Research Plan and Progress:

Tactile Sensing, State Estimation and Embodied Intelligence of a Soft Gripper

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Tactile Sensing, State Estimation and Embodied Intelligence of a Soft Gripper

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1. Introduction

1.1 State of the art

Grippers with rigid body

State known

Grippers with soft body

State unknown

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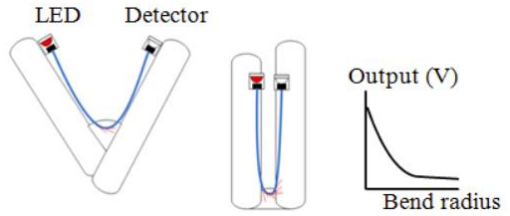
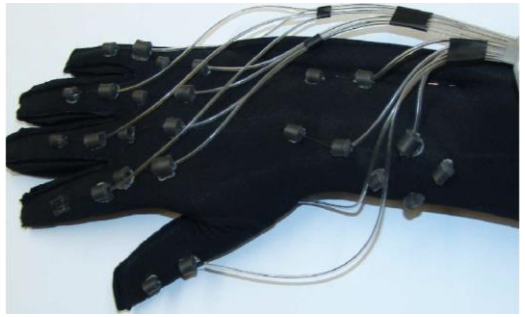
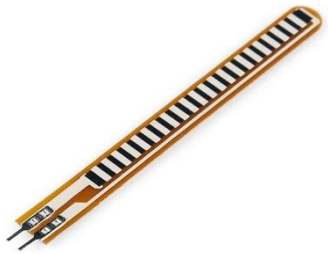
1. Introduction

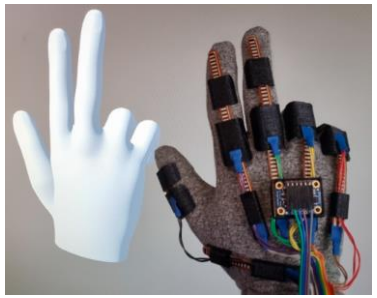
1.1 State of the art





Optical bending sensor





Resistor bending sensor

Limitation: end-to-end bending measuring -> joint angle between rigid-body structures

Different bending state with the same measuring result

Question: How to measure/estimate the state of a soft finger?

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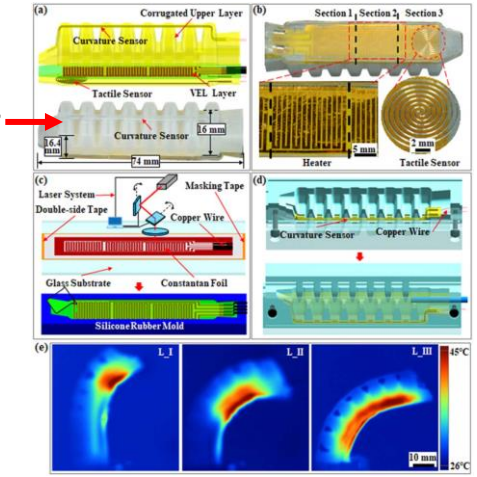
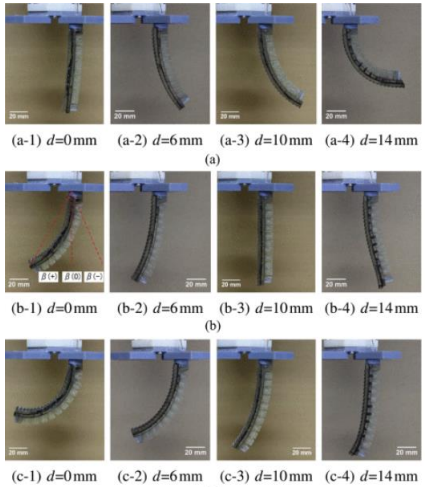
1.1 State of the art

Soft finger



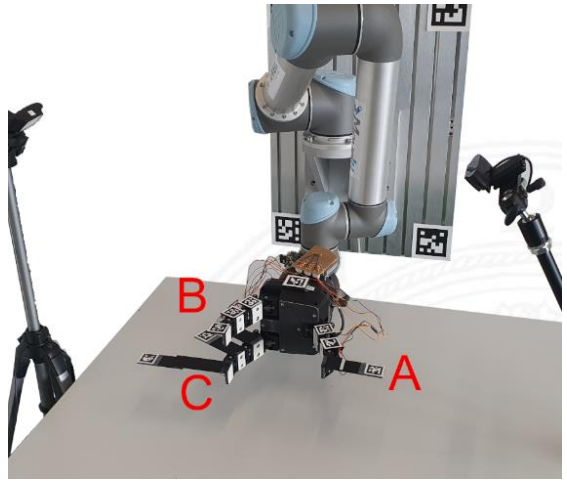
Resistor bending sensor with multiple sensing units

Resolution is limited



Vision-based measuring

Challenging during grasping



Tactile sensing and NN learning

Dataset collection and for a soft gripper

[1] Hao, Y., Liu, Z., Liu, J., Fang, X., Fang, B., Nie, S., Guan, Y., Sun, F., Wang, T. and Wen, L., 2020. A soft gripper with programmable effective length, tactile and curvature sensory feedback. Smart Materials and Structures, 29(3), p.035006.

