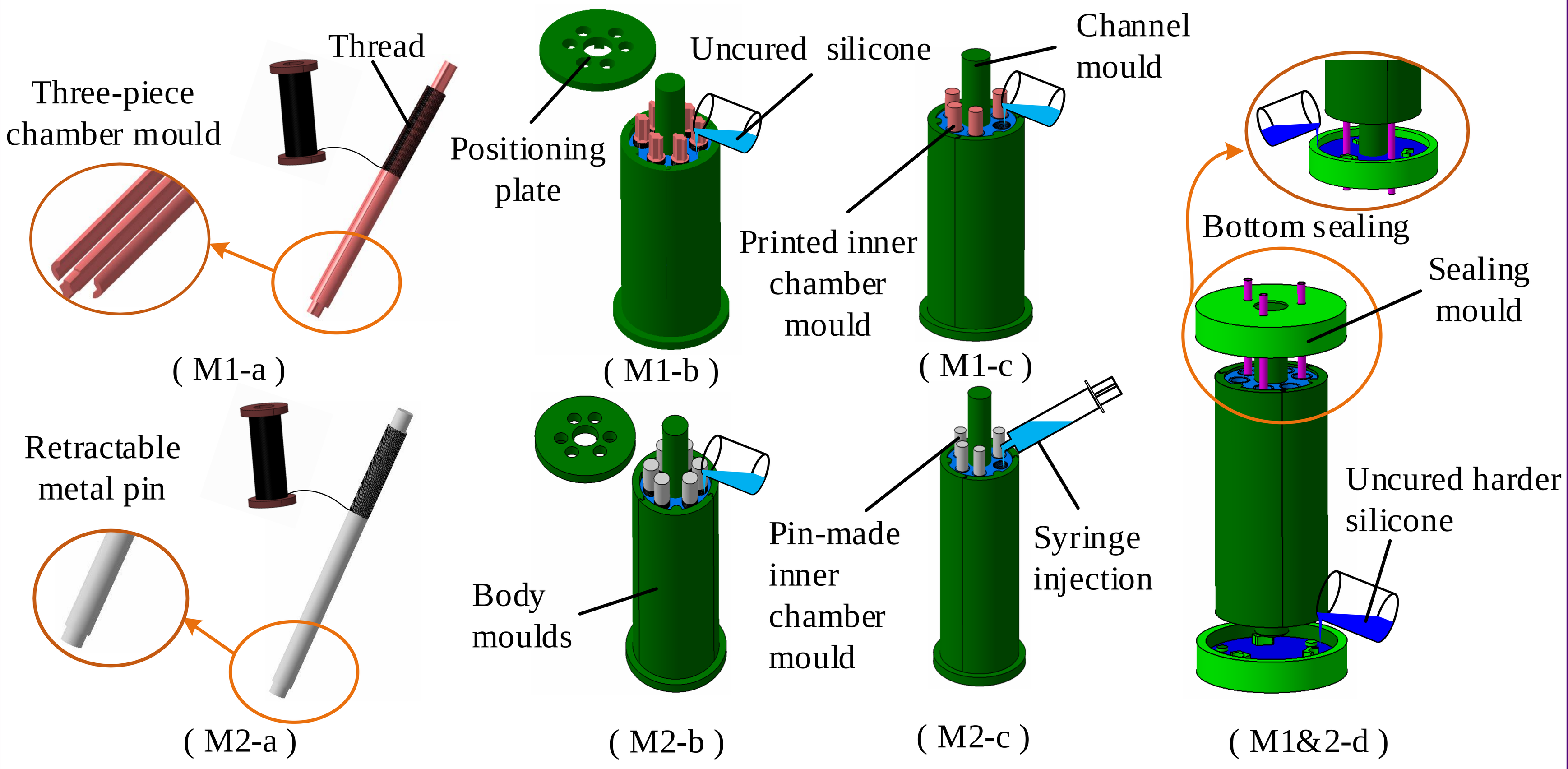
