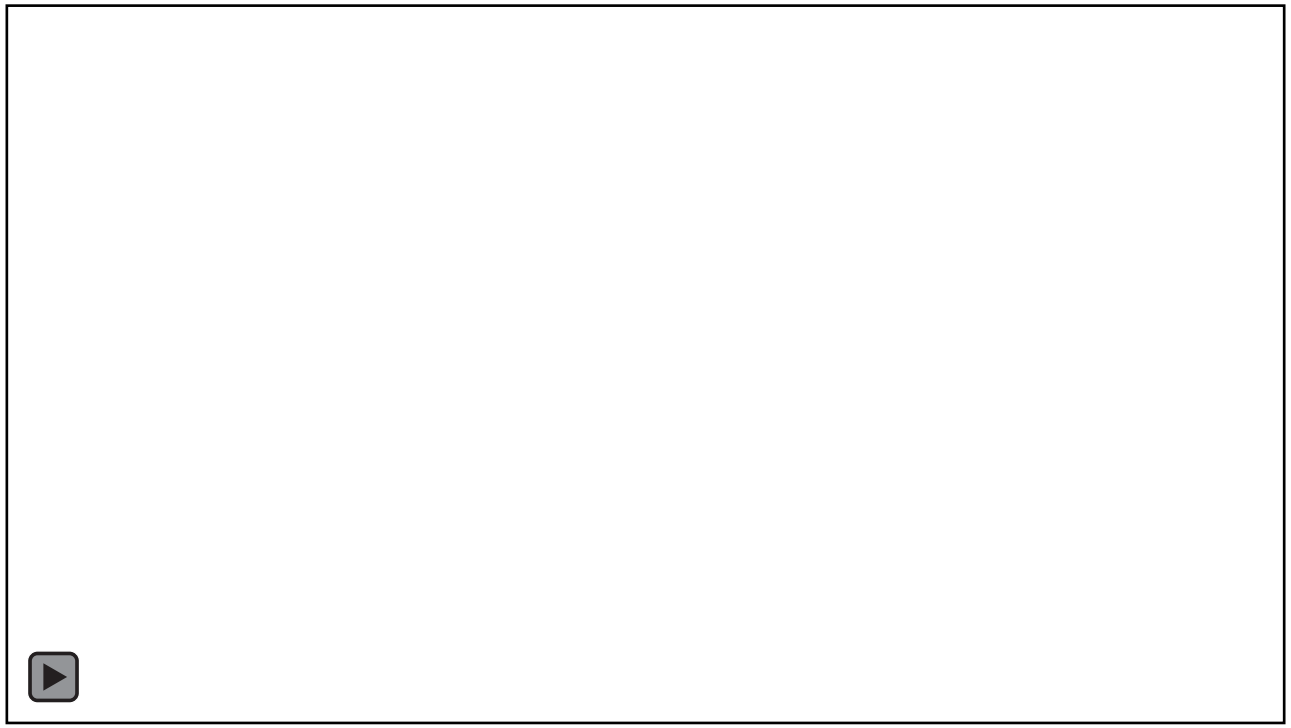
Online Iterative Learning Enhanced Sim-to-Real Transfer for Efficient Manipulation of Deformable Objects

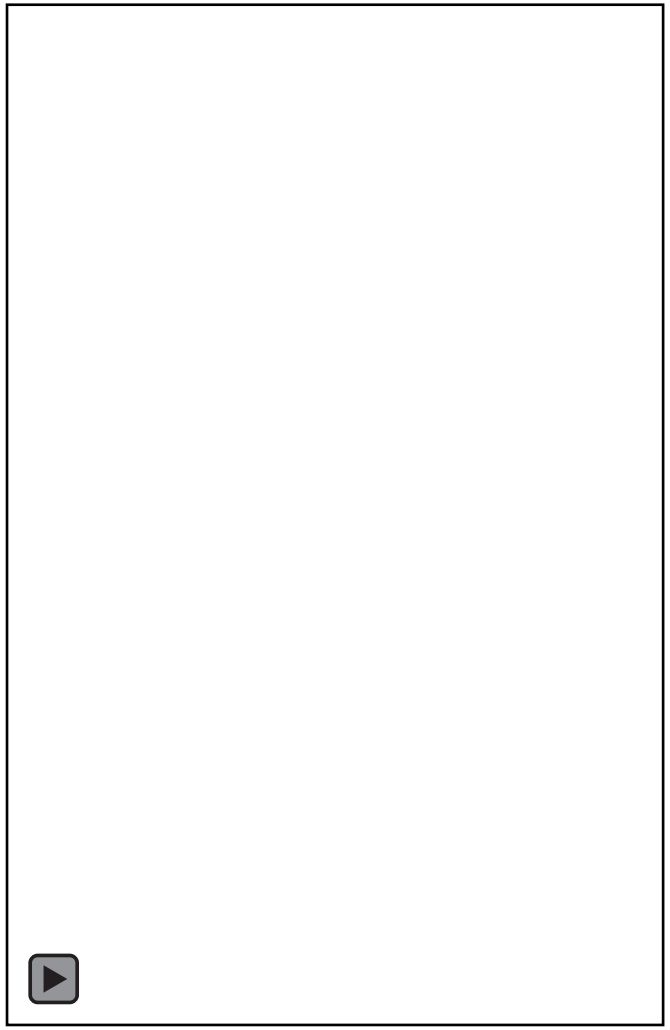
Steven Li[1,2]

