Learning Visual Shape Control of Novel 3D Deformable Objects from Partial-View Point Clouds

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Project website: https://sites.google.com/view/deformernet/home

Problem

➢ How can a robot control the shapes of 3D deformable objects?

Motivation

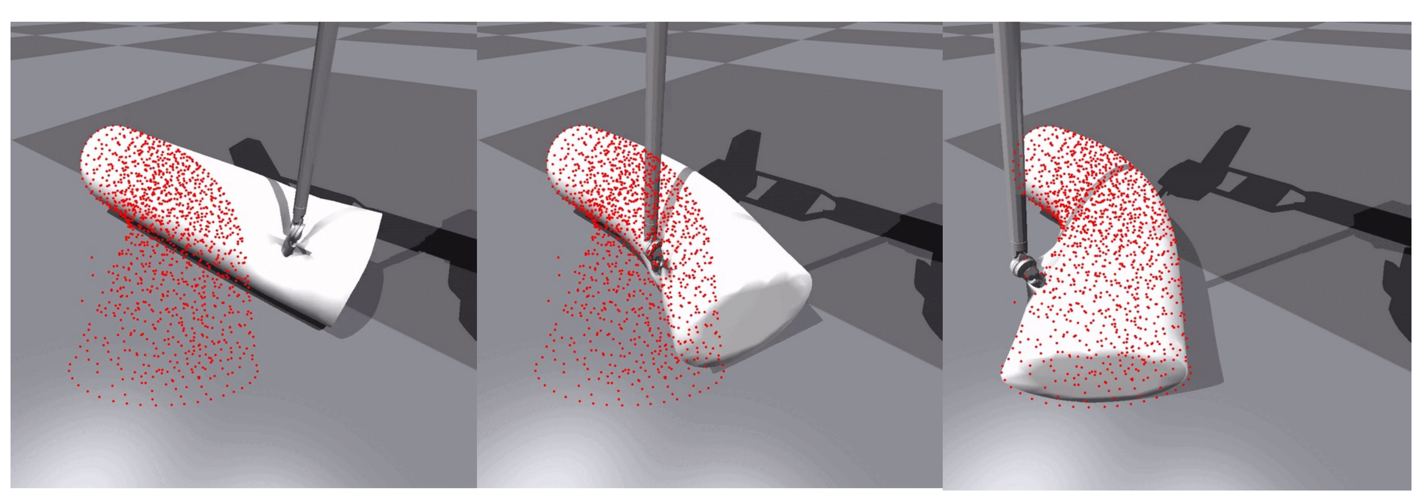
➢ Deriving a low-dimensional but expressive state representation is difficult due to infinite DOFs.

➢ Prior works:

- Points on the object surface
- Simple feature descriptor of object point cloud

➢ These methods over-simplify the *complex dynamics* of 3D deformable objects.

➢ Why not learn it via deep neural networks?



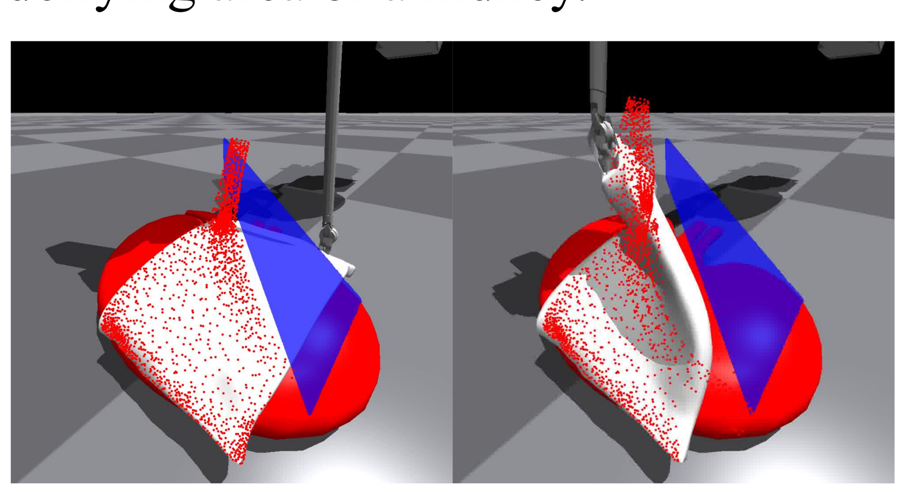
Broader Impact

Critical to many robotic manipulation tasks:

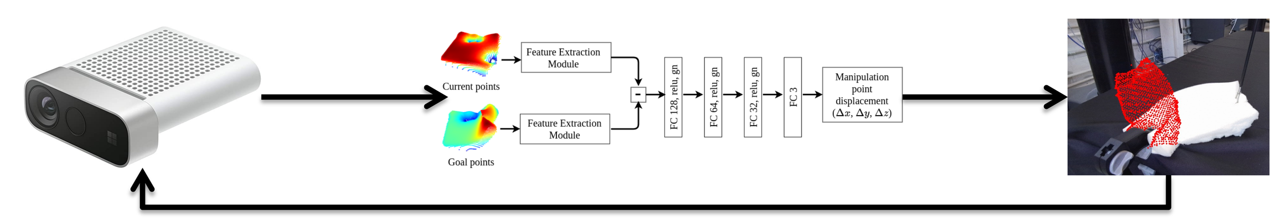
- Surgical assistive robots: tissue and organs
- Home-assistance robots: sponges, clothes, food, etc.
- Warehouse robots: containers, boxes, etc.
- Safe automated productions lines for deformable products.

Surgical Application

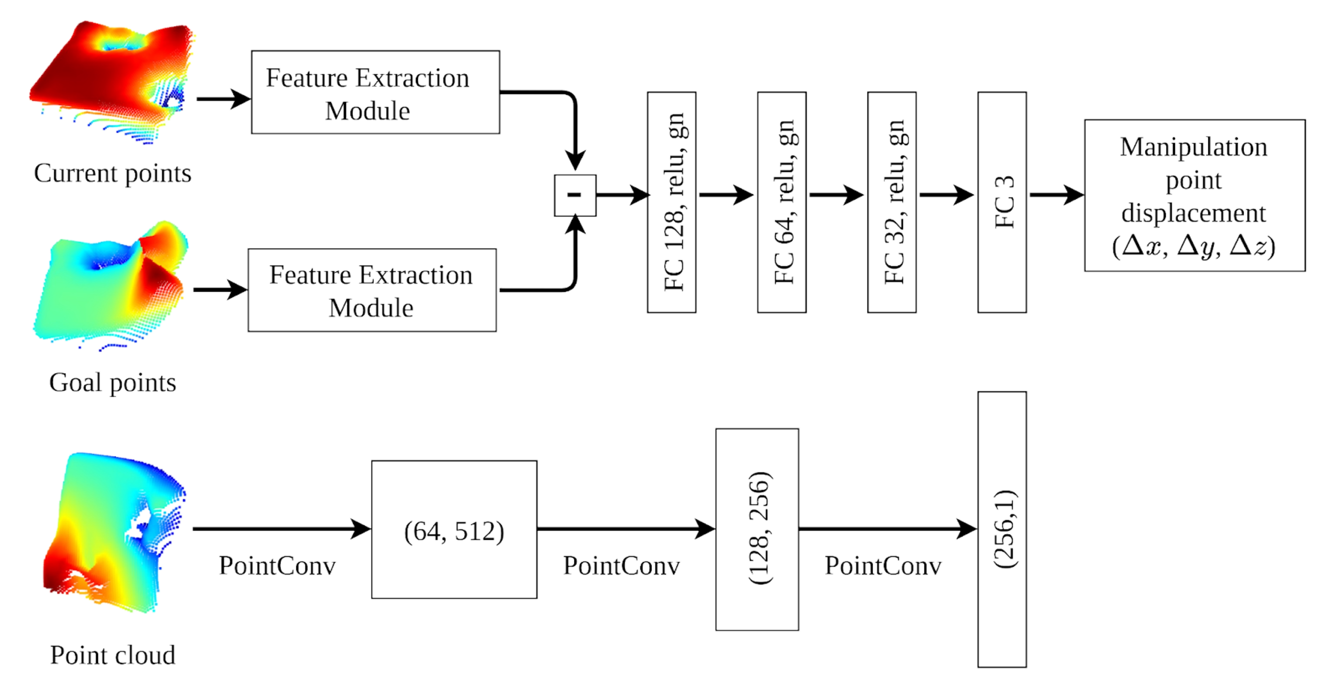
Surgical retraction task: grasping a tissue layer and lifting it up to expose the underlying area of a kidney.