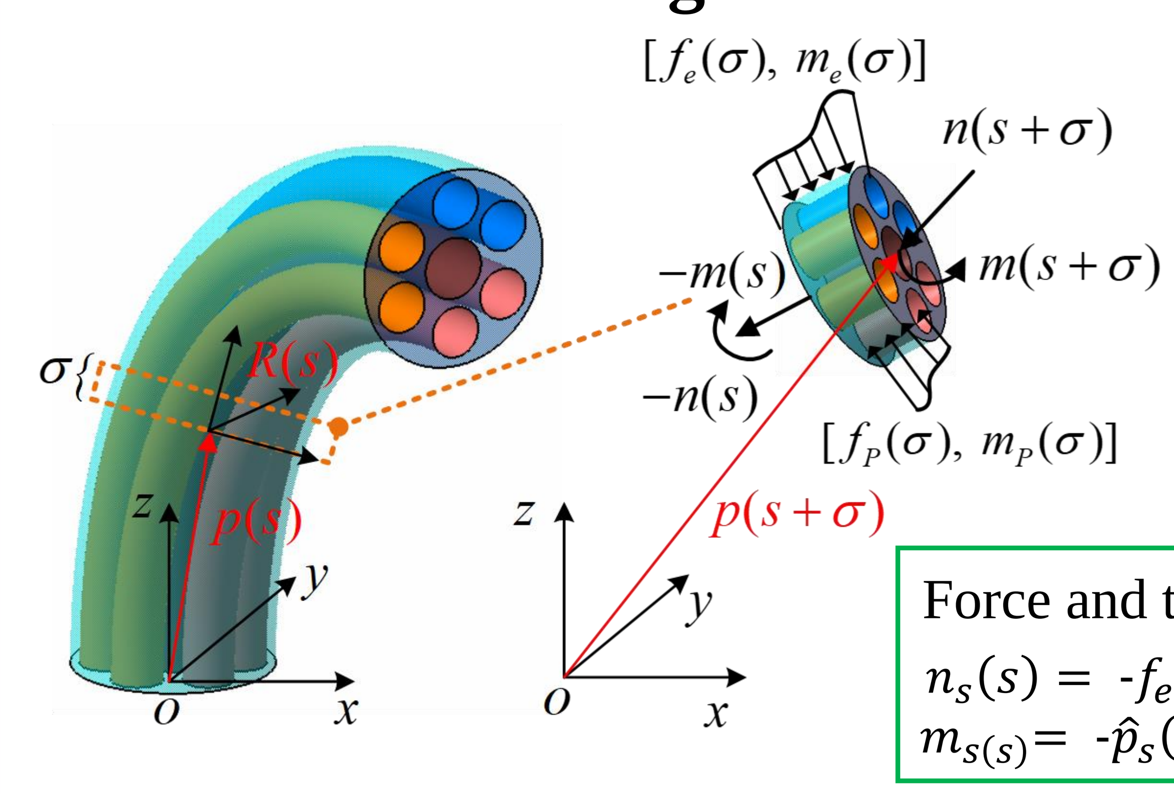


