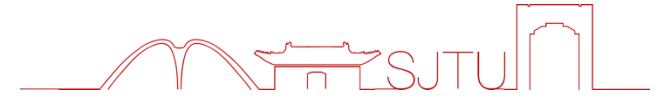




上海交通大学  
SHANGHAI JIAO TONG UNIVERSITY



# Simulating the World from the World

*Ruigang Yang*  
Global Institute for Future Technology

饮水思源 · 爱国荣校



# What is a World Model?



A **world model** in AI is an internal representation or simulation of an environment that an AI agent uses to understand, predict, and plan interactions within that environment.

 **OpenAI**





# OpenAI-way for AD World Model



**Interactive World Model**

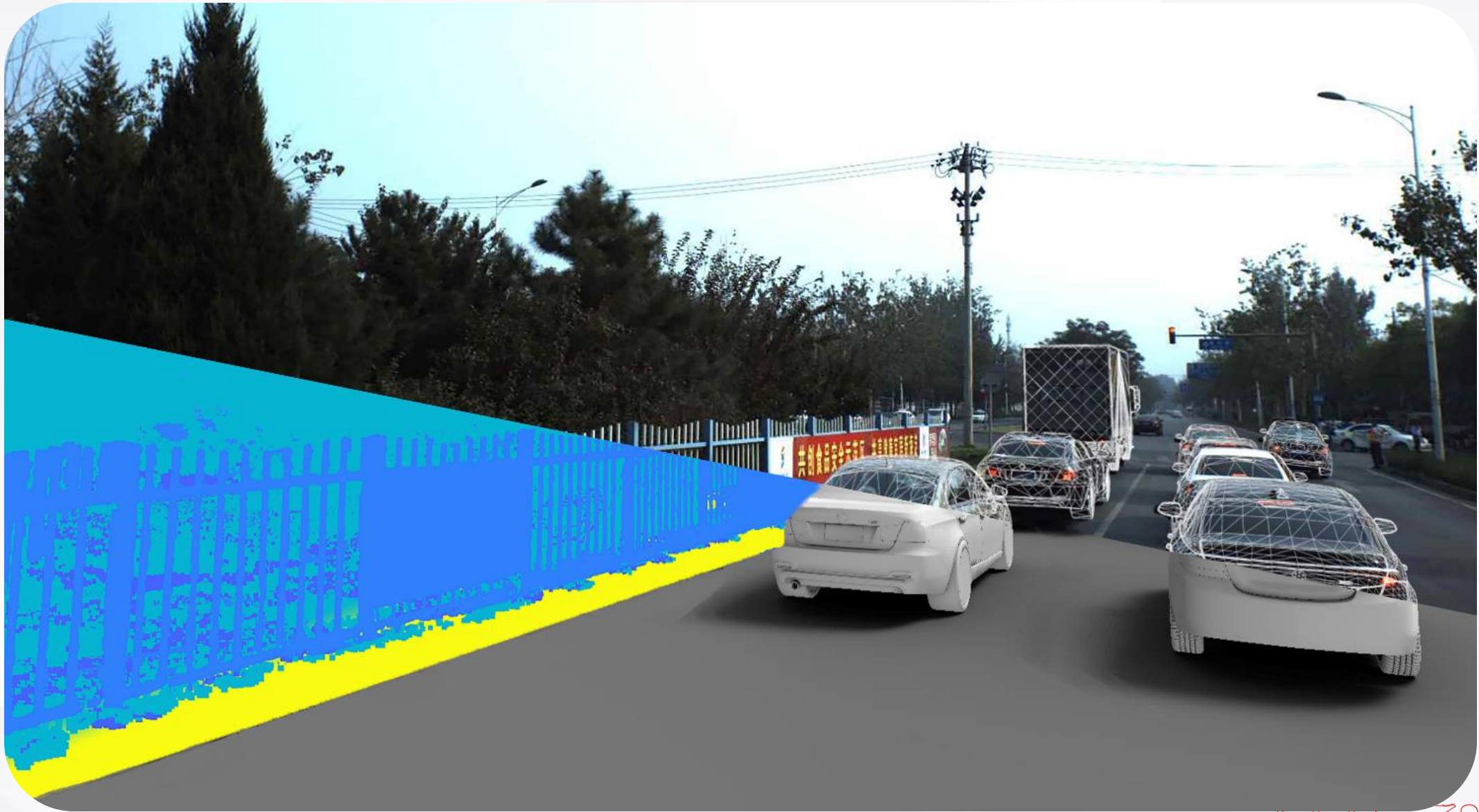


# The CG Way for World Model





# AADS : Augmented autonomous driving simulation





# AADS Pipeline



Input Dataset  
(ApolloScape)