[2] Wang, Z., Torigoe, Y. and Hirai, S., 2017. A prestressed soft gripper: design, modeling, fabrication, and tests for food handling. IEEE Robotics and Automation Letters, 2(4), pp.1909-1916.

[3] Jonetzko, Y., et al., State Estimation of an Adaptive 3-Finger Gripper using Recurrent Neural Networks, IEEE IROS 2024.

1. Introduction

1.2 Motivation

Given a pneumatic soft gripper, how to measure/estimate the state and tactile forces?

- Mount optical/resistor bending senor for every joint is unrealistic (without joint).
- Visioned-based measuring is not convenient.
- Multiple sensors for different functions are crowded.

Tactile Sensing, State Estimation and Embodied Intelligence of a Soft Gripper

1. Introduction

   1.1 State of the art
   1.2 Motivation

2. Method

   2.1 System overview
   2.2 Hardware development
   2.3 FEM simulation
   2.4 Dataset collection and deep learning
   2.5 Grasping and manipulation with small language model

2. Method

2.1 System Overview

Envisioned soft gripper

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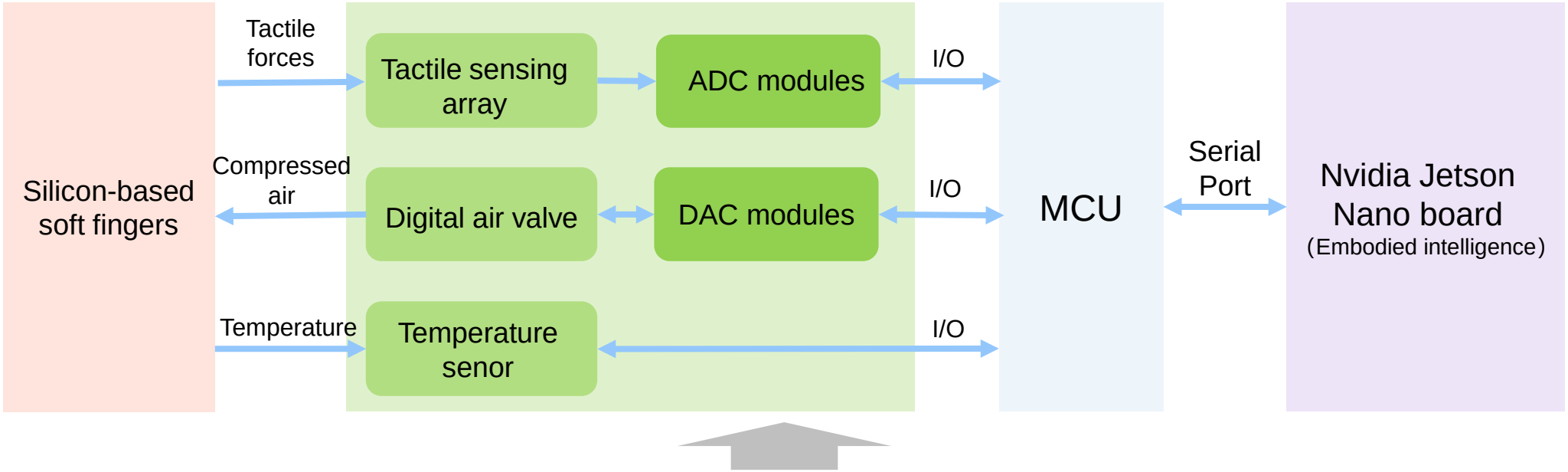
2. Method

2.1 System Overview



- 24.0 V: Digital air valve.
- 12.0 V: Nvidia Jetson Nano.
- 5.0 V: ADC, DAC.
- 3.3 V: MCU, temperature sensor, tactile sensing array.