[1]University of Oulu [2]VTT Finland

Manipulation of Deformable Objects

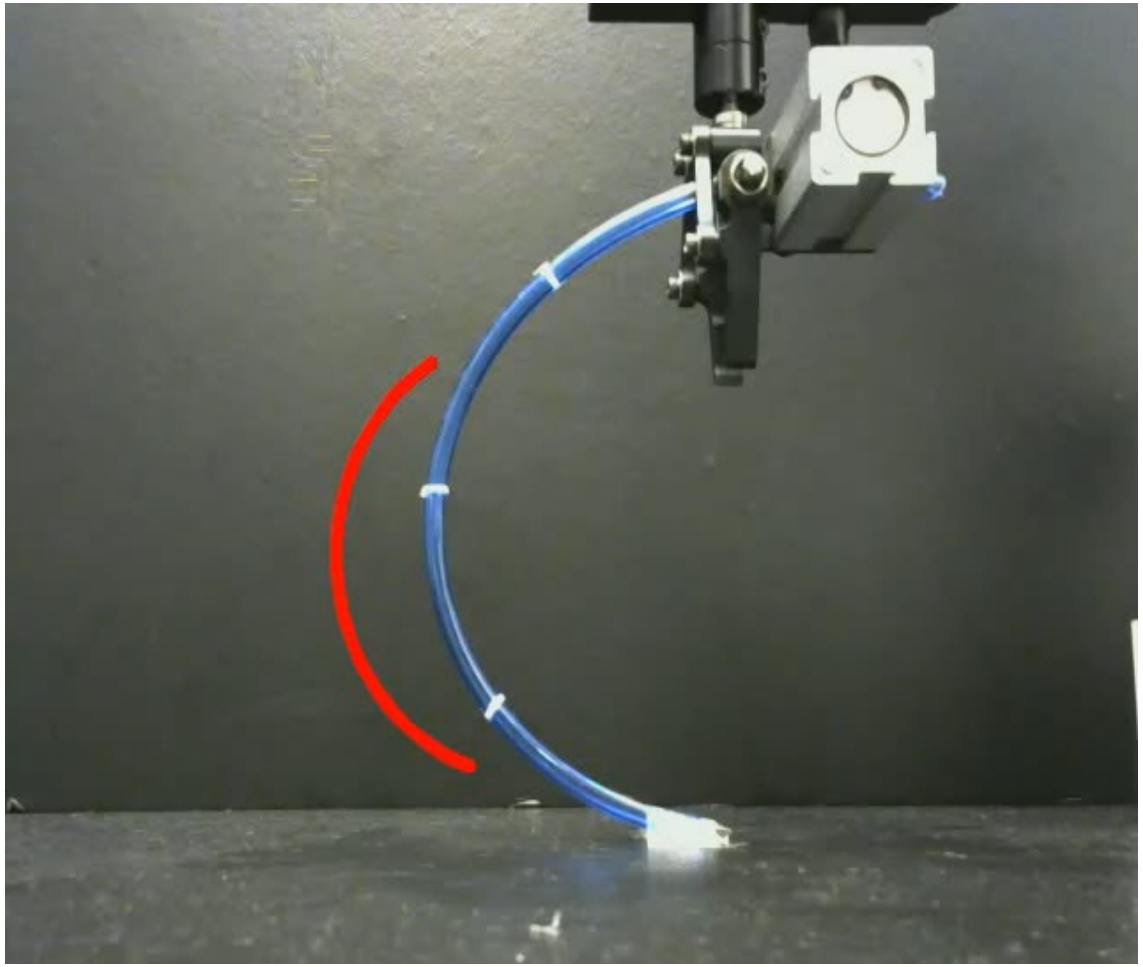
Agriculture Applications





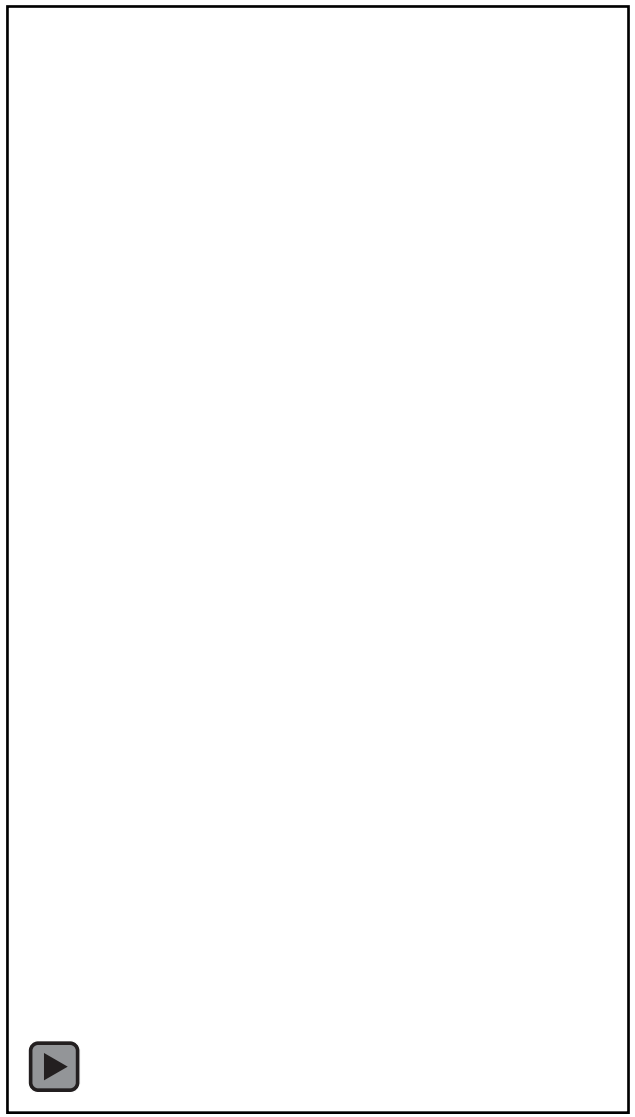
Manipulation of Deformable Objects

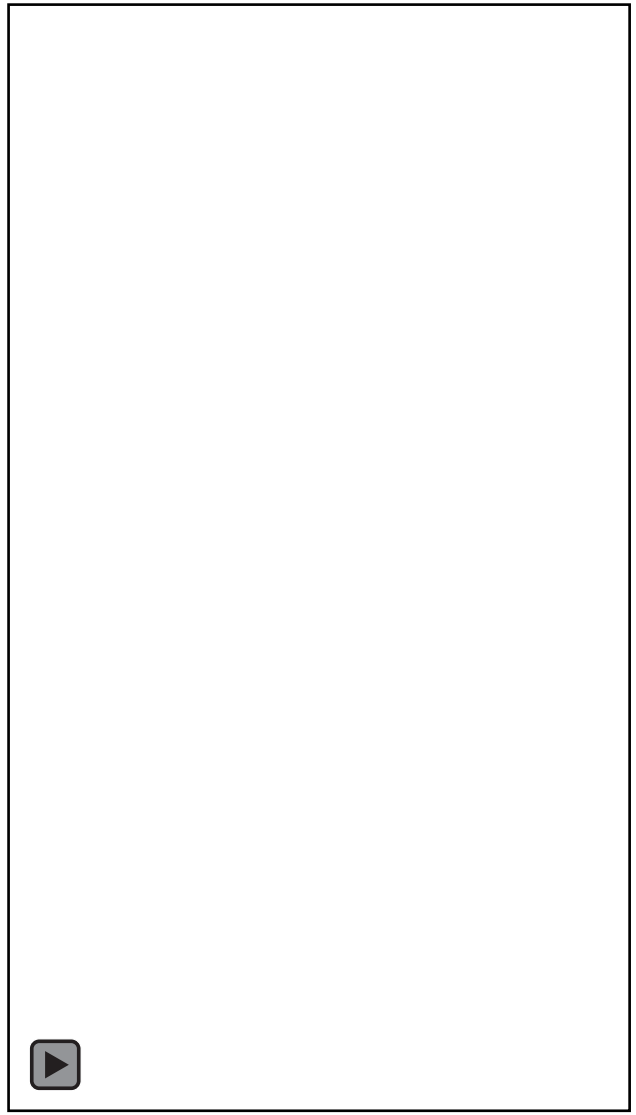
Industrial manipulation



Manipulation of Deformable Objects

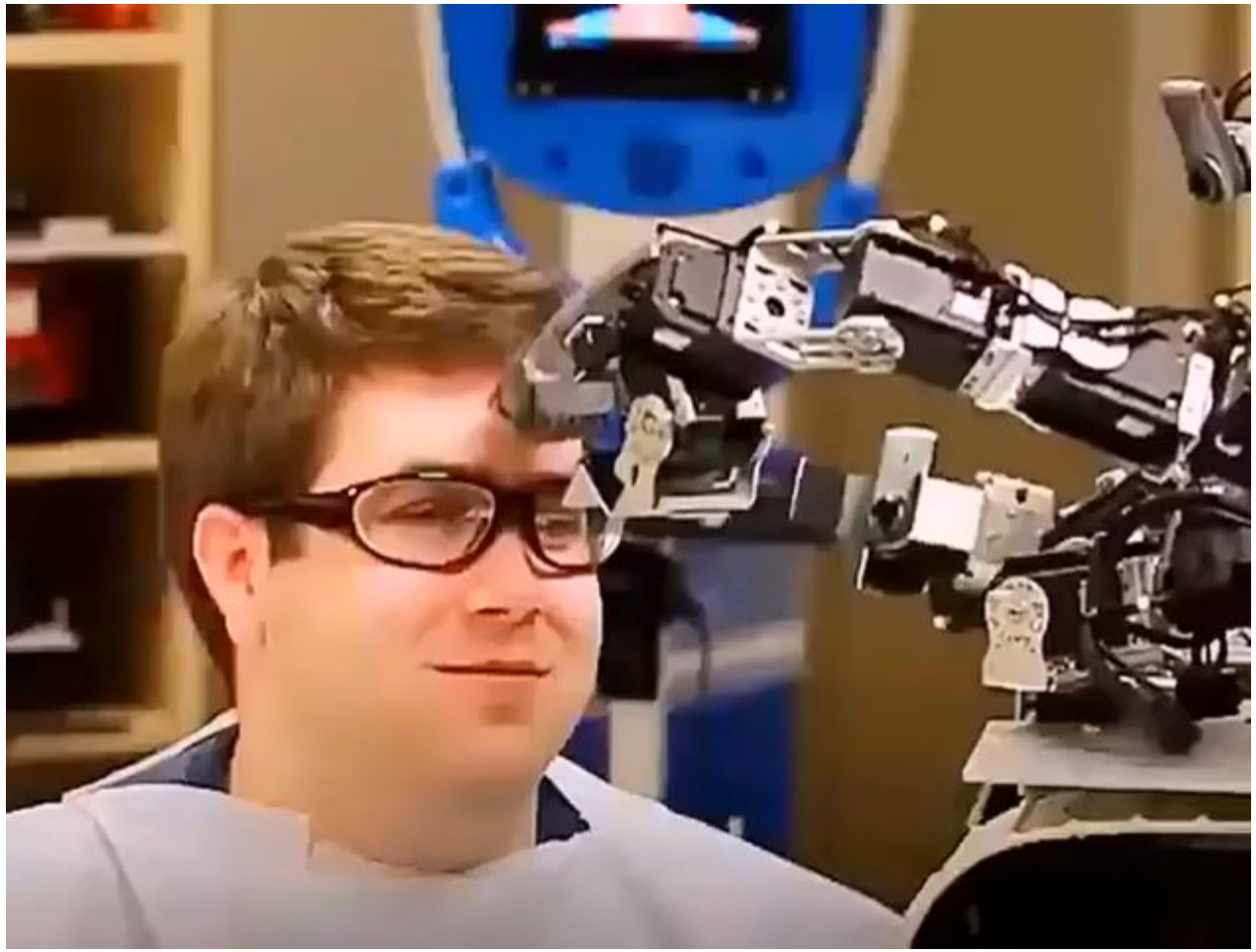
Daily lives





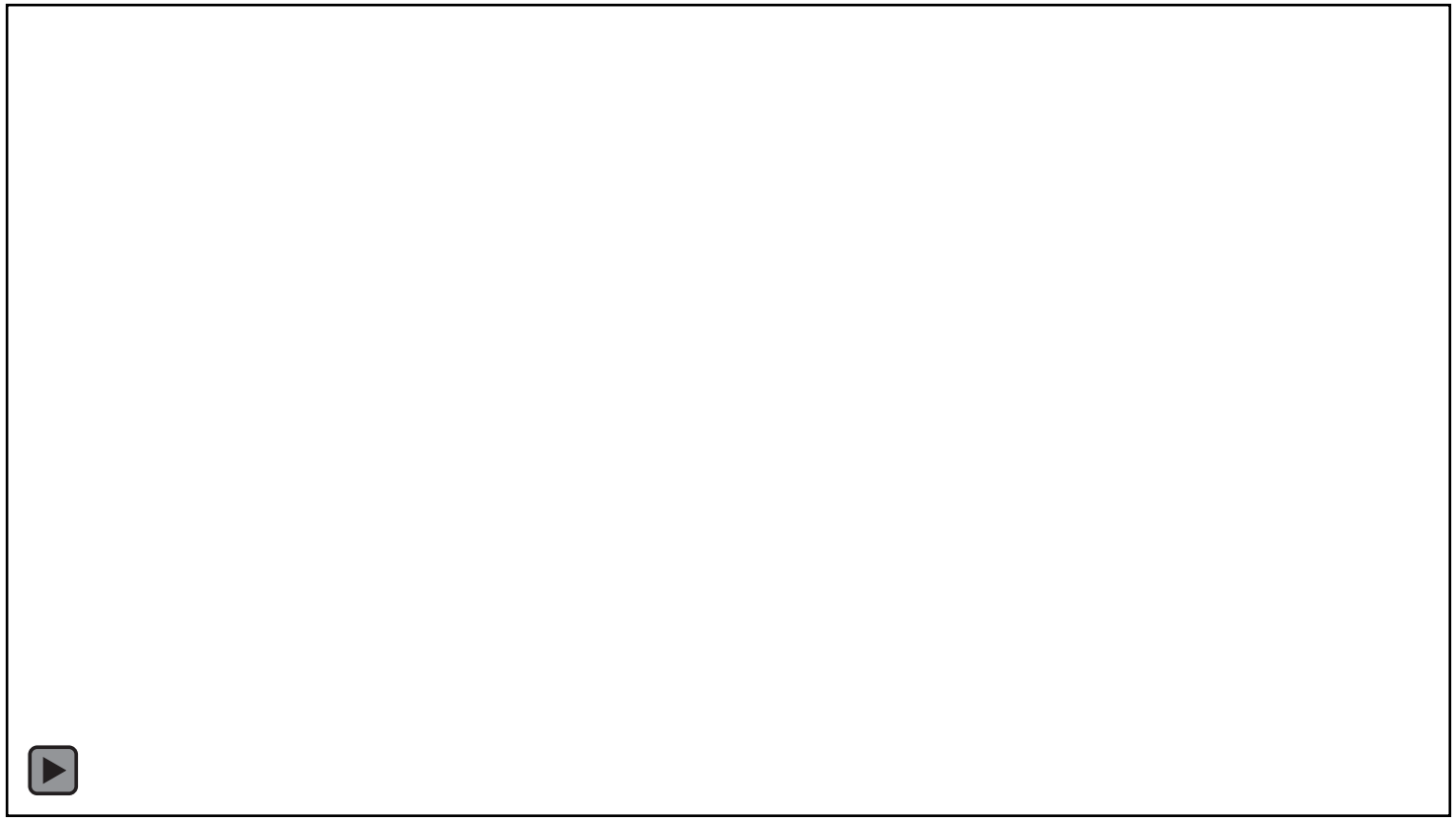
Manipulation of Deformable Objects

haircutting

