

Data-Driven Control of a Soft Bioinspired Grasper

Introduction

- Soft graspers have inherent advantages in handling fragile and deformable objects e.g. fruits, food, biological tissues
- However, even very deformable items like soft clays may require active force control to minimize deformation

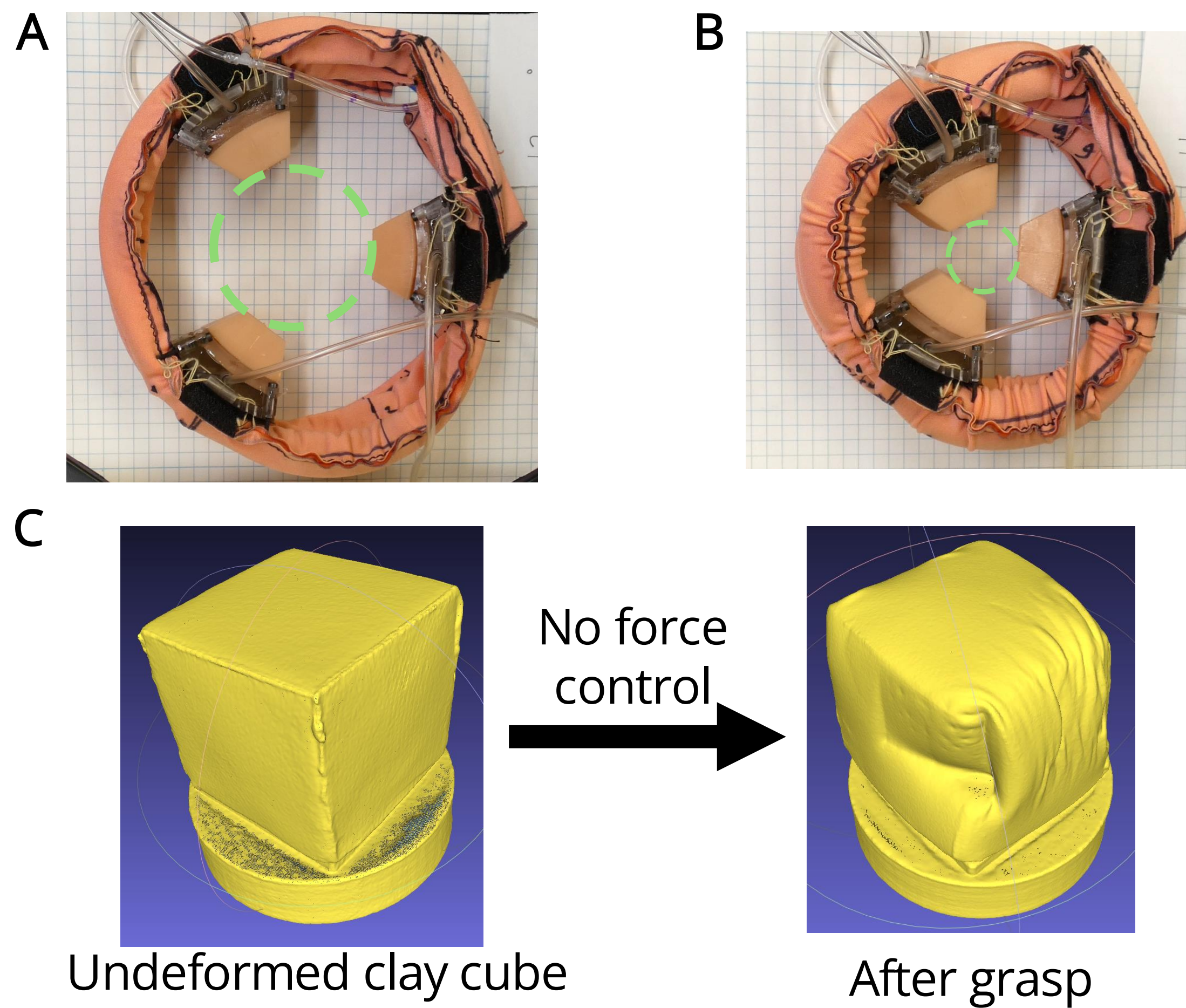


Fig. 1: Bio-inspired soft grasper with contact sensing via pneumatic jaws [1]. The grasper decreases the enclosed area when moving from the rest state (A) to the actuated state (B). Without force control, the grasper can impart significant deformations on very soft plastically deformable objects (C).