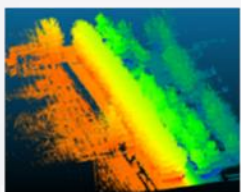
AADS

AADS  
Augmented Data

RGB Images



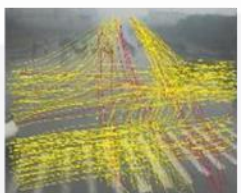
Point Cloud / Depth



Semantic Labels



Trajectories



Data Preprocessing

Background Synthesis

Trajectory Synthesis  
& Data Augmentation

LiDAR Synthesis



Moving Objects  
Removal



Inpainting



Illumination  
Estimation



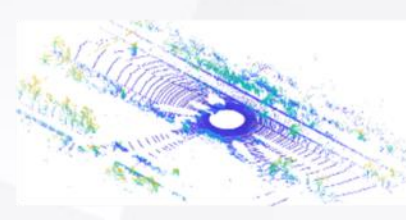
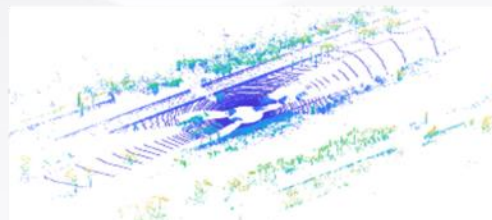
Models' Texture  
Enhancing