Fig. 2 A **fabrication paradigm** for creating chamber-reinforced soft robots with **dimension scalability**, e.g., the overall diameter can be from **25 mm to 10 mm**.

Kinematic modelling:



Kinematic ODEs:

$$p_s(s) = R(s)v(s)$$
$$R_s(s) = R(s)\hat{u}(s)$$

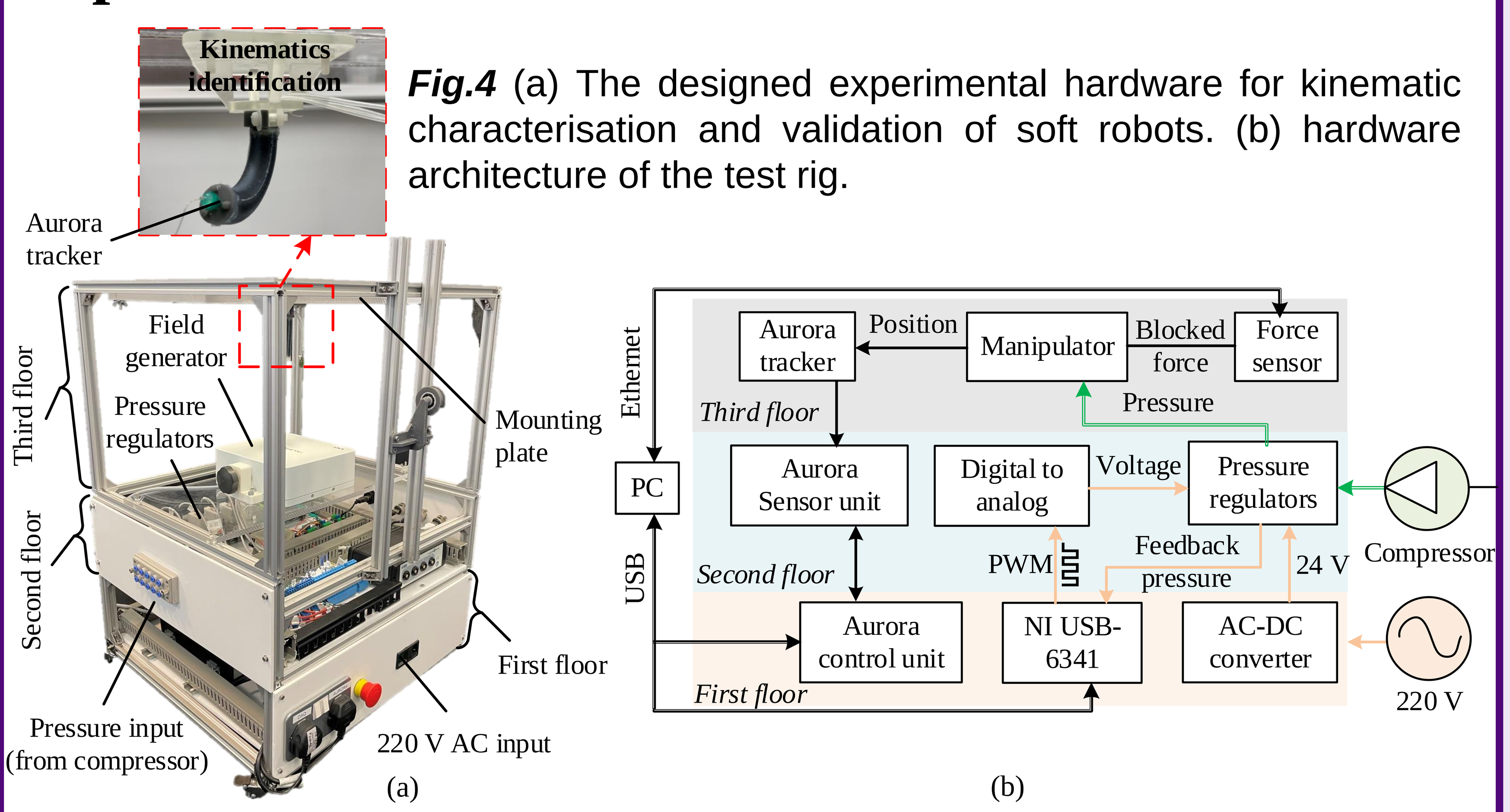
Force and torque balance ODEs:

$$n_s(s) = -f_e(s) + f_P(s)$$
$$m_{s(s)} = -\hat{p}_s(s)n(s) - m_e(s) + m_P(s)$$

Fig. 3 Illustration of the force and torque equilibrium. The length of the element is σ. Apart from the external distributed force $f_e(s)$and moment $m_e(s)$, the pressurisation also introduces the distributed force $f_P(s)$ and moment $m_P(s)$ along the arc s.

Experiment Hardware:

Fig.4 (a) The designed experimental hardware for kinematic characterisation and validation of soft robots. (b) hardware architecture of the test rig.