Shape Servoing with *DeformerNet*



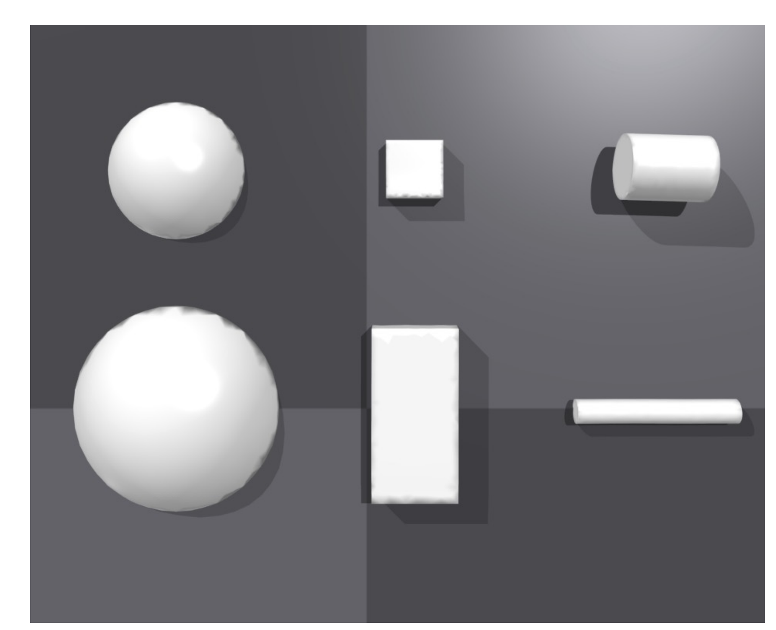
➢ Obtain point cloud → Pass to DeformerNet to compute action → control robot → repeat until convergence



➢ Feature extraction: generate a 256-dim feature vector from partial-view point cloud using PointConv

➢ Deformation control: compute end effector displacement given difference of current and target features

➢ We train on random size and stiffness instances of these shapes

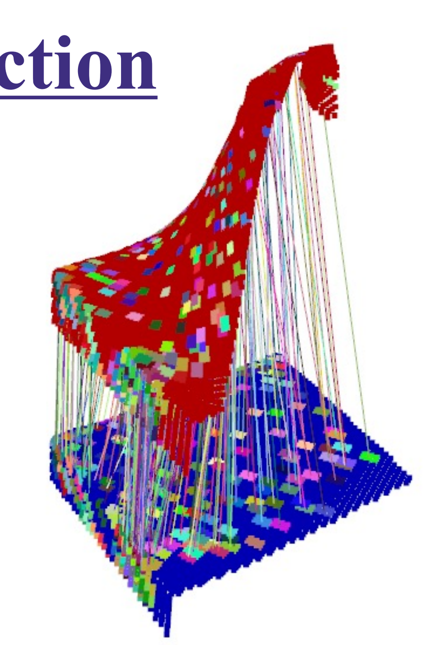


Manipulation Point Prediction

➢ Where to grasp when performing shape control?

➢ Insight: points on the object that move more should generally be close to the grasp point

➢ Manipulation point = displacement-weighted average of keypoints matched between initial and target shape.