Left Lane



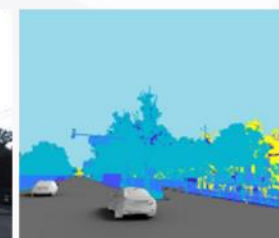
Center Lane



Images



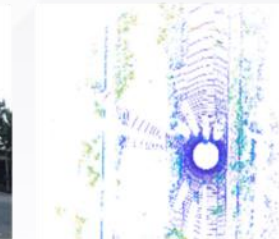
Annotations



Images



LiDAR



Images



Trajectories







# The CG Way for World Model

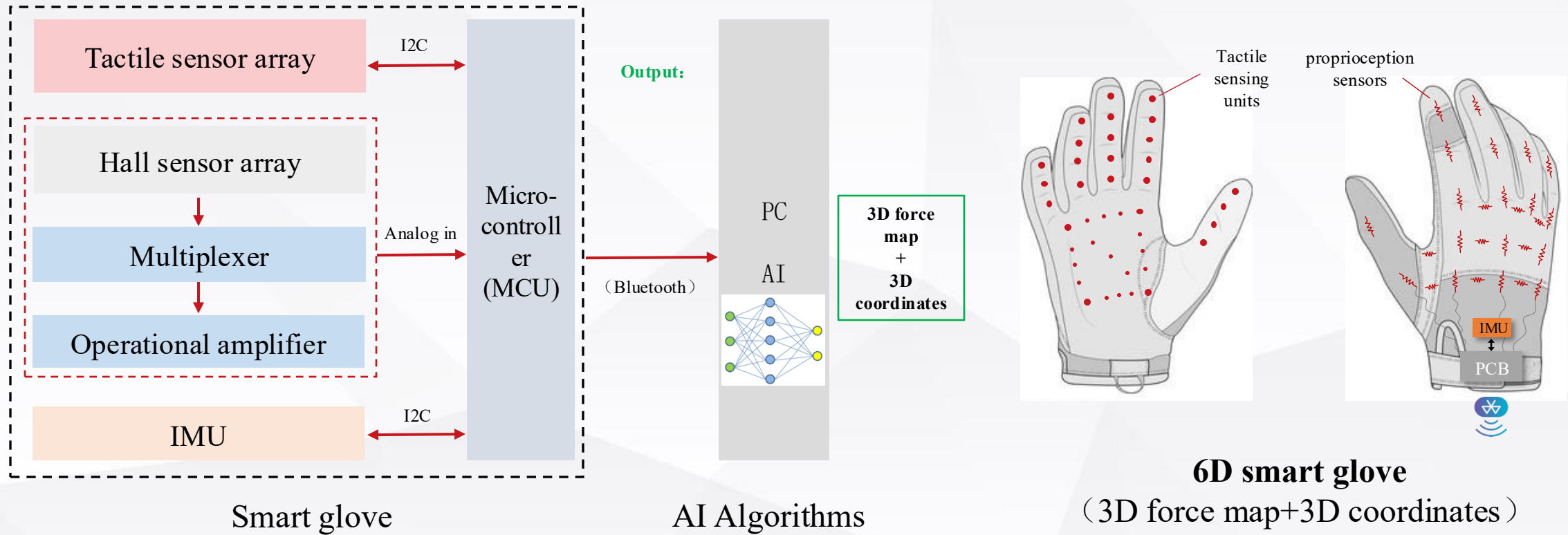


# Tactile Sensing

In Collaboration with Youcan Yan

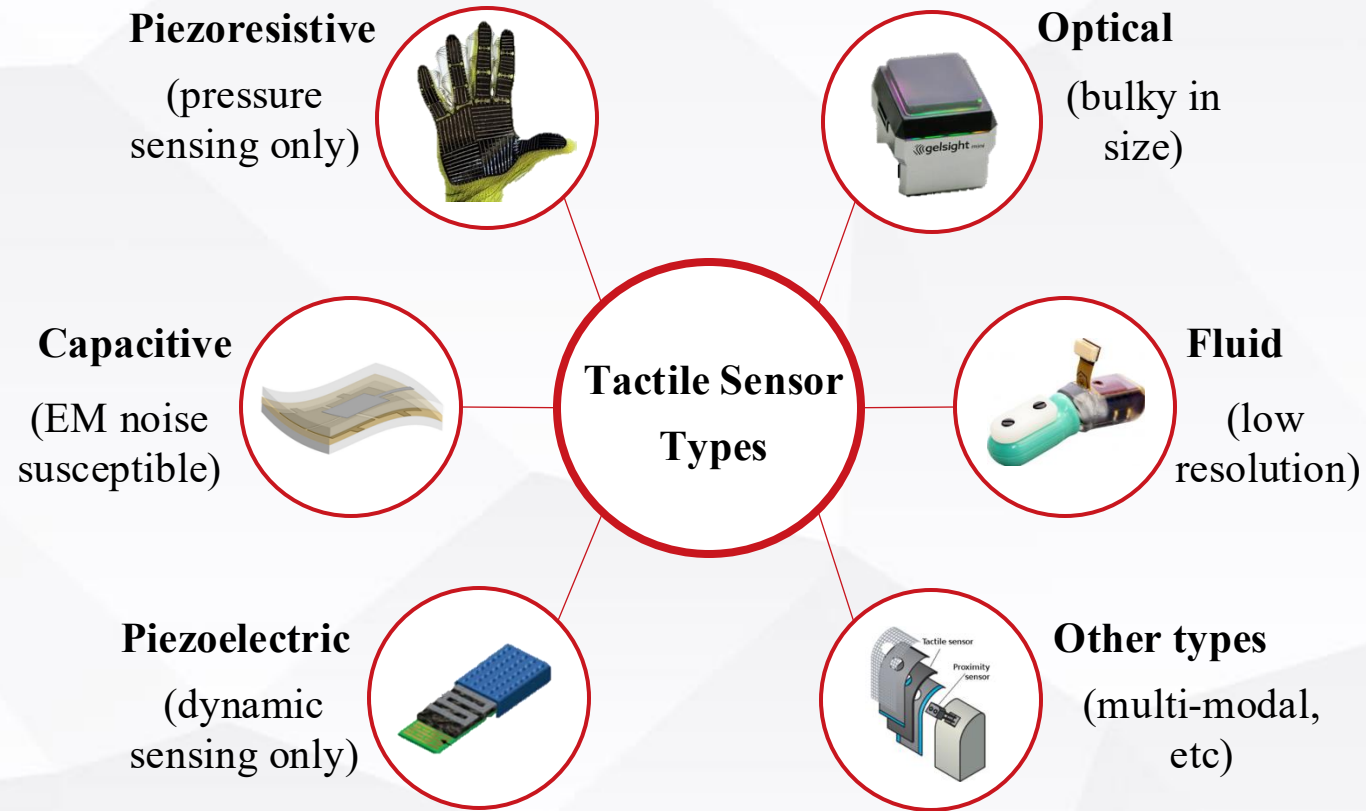


## ➤ Innovation: 3D force map + 3D coordinates outputs





## ➤ State-of-the-art tactile sensing technologies

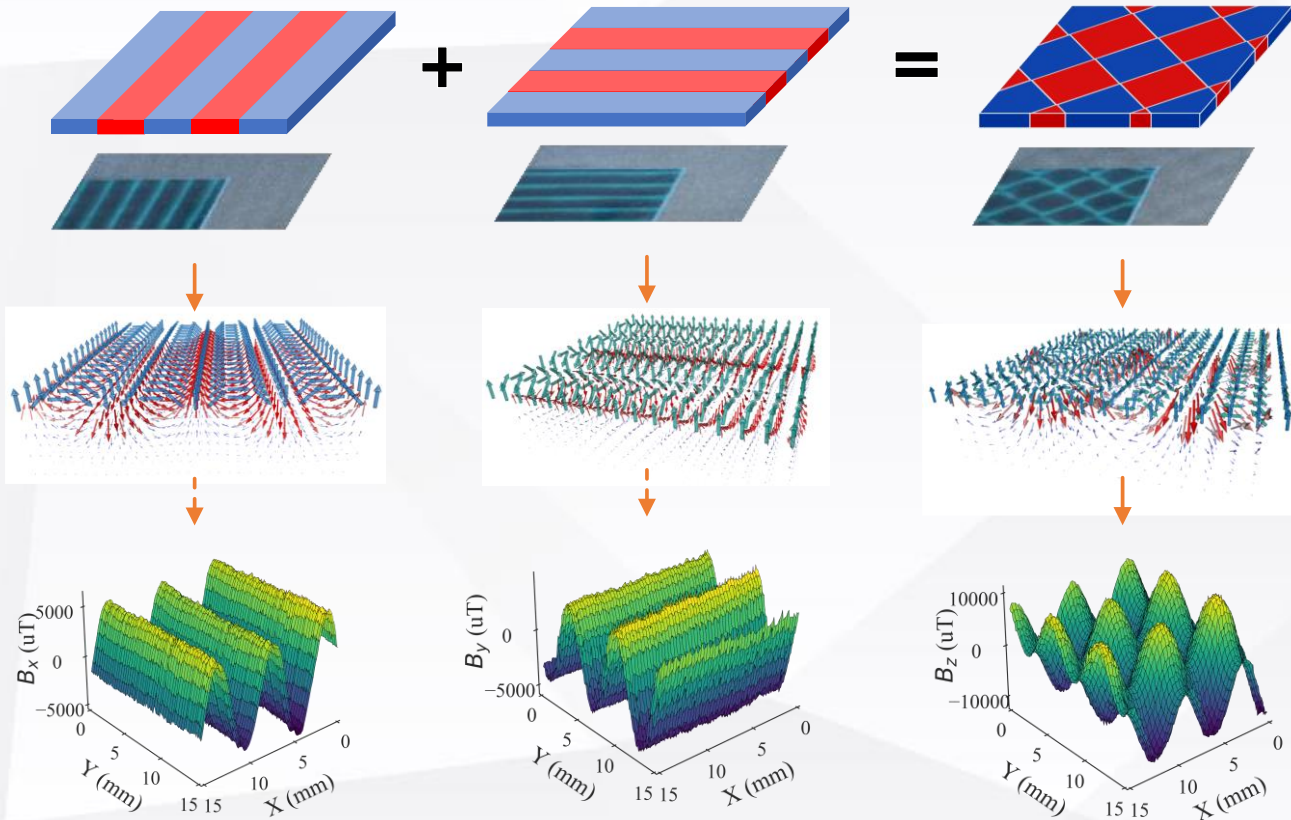


### Common problem

struggle to measure shear force or suffer from low spatial resolution



## ➤ Superposition of two Halbach array



## ➤ 3D force self-decoupling principle

- $B$  and  $R_B$  are naturally decoupled