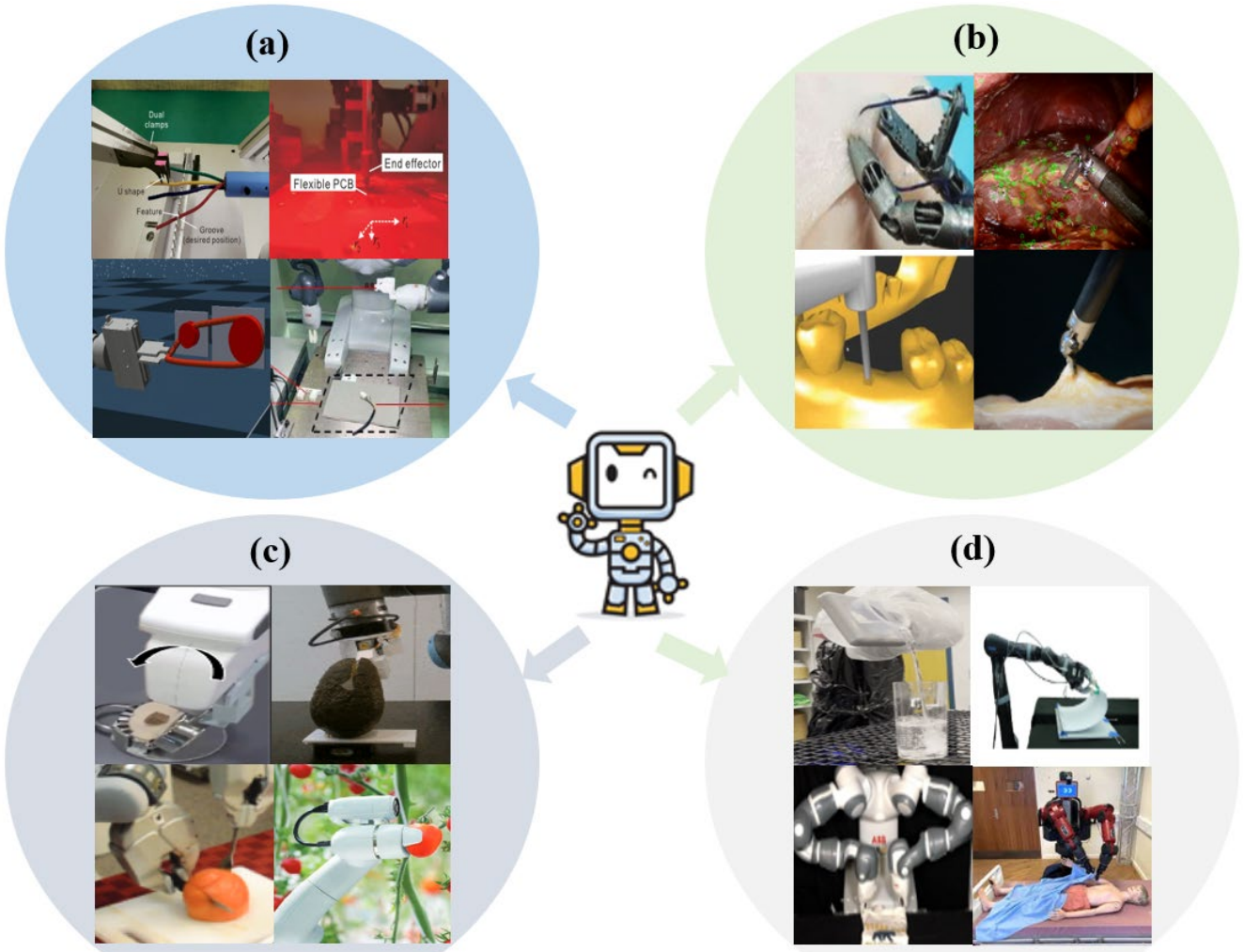


Manipulation of Deformable Objects

Surgical Robots



Manipulation of Deformable Objects



(a) Manufacturing industry

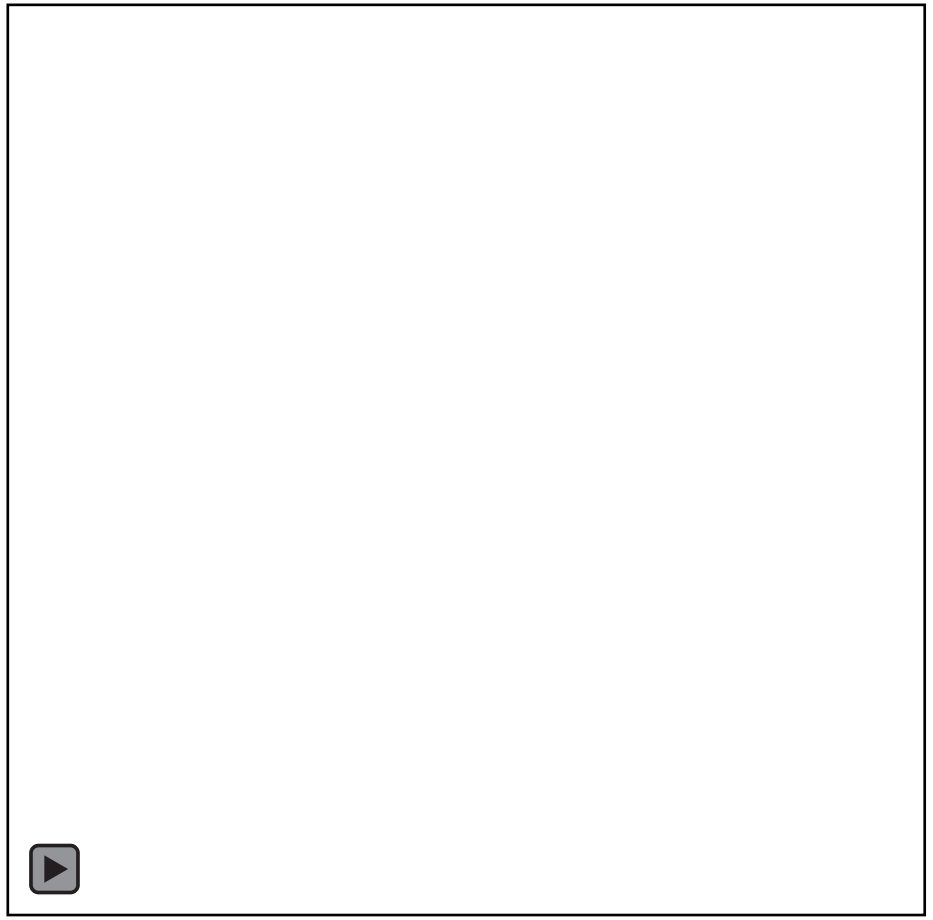
(b) Medical surgery

(c) Food processing

(d) Daily living activities

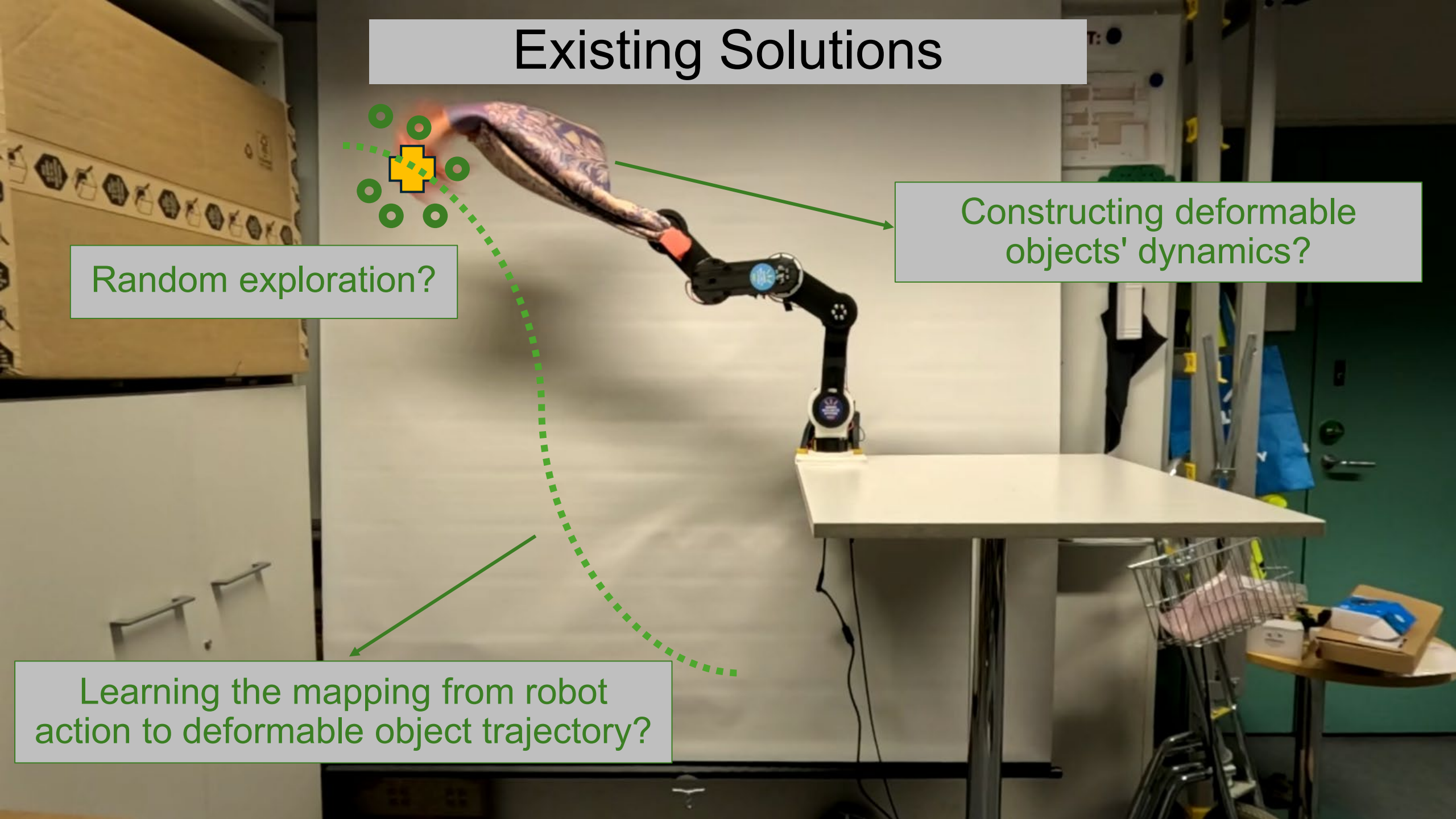
Gu, Feida, et al. "A survey on robotic manipulation of deformable objects: Recent advances, open challenges and new frontiers." *arXiv preprint arXiv:2312.10419* (2023).