Goal: Track arbitrary contact pressure trajectories during grasping of rigid and deformable objects using optimal control techniques

Methods

- Soft graspers exhibit behaviors that are hard to analytically model e.g. non-linear material properties, hysteresis, deformable contact etc.
- We use a data-driven approach to get the dynamics of the grasper so we can apply optimal control techniques.

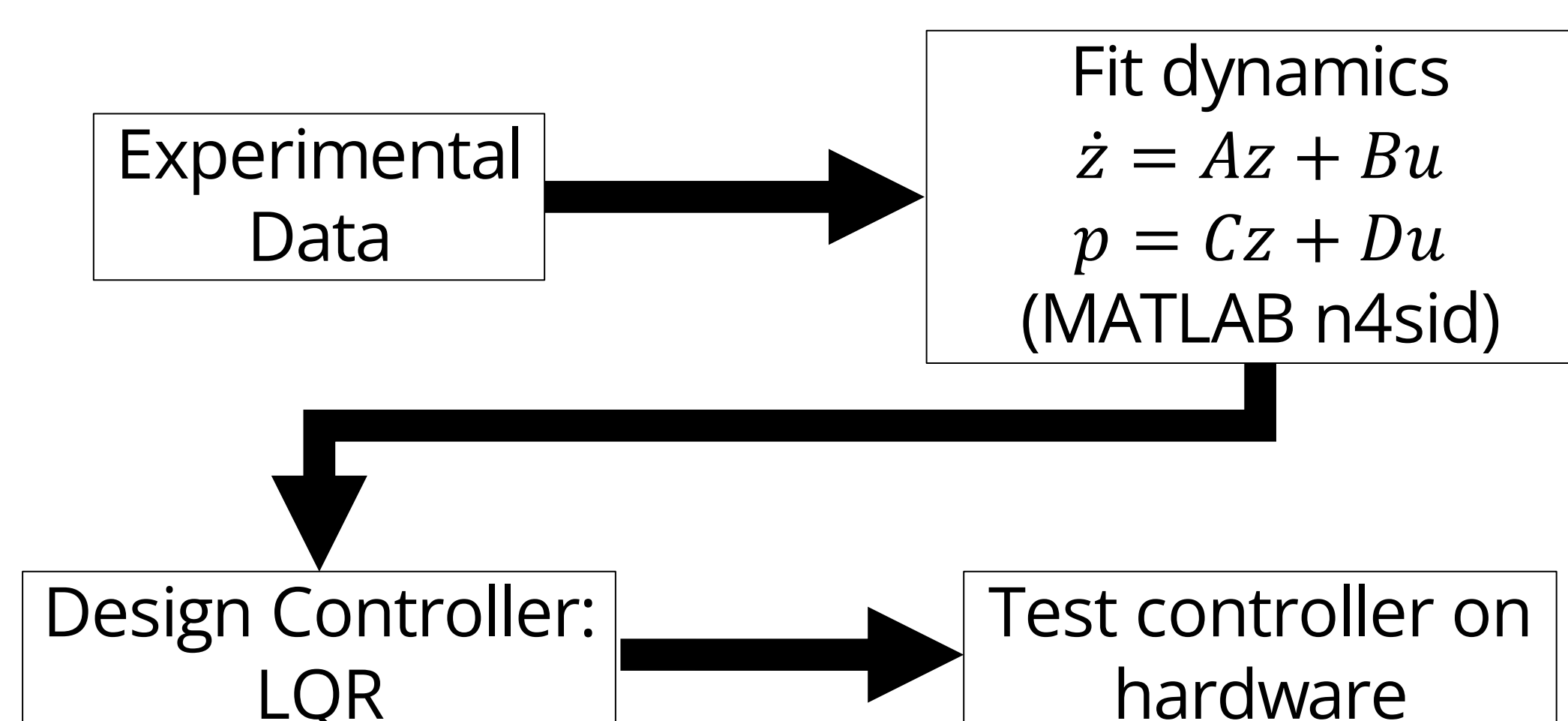


Fig. 2: Flow chart for controller development

Methods

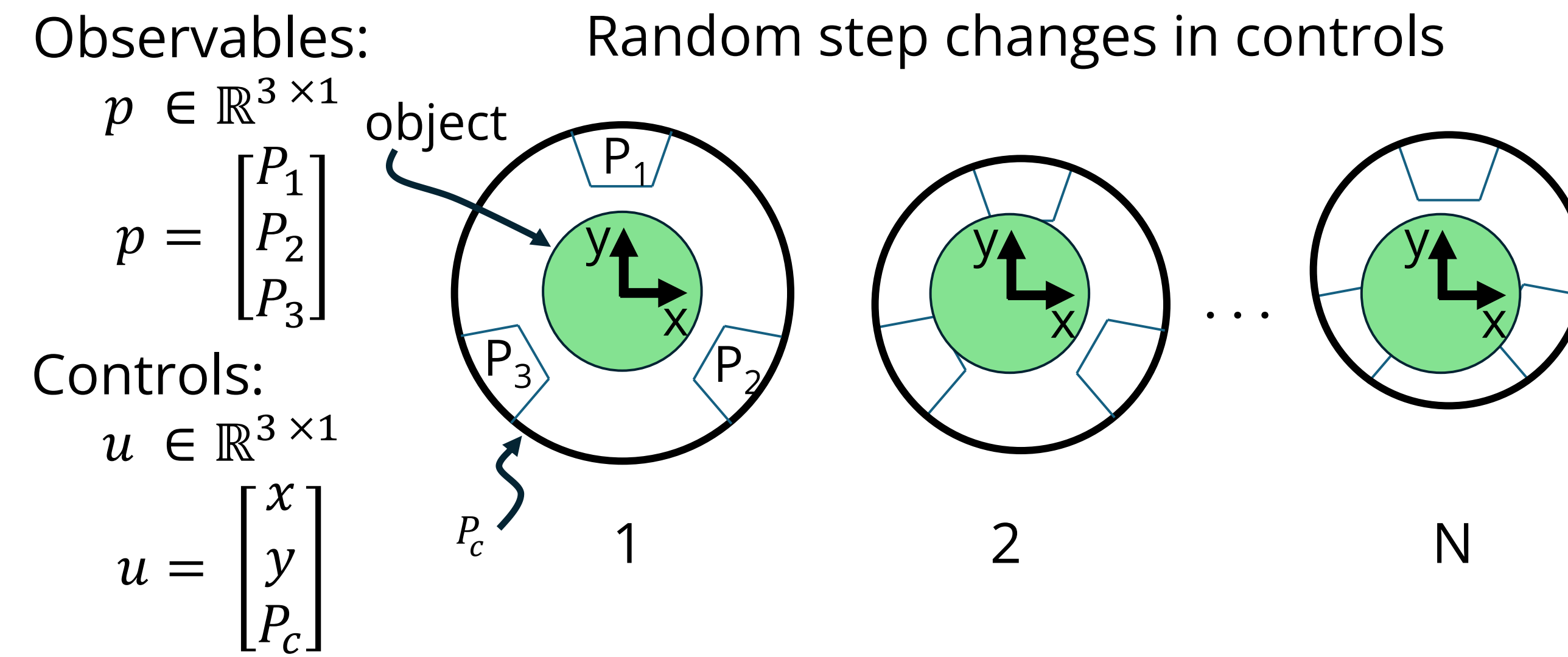


Fig. 3: Experimental setup to gather data for fitting using random step changes in controls on a fixed cylinder ($N = 58$). Data was gathered at a sampling rate of 16 Hz.