$$\begin{bmatrix} B \\ R_{xz} \\ R_{yz} \end{bmatrix} = \begin{bmatrix} a_0 e^{kz} + b_0 \\ a_1 \tan(kx) + b_1 \\ a_2 \tan(ky) + b_2 \end{bmatrix}$$

- Thus  $F_z$ ,  $F_x$ , and  $F_y$  are also naturally decoupled

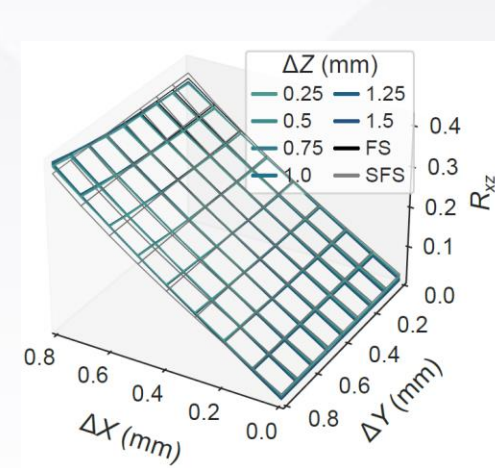
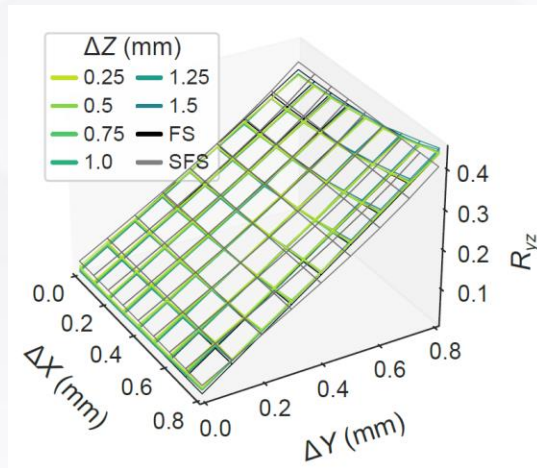
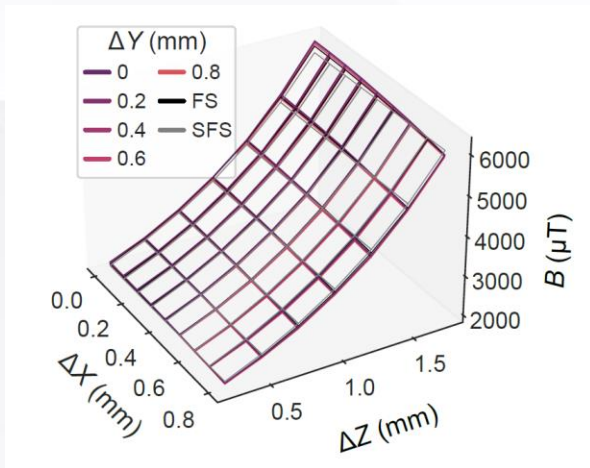
$$\begin{bmatrix} F_z \\ F_x \\ F_y \end{bmatrix} = \begin{bmatrix} \frac{a_z \cdot S \cdot E}{k \cdot h} \ln \frac{B(z_i) - b_0}{B(z_0) - b_0} + b_z \\ \frac{a_x \cdot S \cdot G}{k \cdot h} \left( \arctan \frac{R_{xz}(x_i) - b_1}{a_1} - \arctan \frac{R_{xz}(x_0) - b_1}{a_1} \right) + b_x \\ \frac{a_y \cdot S \cdot G}{k \cdot h} \left( \arctan \frac{R_{yz}(y_i) - b_2}{a_2} - \arctan \frac{R_{yz}(y_0) - b_2}{a_2} \right) + b_y \end{bmatrix}$$