Efficient Manipulation of Deformable Objects



- Nonlinear deformations
- Strong air disturbance
- Unpredicted dynamics
- Complex control strategy

Existing Solutions



Random exploration?

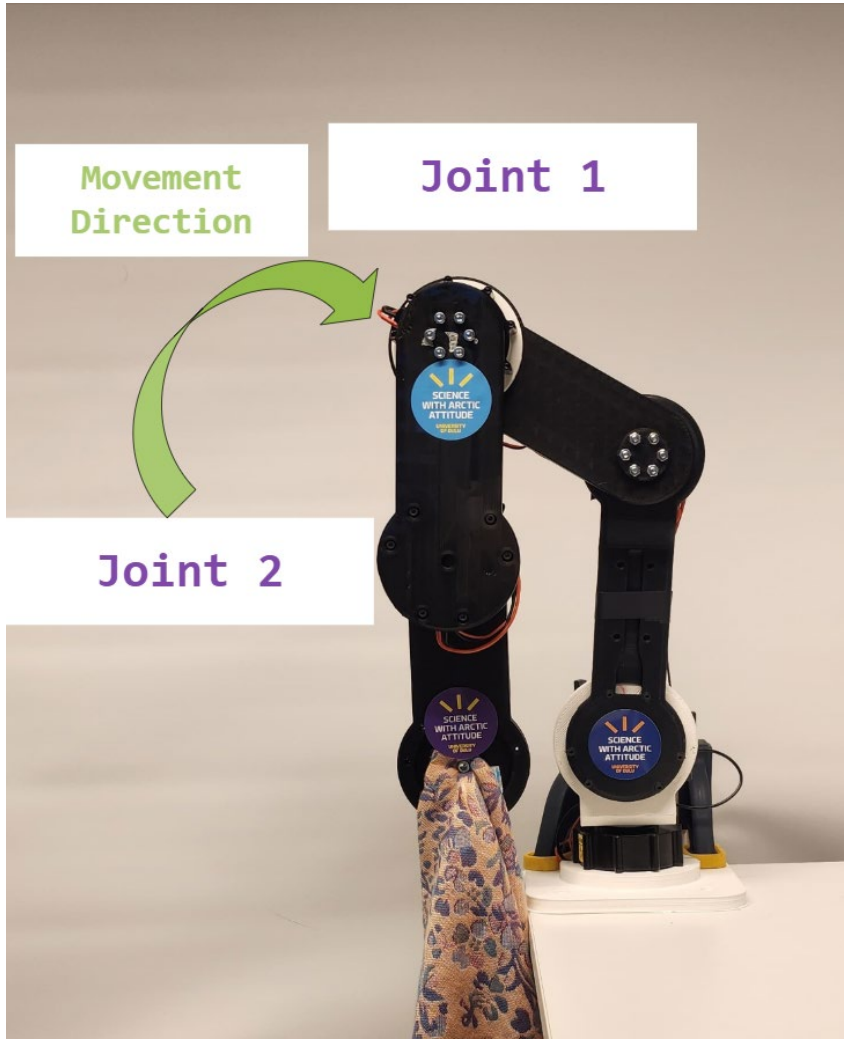
Constructing deformable objects' dynamics?

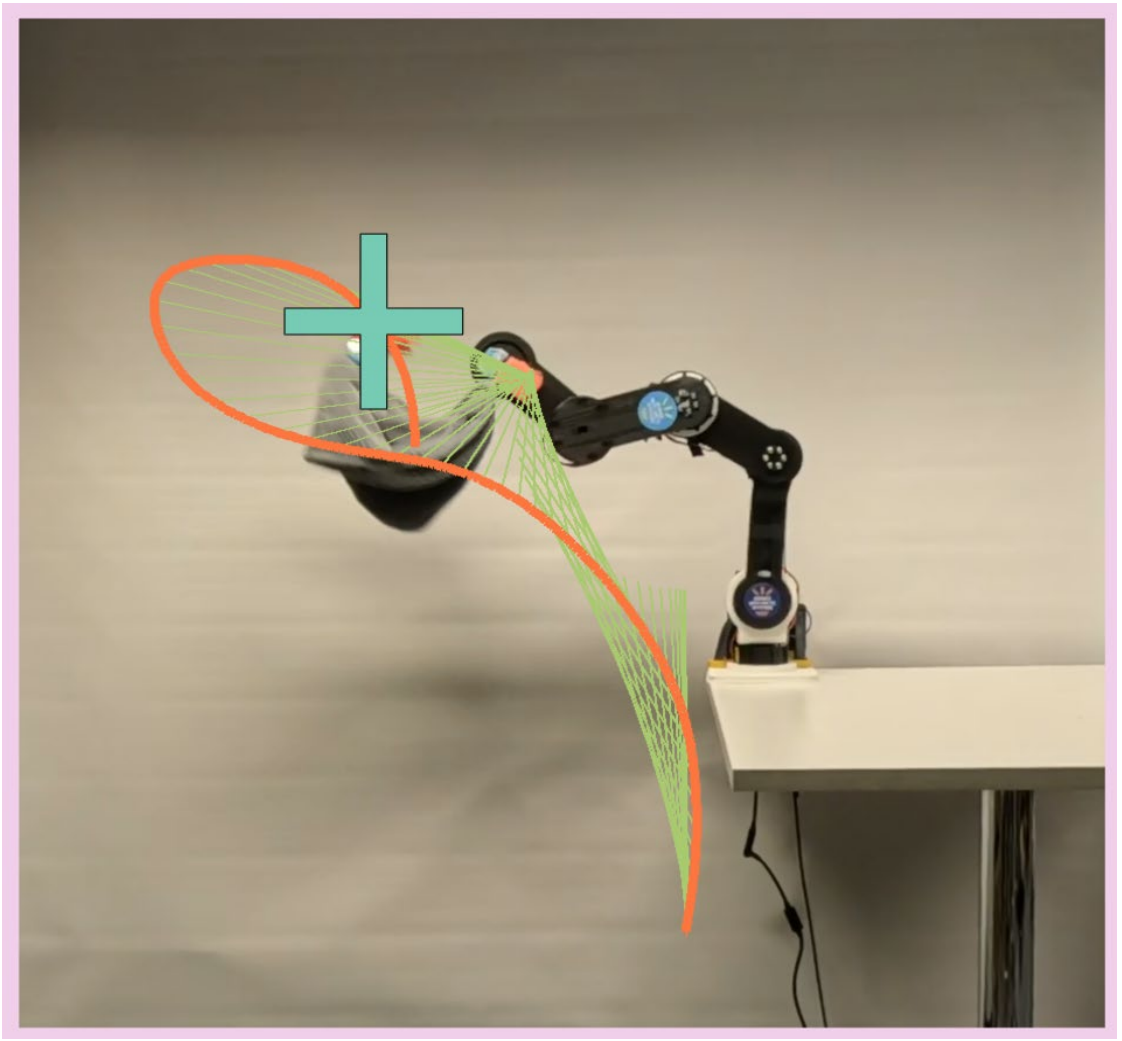
Learning the mapping from robot action to deformable object trajectory?

Existing Solutions

Year	Representative literature	Type of objects			Peception		Modeling		
		1-D objects	2-D objects	3-D objects	Visual	Tactile	Analytical approaches	Data-driven approaches	None
Analytical planning and control									
2014	Bretl and McCarthy [114]	✓			✓		✓		
2015	Li et al. [110]		✓		✓		✓		
2015	Li et al. [111]			✓	✓		✓		
2017	Zaidi et al. [61]			✓		✓	✓		
2018	Navarro-Alarcon and Liu [118]		✓		✓		✓		
2018	Li et al. [4]	✓			✓		✓		
2020	Sintov et al. [112]	✓			✓		✓		
2020	McConachie et al. [91]	✓			✓		✓		
2021	Koessler et al. [101]	✓			✓		✓		
2021	She et al. [51]	✓				✓	✓		
2022	Shi et al. [60]			✓	✓			✓	
2022	Lv et al. [127]	✓			✓		✓		
2023	Huang et al. [109]	✓			✓			✓	

Efficient Manipulation of Deformable Objects





Canvas Bag

Pillowcase

Blanket

Shower Cap

Different Properties of Deformable Objects

Challenges

In conventional method, differential equations are always utilized to describe the dynamics. However, it is hard to construct the suitable equation for this case.

How to design a neural network to learn the dynamics

The method may work well for trained deformable objects but not well for new objects

How to migrate to new deformable objects

Challenges

It may happen that the system works well with out disturbance, e.g., aerodynamic impact, but bad with it.