Results

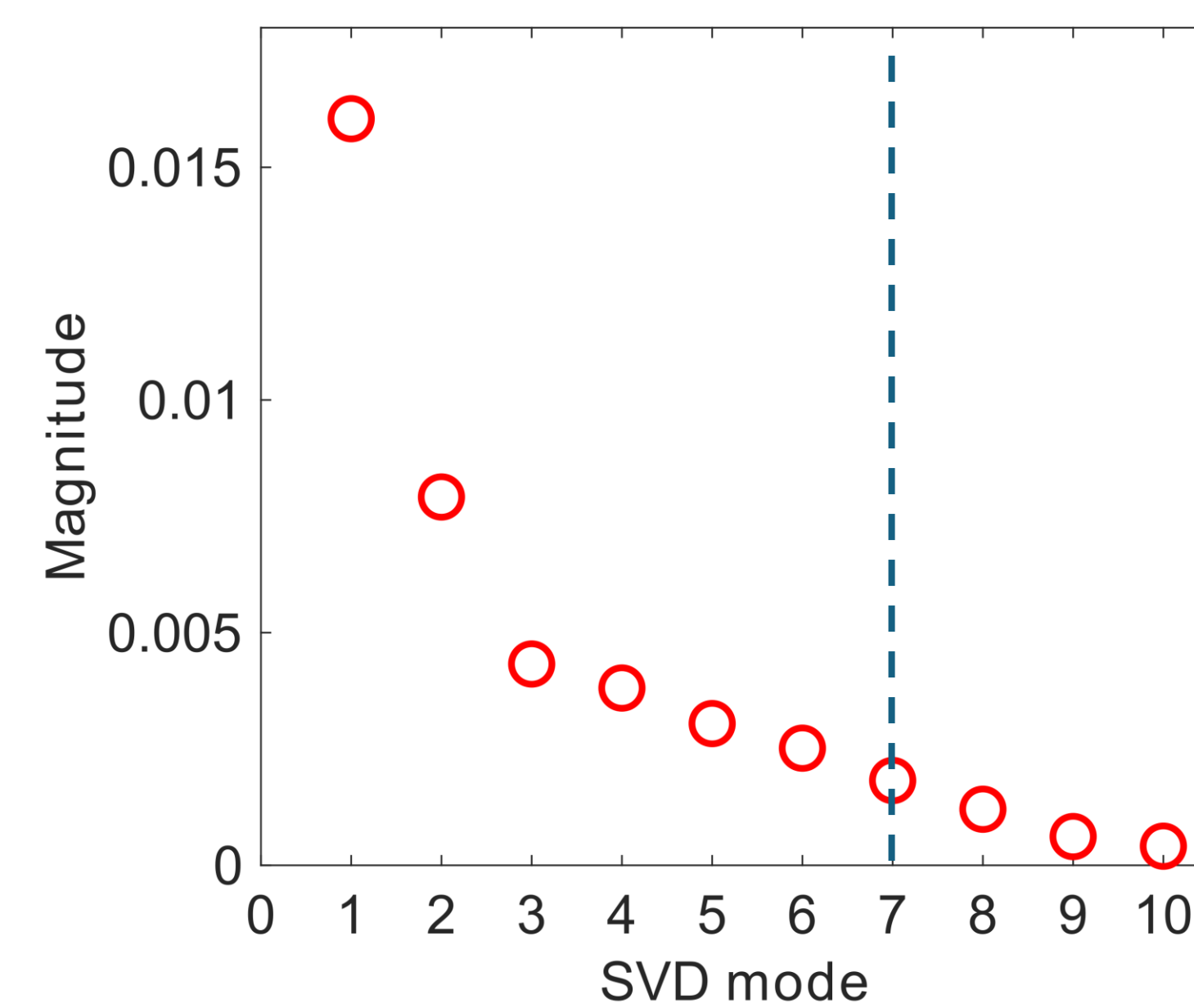


Fig. 4: Magnitude of the SVD modes of the Hankel matrix. 7 modes were chosen to represent the lifted state, z .