# Multi-axis tactile sensing (3D)

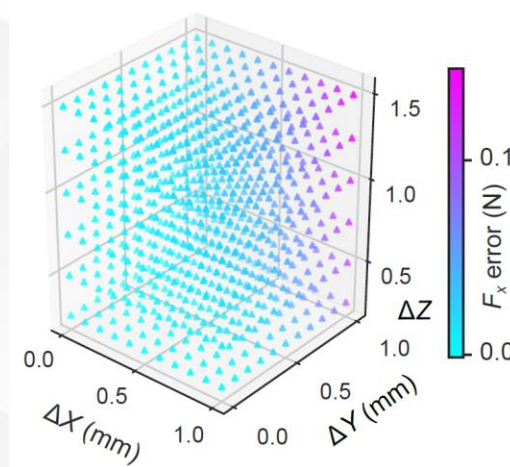
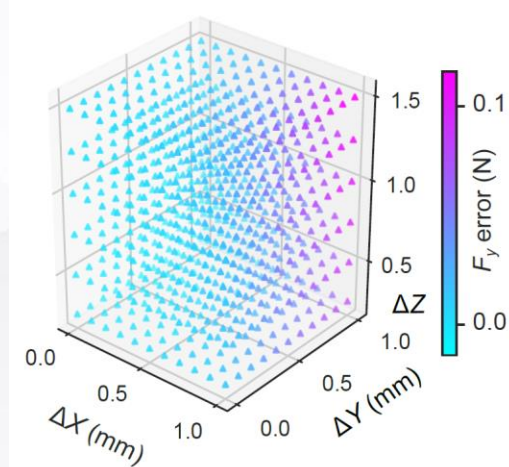
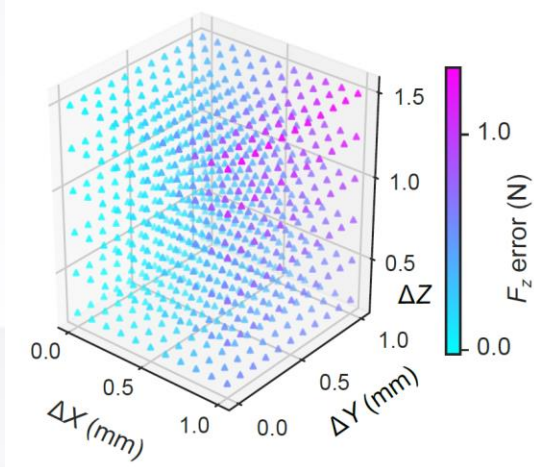


## ➤ Performance evaluation



- **Normalized absolute error**  
(between surface fitting and GT)

- ❖  $B$ : 2.88%
- ❖  $R_{yz}$ : 4.56% (with Eq. 1)
- ❖  $R_{xz}$ : 3%



- **Root mean square error**  
(between force estimation and GT)

- ❖  $F_z$ : 0.49N
- ❖  $F_y$ : 0.03N (with Eq. 2)
- ❖  $F_x$ : 0.04N

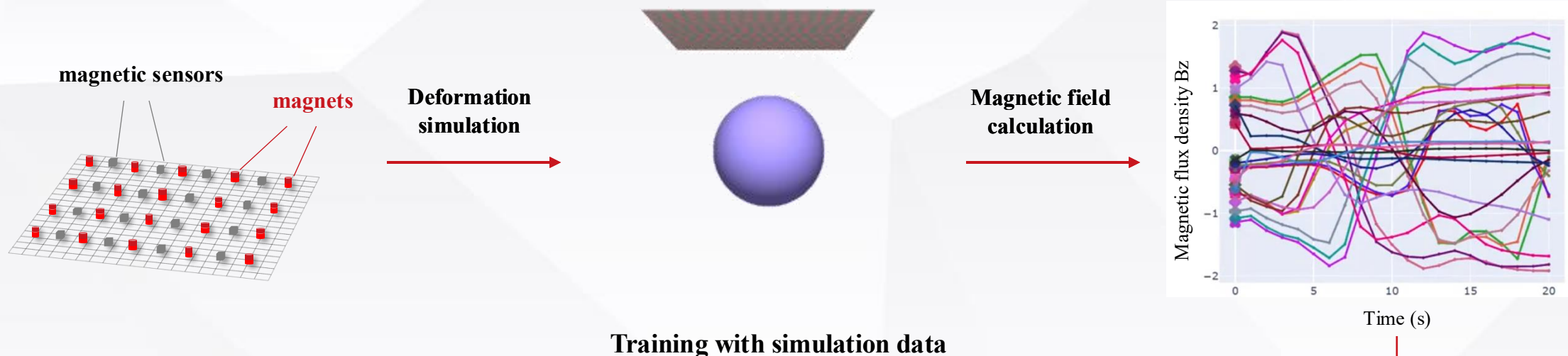




# 3D proprioception

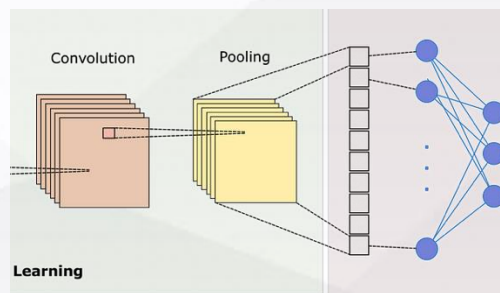


➤ Goal: Free-form shape reconstruction using wearable sensors

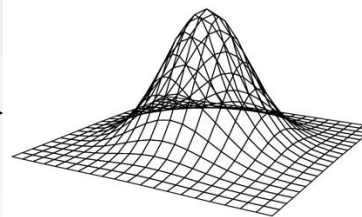


$$\begin{bmatrix} B_{x1} & B_{y1} & B_{z1} \\ B_{x2} & B_{y2} & B_{z2} \\ \vdots & \vdots & \vdots \\ B_{xN} & B_{yN} & B_{zN} \end{bmatrix}$$