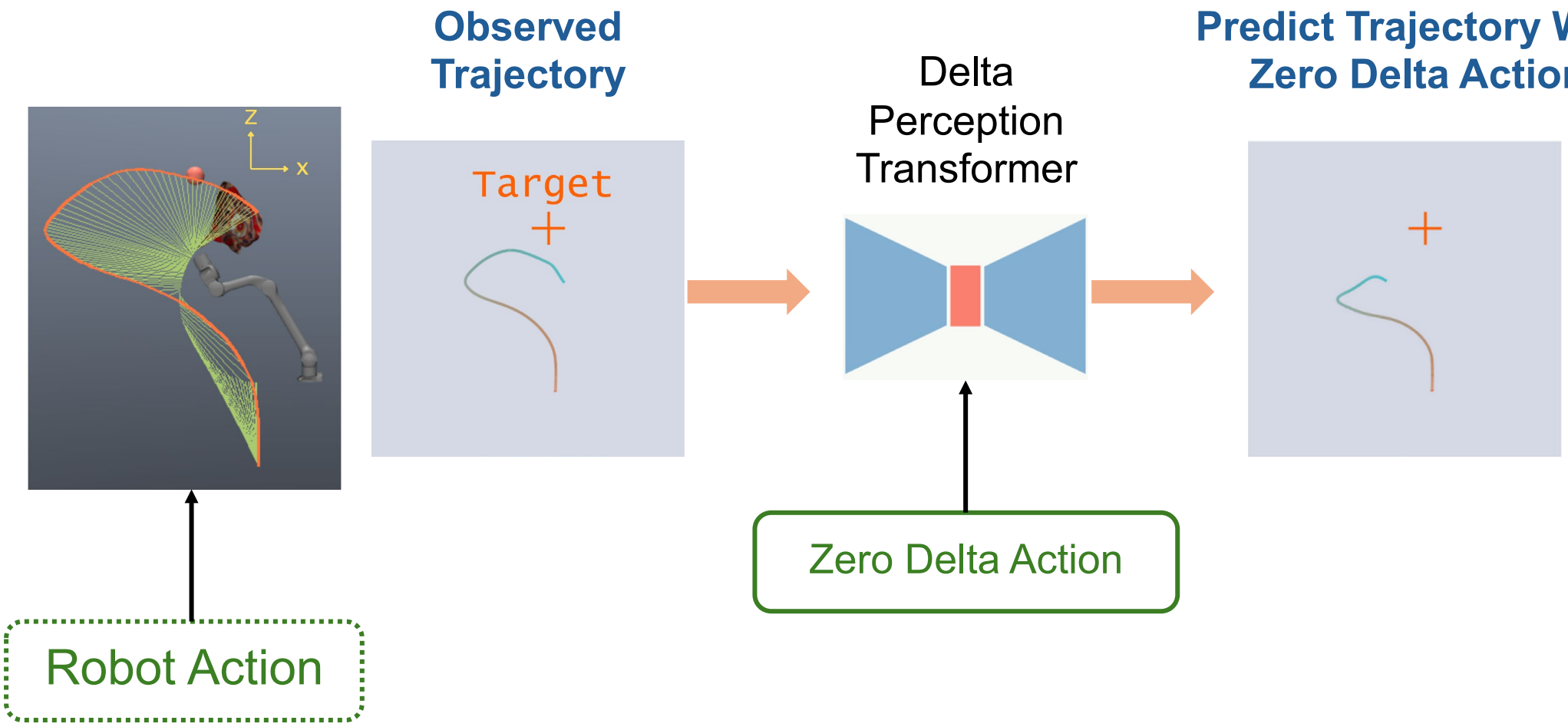
How to make it robust against disturbances

It may happen that the system works well in simulation but bad in real experiment

How to mitigate the sim-to-real gap

Online Iterative Learning

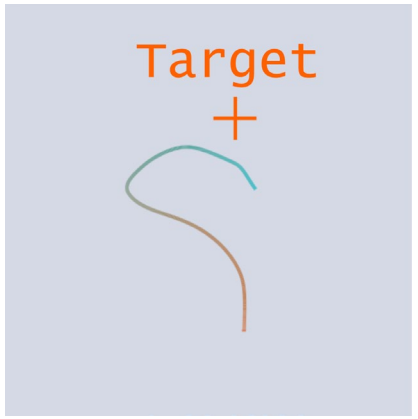
Zero Perception Transformer



Online Iterative Learning

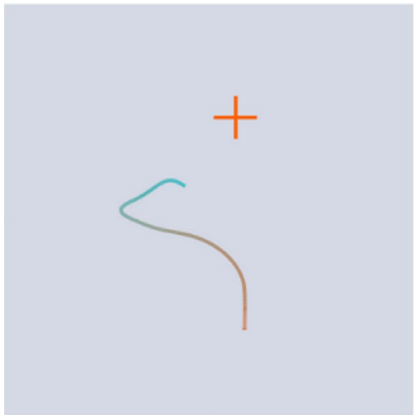
Perception Transform

Observed Trajectory



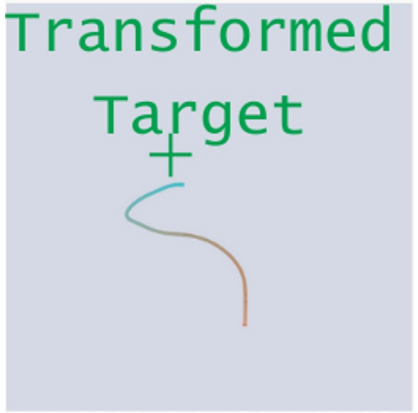
Target Point

Predict Trajectory With Delta Action



Generate perception transform parameters for various properties deformable objects

Perception Transform



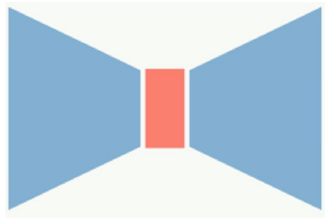
The following iteration of proposed policy will set the Transformed Target as input