4. Results

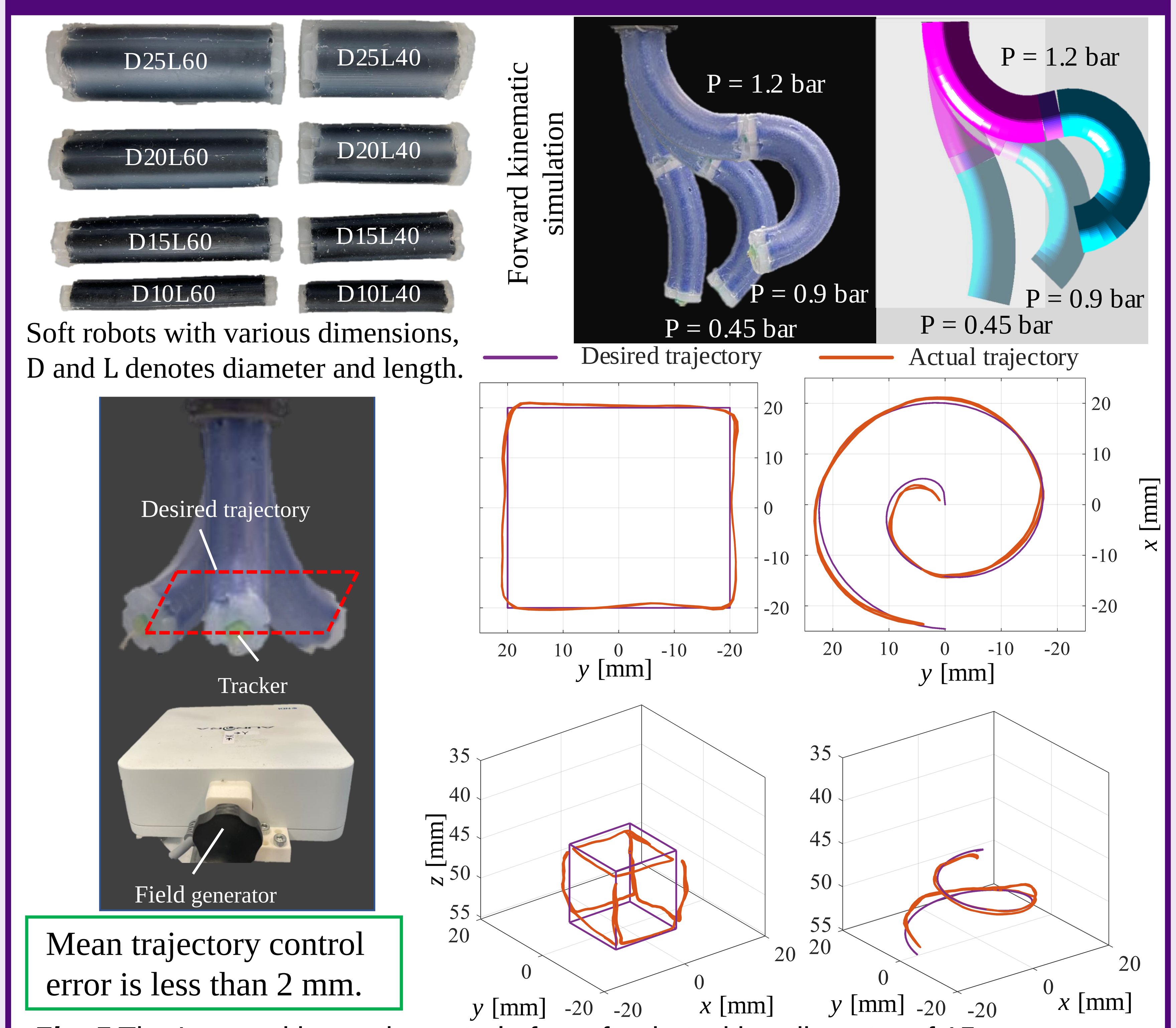


Fig. 5 The Inverse kinematic control of a soft robot with a diameter of 15 mm.

5. Conclusions and Future work

- A **generalised design** paradigm for **different-scale** soft robots with **reinforced chambers** is proposed, e.g., the overall diameter can be from **25 mm to 10 mm, with different lengths.**
- A **modelling and control methodology** is proposed based on the Cosserat rod model, with the **tip error less than 2 mm.**
- More **medical applications** can be explored in the future.

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