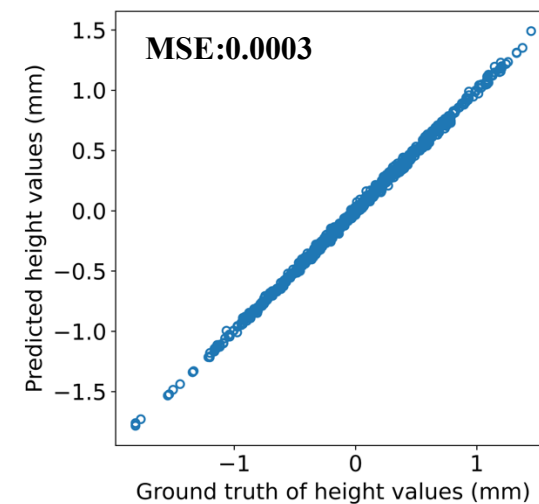
**Input**  
(magnetic sensor measurements)



**CNN**  
(neural networks)



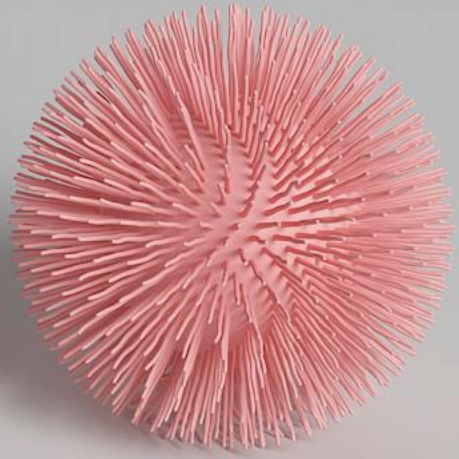
**Output**  
(3D deformation)