Online Iterative Learning

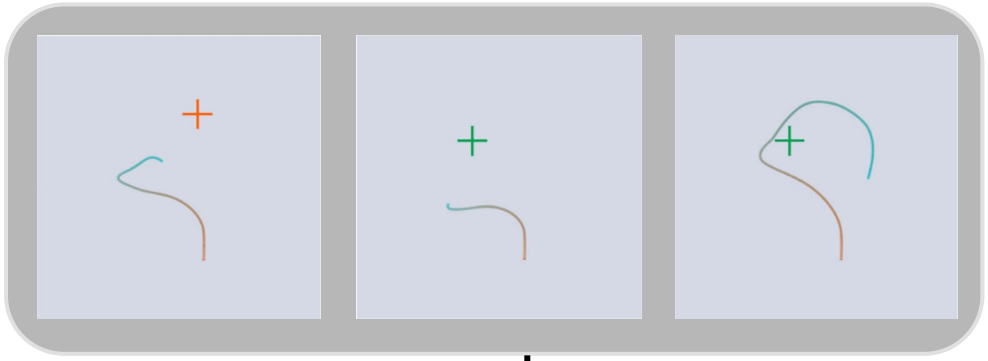
Delta Perception Transformer

Transformed Trajectory

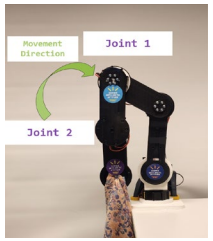
Delta Perception Transformer



Predict Trajectory With Sampled Delta Action



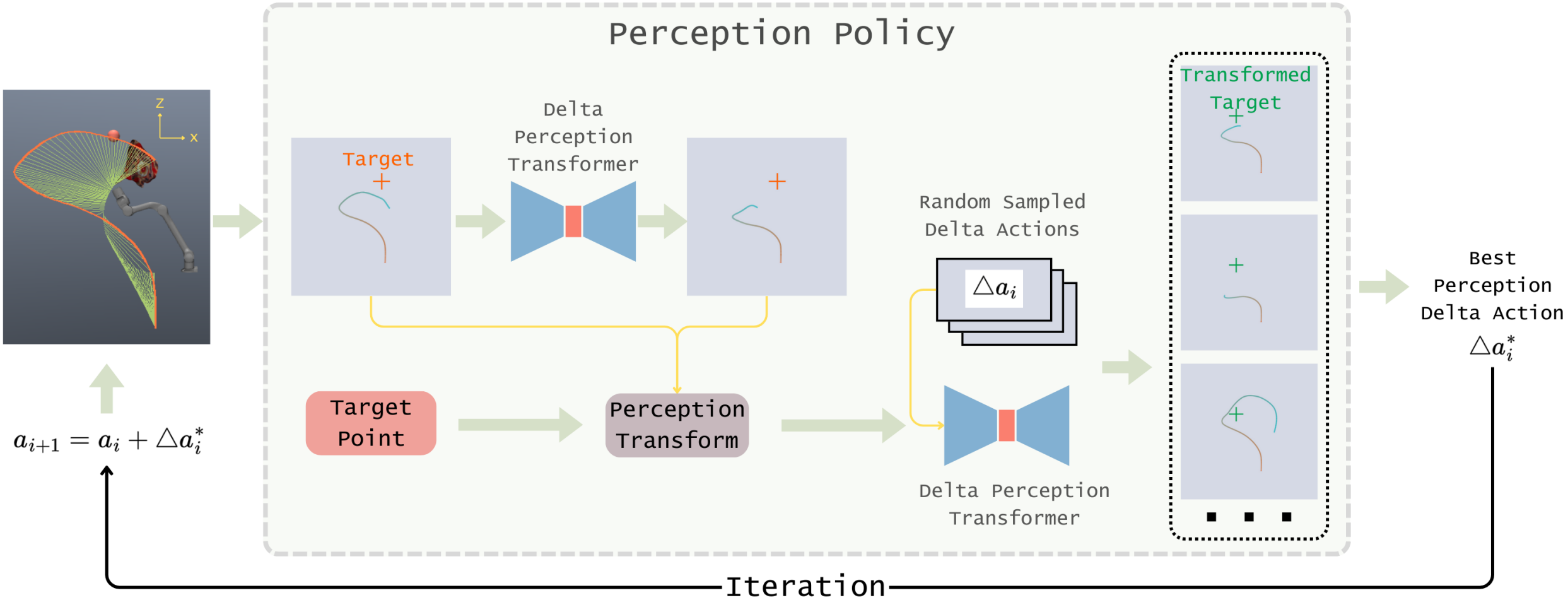
Delta Action Sample



Best Perception Delta Action

Online Iterative Learning

Whole Framework



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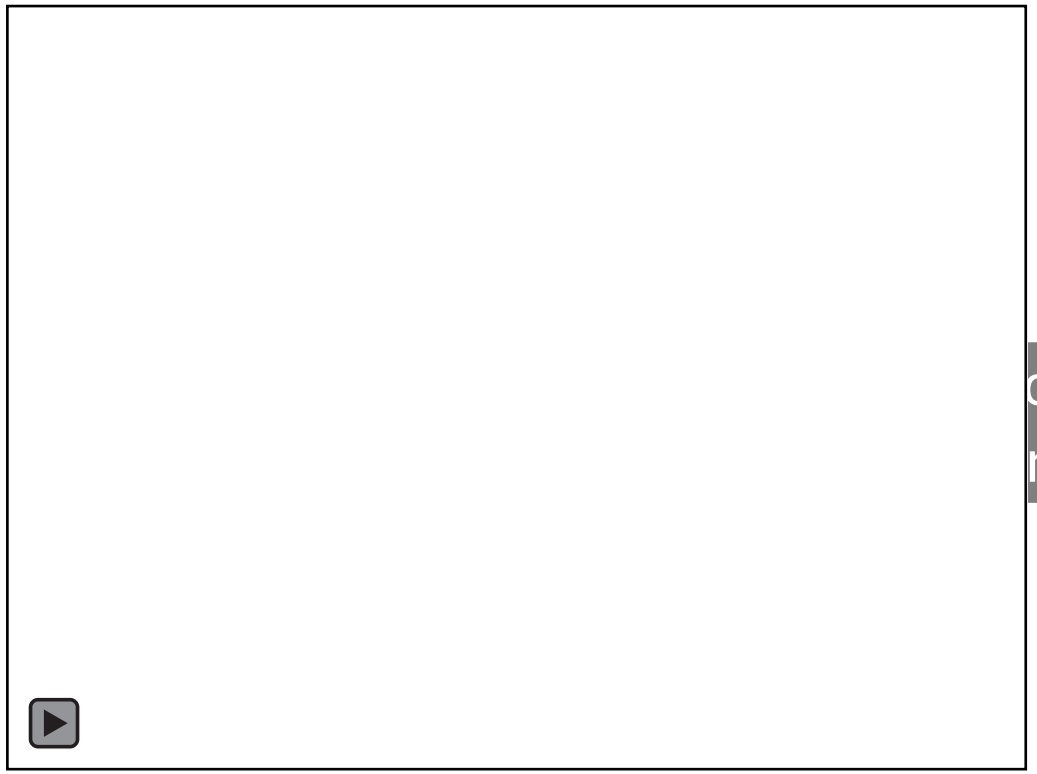
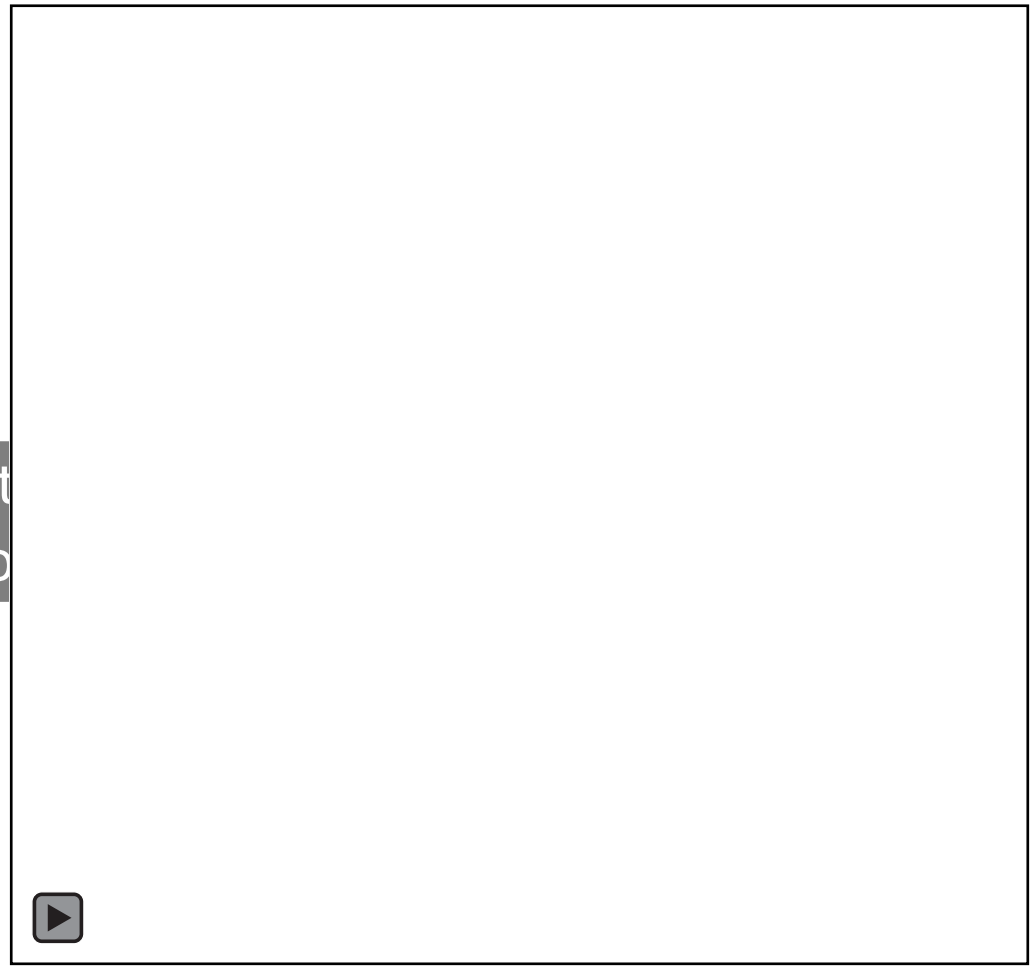
Simulation and Real Test

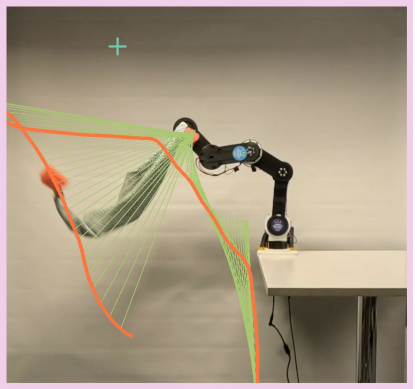


Simulation with a recognized deformable object

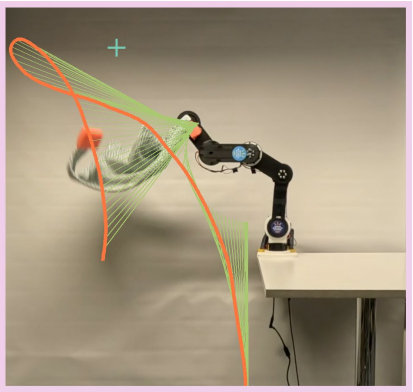


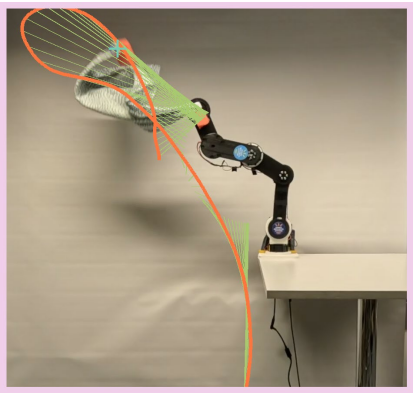
Real test on an unkown deformable object

Iteration 0

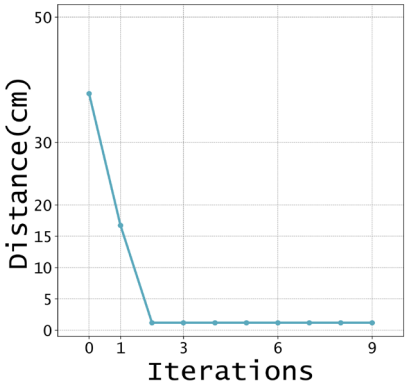


Iteration 1





Iteration 2



Shortest Distance Convergence Curve

Challenges

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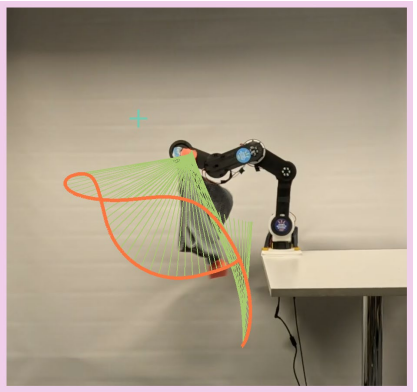
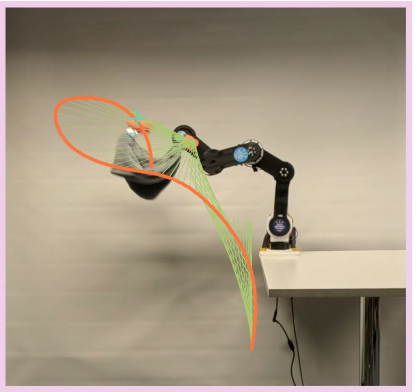
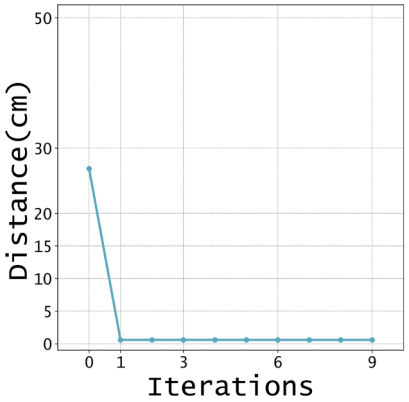
Iteration 0