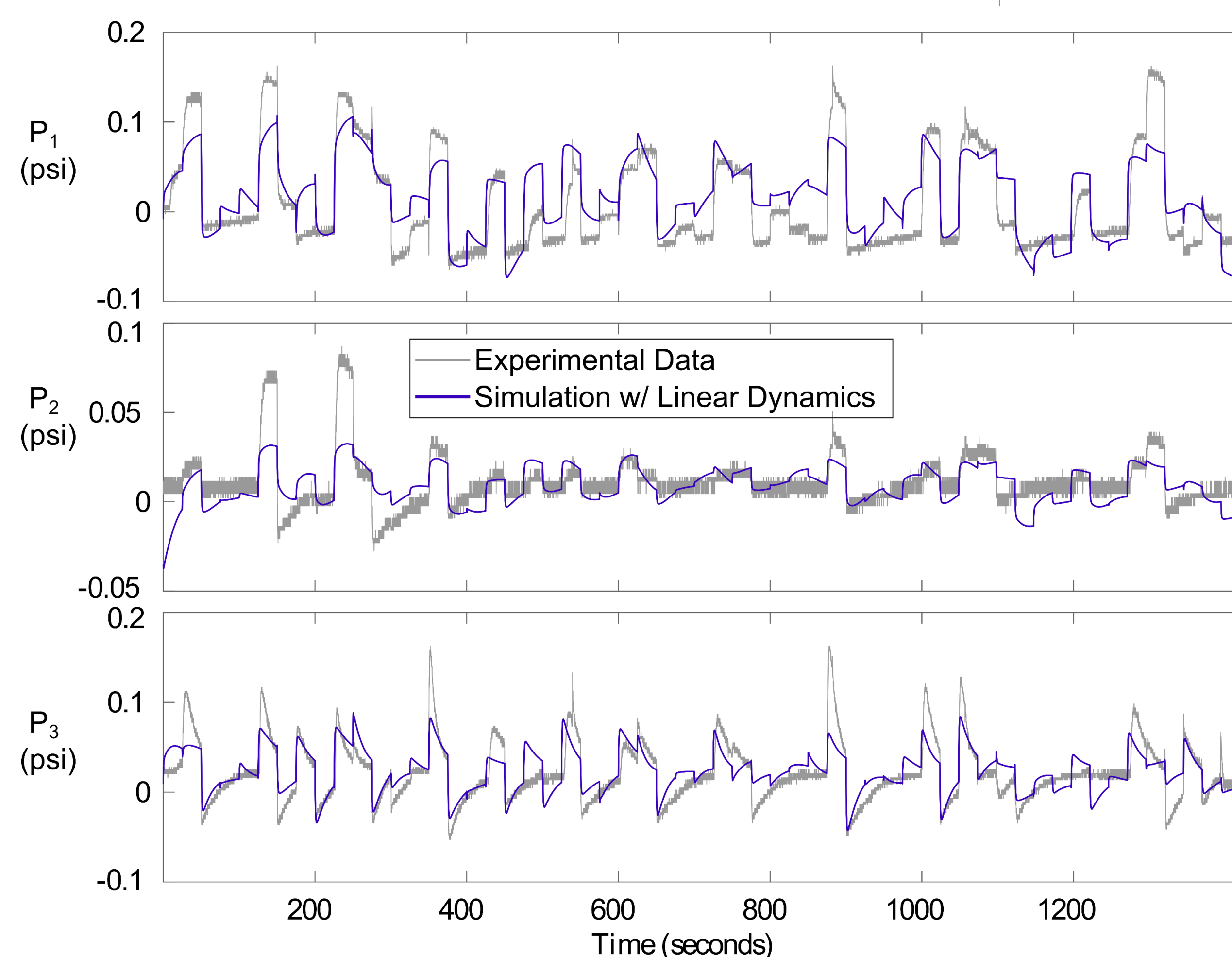


Fig. 5: Contact jaw pressures from random perturbations of the grasper position (x, y) and control pressure (P_c). The simulated response from the linear dynamics is shown in blue.