# Physically Accurate Soft Body Simulation

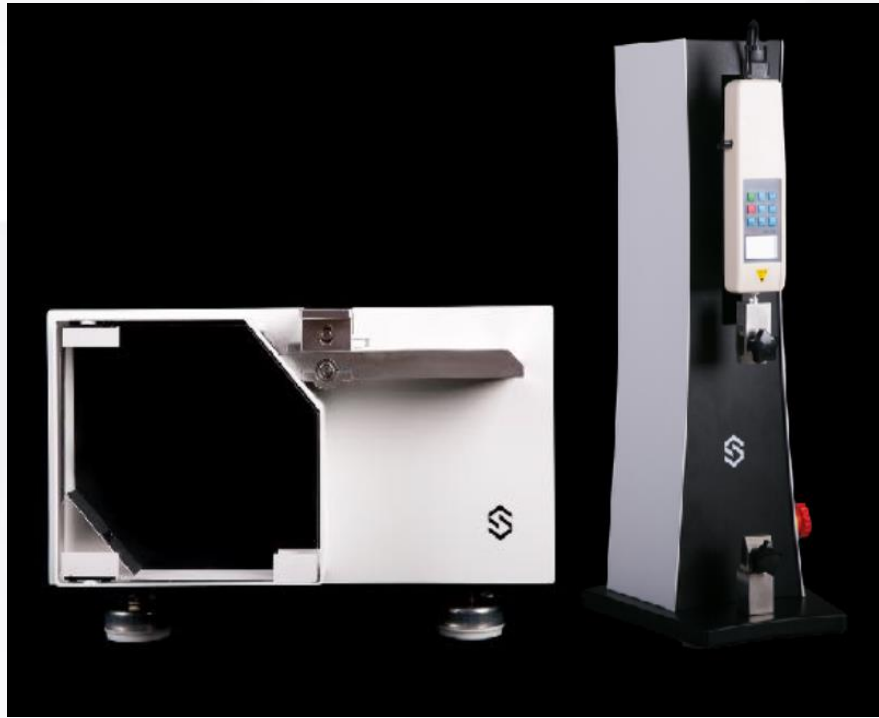
In collaboration with Huamin Wang







# Physical Measurement

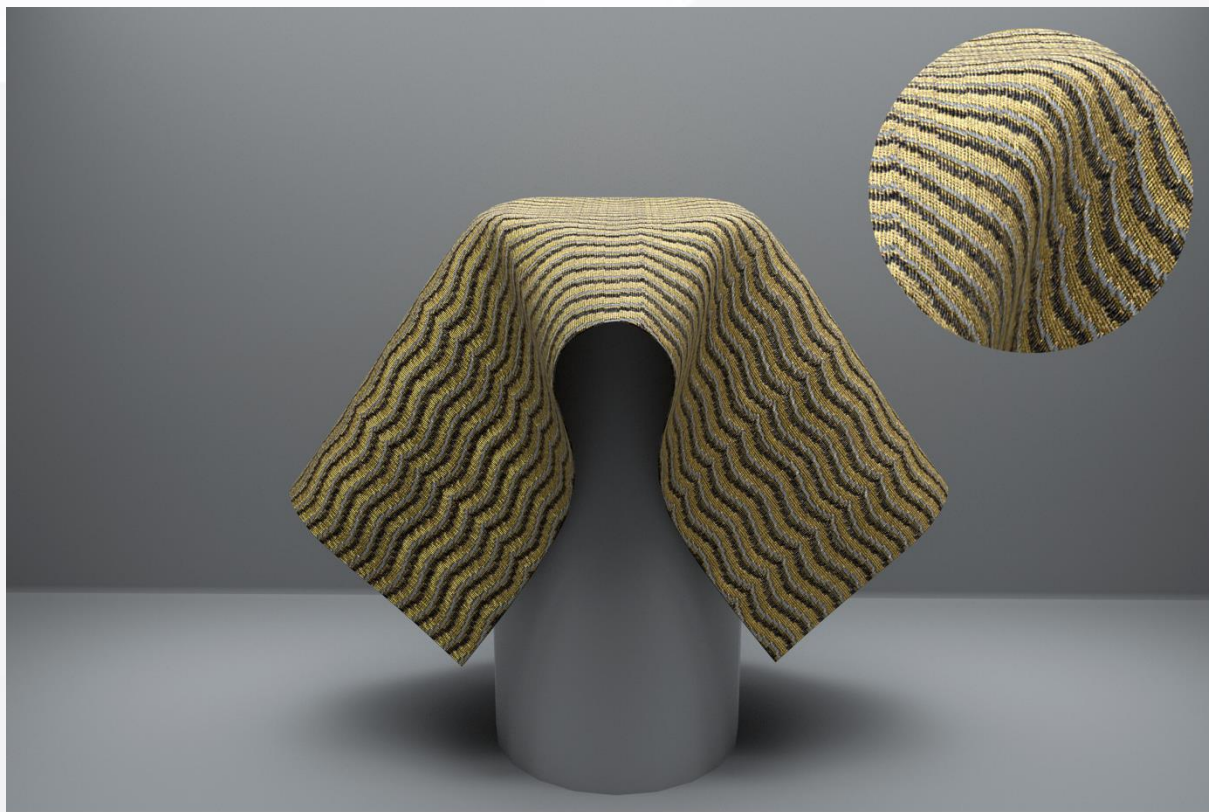


- stretch/bending stiffness,
- thickness,
- density, etc.