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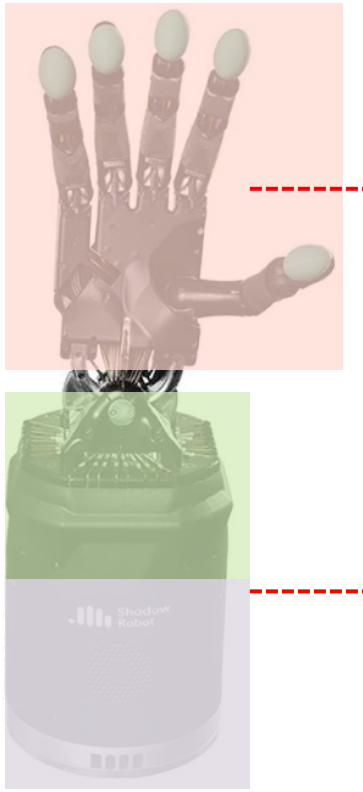
2. Method

2.2 Hardware development

- 4x4 tactile sensing arrays (1st version)



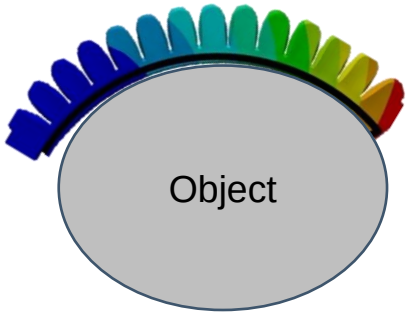
- A gripper with two soft fingers
- Tactile sensing array
- Temperature sensor.

- Part of power supply
- Jetson Orin Nano
- Digital air valve
- MCU
- ADC
- DAC

- Tactile sensing and state estimation based on the data from the tactile sensing arrays

2. Method

2.3 FEM simulation



Key parameters concerning the **linear elasticity**:

- Temperature: T
- Cauchy stress tensor: $\boldsymbol{\sigma}$ (3x3 matrix)
- Air pressure: P
- Tactile forces: f

Suggestions from:

- Southeast University Prof. Aiguo Song
- Shanghai Jiaotong University Prof. Daolin Ma

Tactile Sensing, State Estimation and Embodied Intelligence of a Soft Gripper

2. Method

2.4 Dataset collection and deep learning (Embodied Intelligence)

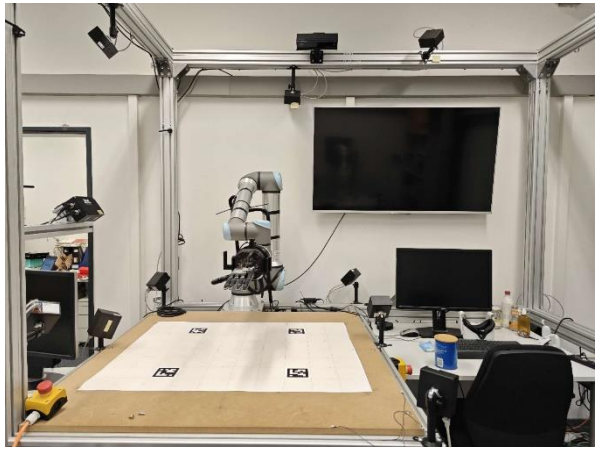
Input:
- Tactile forces
- Air pressure
- Payload …

Normalization

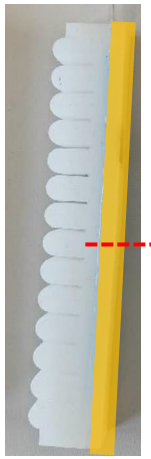
Jetson Nano:
Neural networks
(GCN, Transformer)

Projection

Output:
- Real-time gripper state



PhaseSpace Impulse X2 Motion-capture system



- LED markers

Real-world dataset:

- Grasps
- Object shapes
- Tactile forces with time stamps
- Air pressure with time stamps
- Finger status with time stamps
- Temperature

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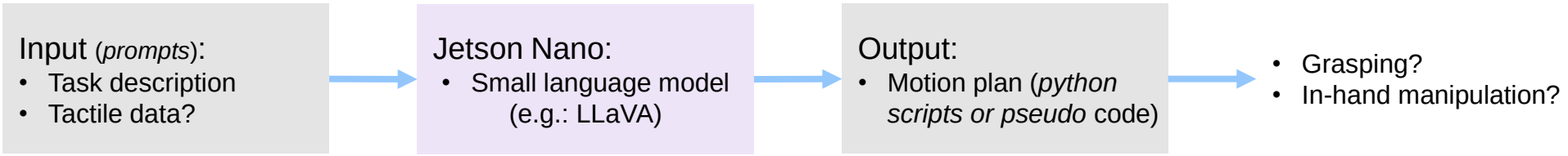
2. Method

2.5 Grasping and manipulation with small language model (Embodied Intelligence)



Thanks for your attention

Any questions?