Results

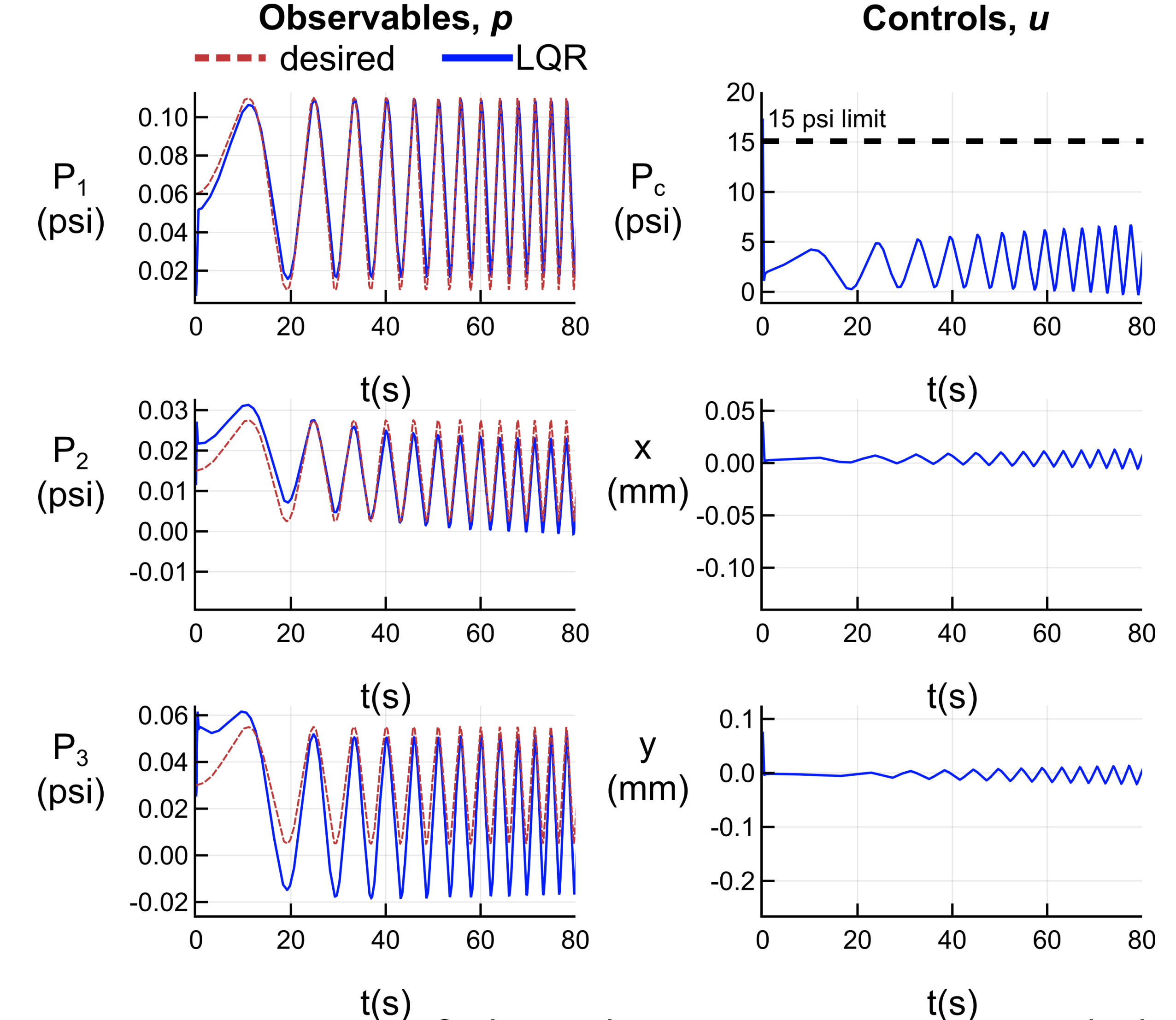
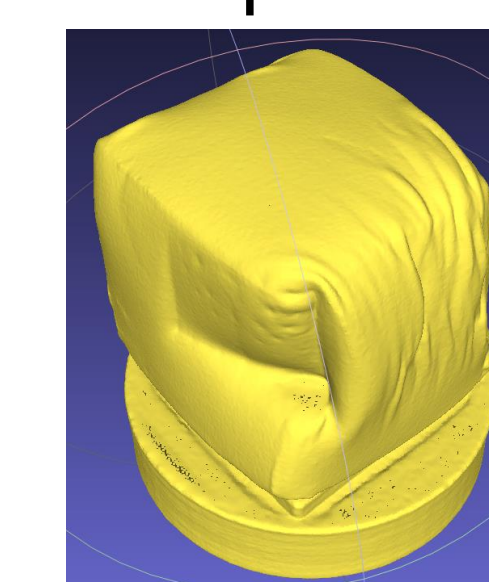


Fig. 6: Comparison of desired contact pressures and the simulated response with LQR. The stage cost corresponding to jaw 1's pressure was given more weight to facilitate closer tracking of that trajectory.

Future Work

- Further refine the dynamics regression model:
 - Parse the data and regression such that the dynamics model is fit solely to when the grasper experiences contact
 - Perform cross validation on tracking error vs quantity of time delays embedded
 - Cylinders of different sizes
 - Materials of different rigidity (PLA and soft clay)
- Try the LQR controller on hardware and compare the result to the simulation
- Quantify deformation induced on deformable material with LQR controller and compare to existing neural-network open-loop controller [1]

NN open-loop



LQR

Work in progress

References

- [1] R. Sukhnandan et al., LNCS, 2023