# Ultra-high Realistic Cloth Modeling



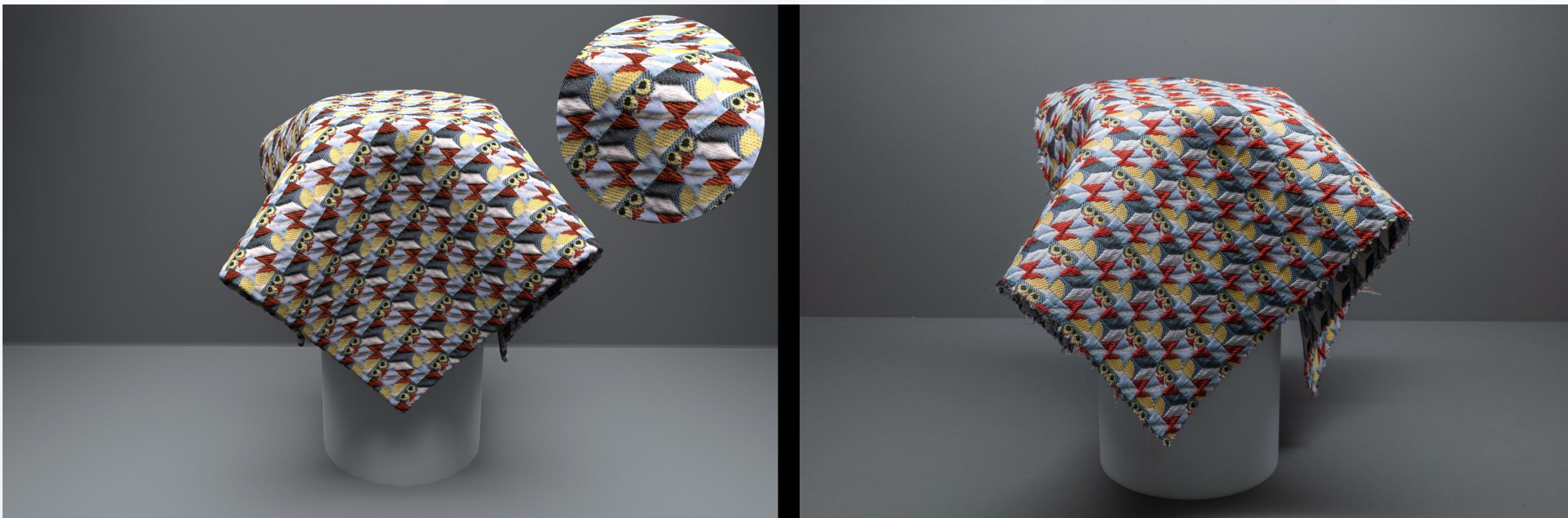
渲染图



照片



# Ultra-high Realistic Cloth Modeling



# Physical accuracy



Real world Garment



Sim result



Real world Garment



Simr esult



Real world Garment



Sim result



# Complex



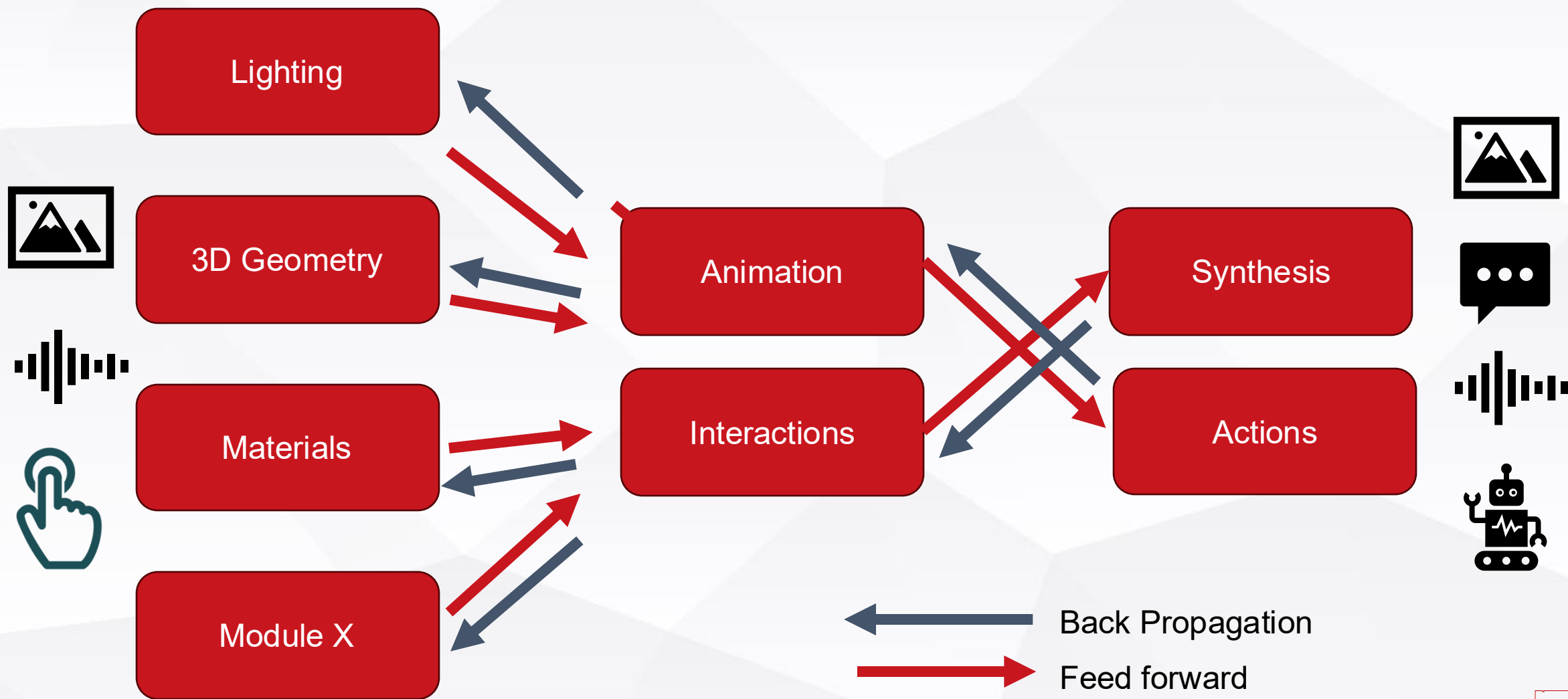


# The CG Way for World Model





# Looking Forward – **Modular** World Model



Thank  
you



Thank  
you



ryang2@sjtu.edu.cn

饮水思源 爱国荣校



# Backup

饮水思源 爱国荣校



# Multi-axis tactile sensing



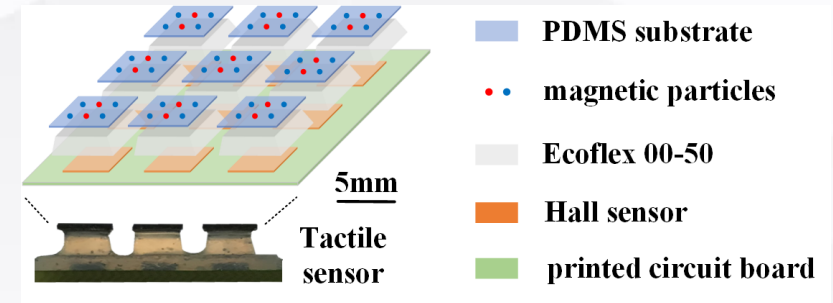
## ➤ State-of-the-art tactile sensing technologies



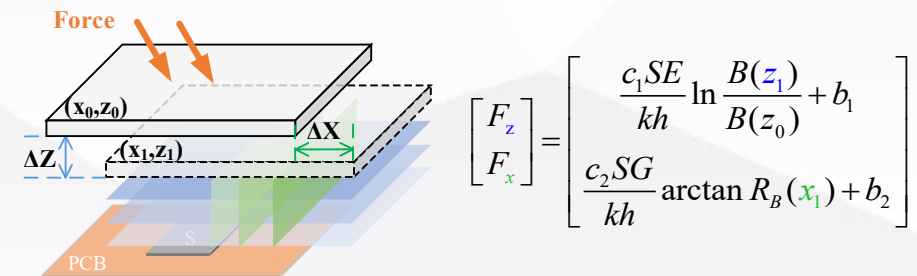
**Common problem**

struggle to measure shear force or suffer from low spatial resolution

## ➤ Our approach (built on our early research on magnets-based tactile sensing)



↓ 2D force decoupling



Capable of measuring both normal and shear forces

Youcan Yan, *et al. Science Robotics*, 2021