Iteration 1

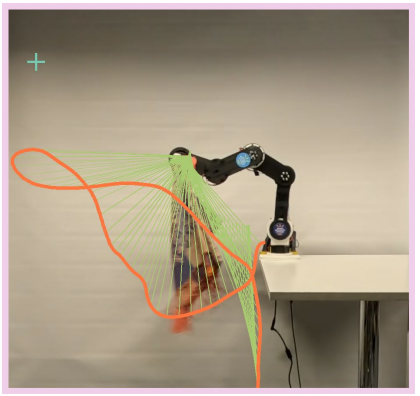


Iteration 2

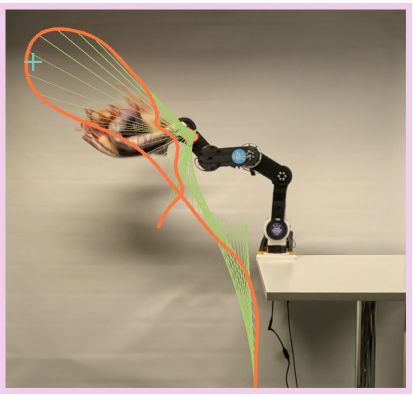


Shortest Distance Convergence Curve

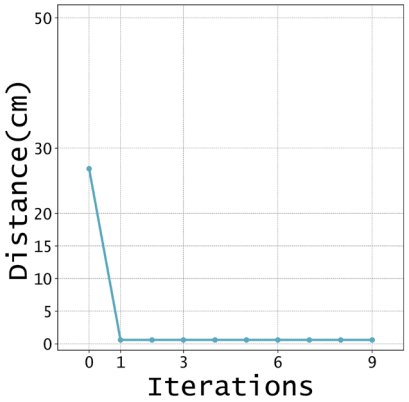
Iteration 0



Iteration 1

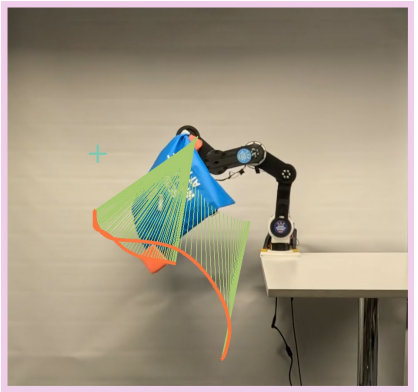


Iteration 2

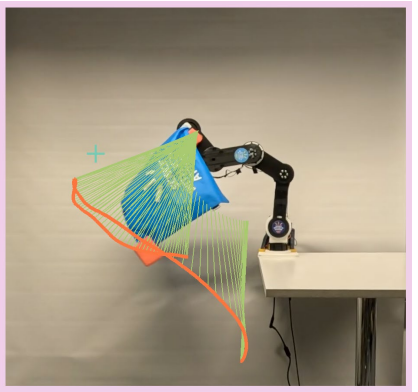


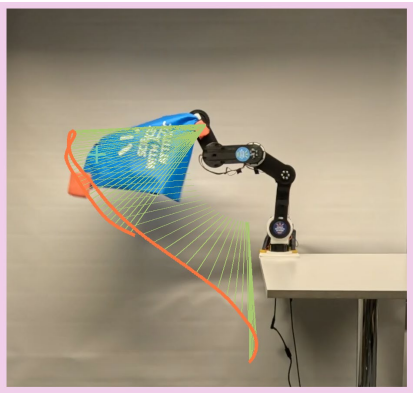
Shortest Distance Convergence Curve

Iteration 0

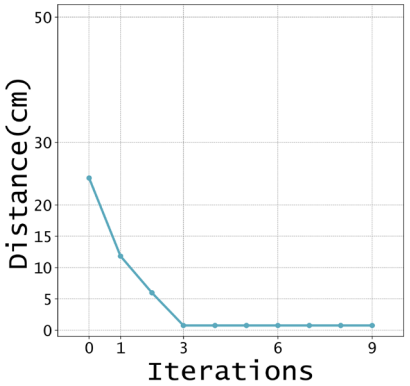


Iteration 1



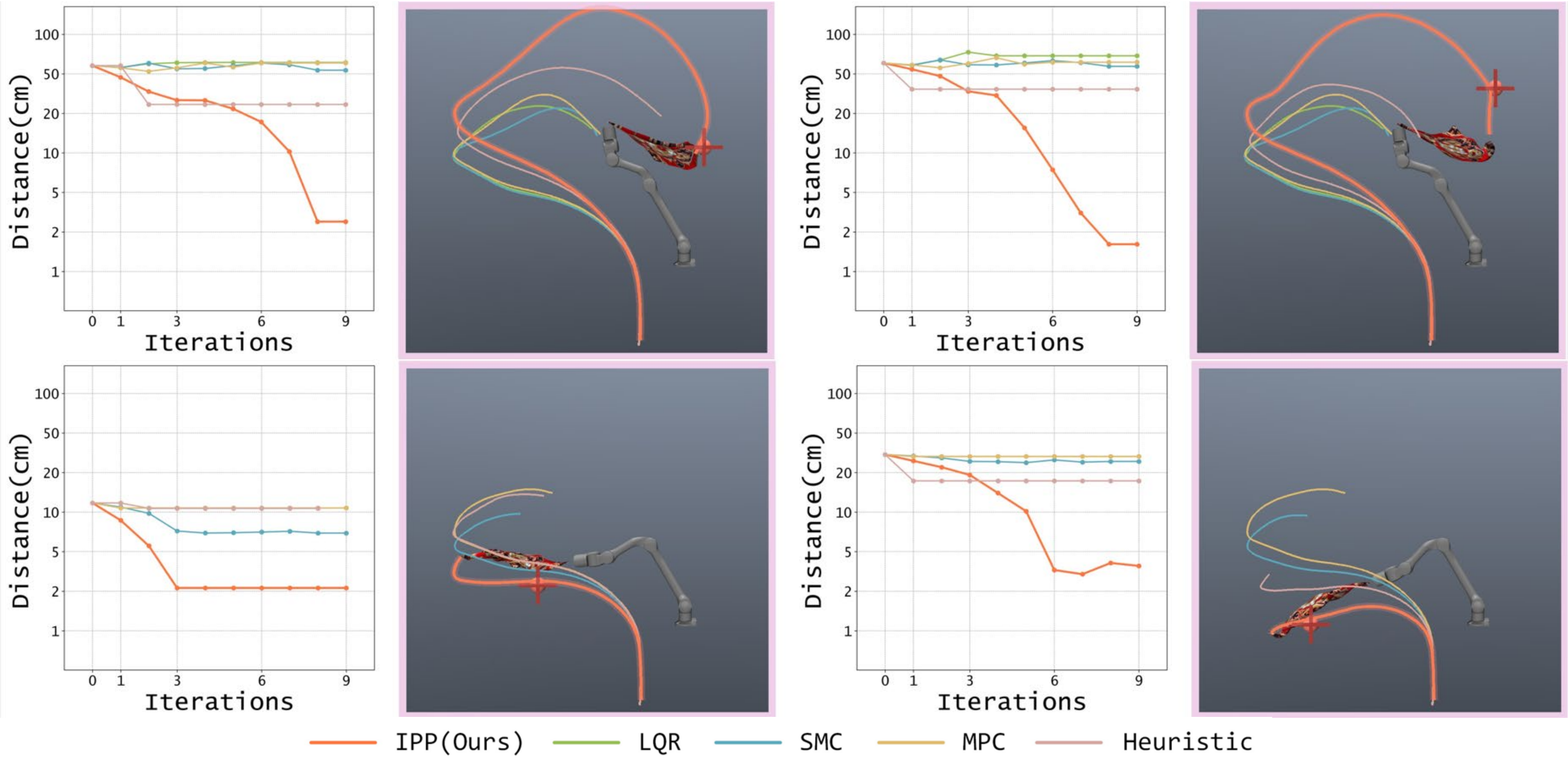


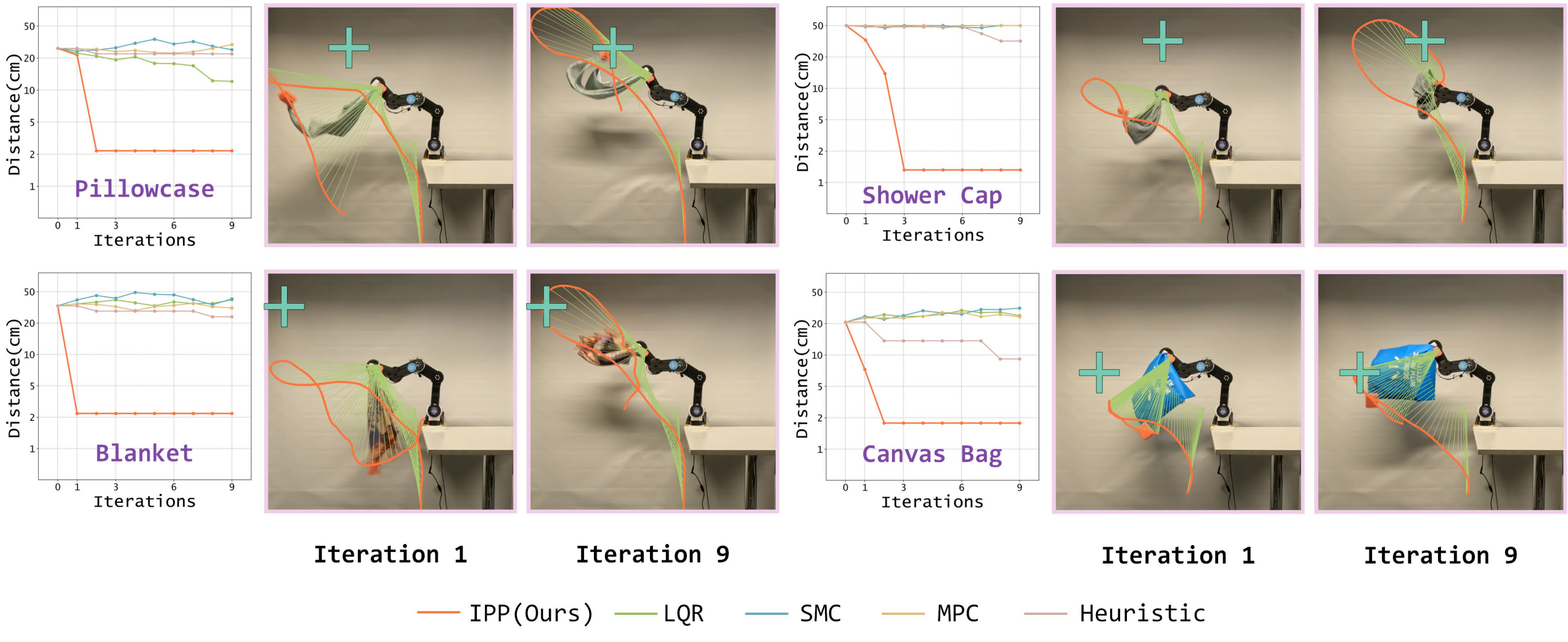
Iteration 2



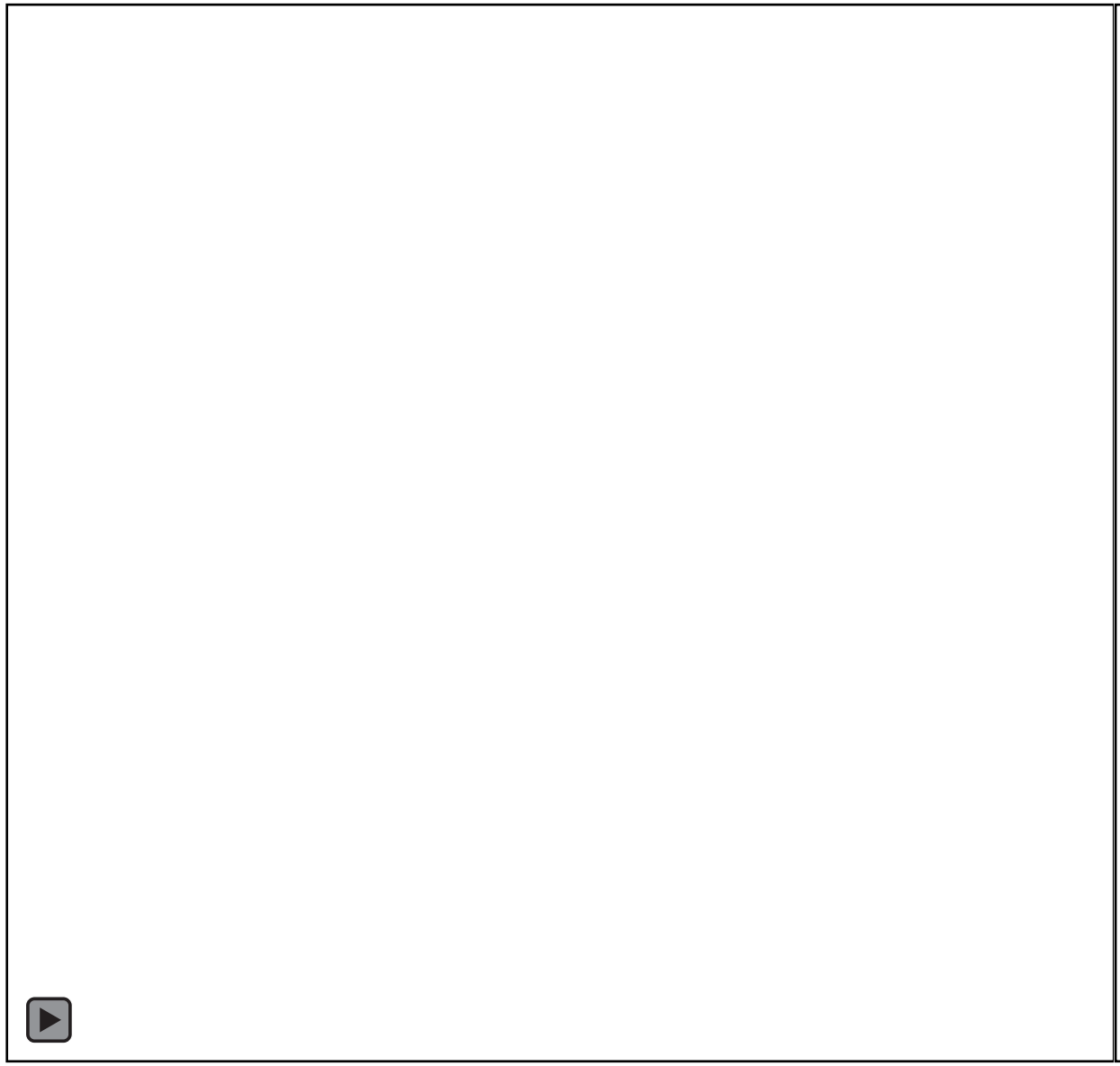
Shortest Distance Convergence Curve

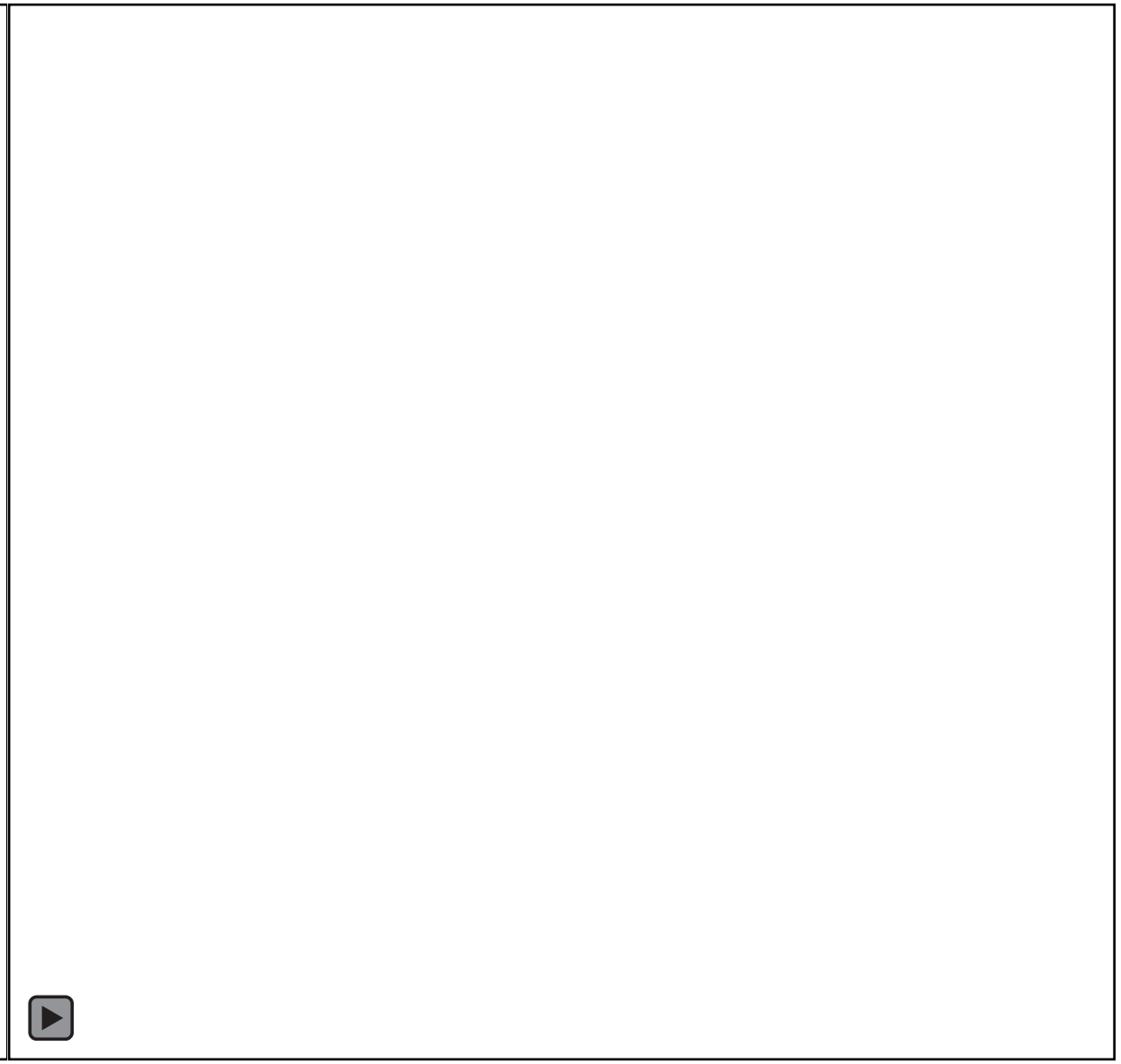
Comparison in Simulation





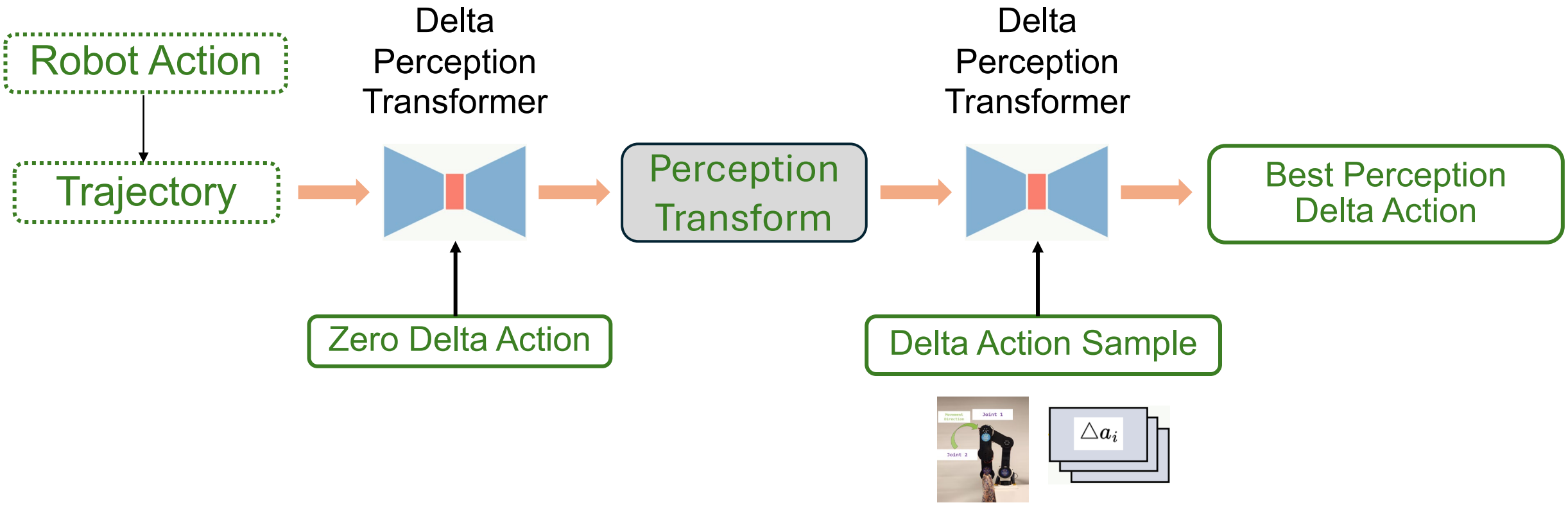
Comparison in Real Scene





Online Iterative Learning

An method for efficient manipulation of various deformable objects



Conclusion

- A method for deformable object manipulation that features
- Fast convergence
- Adaption to different deformable objects
- Robust to air disturbance
- Trained in simulation but works well in experiment

Thanks!
Questions and Comments?