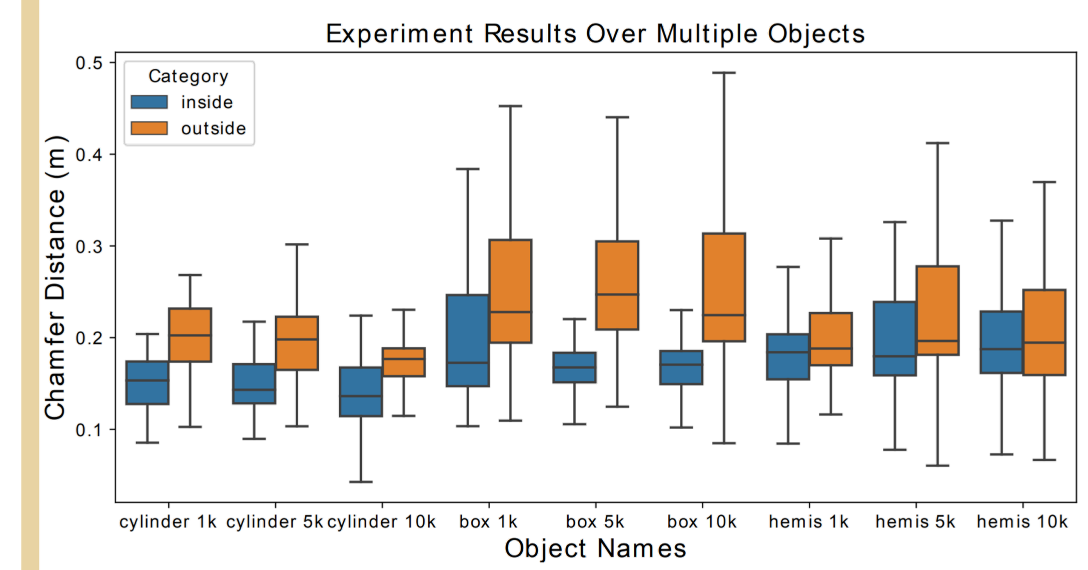


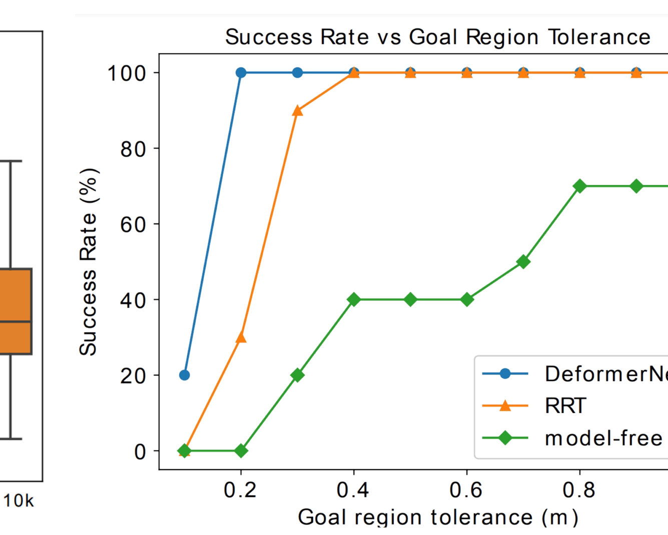
Experiments

Quantitative Results

➢ In simulation, use dVRK surgical robot to manipulate a variety of object geometries and stiffnesses.

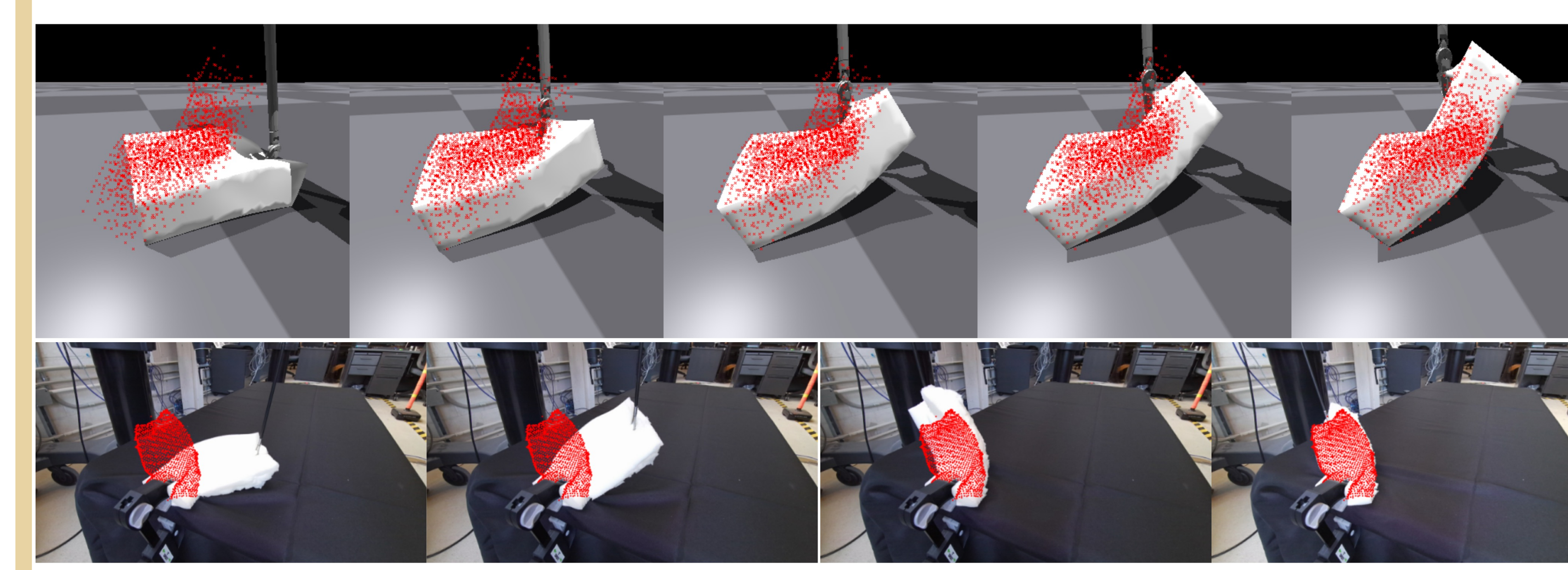
➢ Evaluate performance in 2 categories: objects inside and outside the training distributions



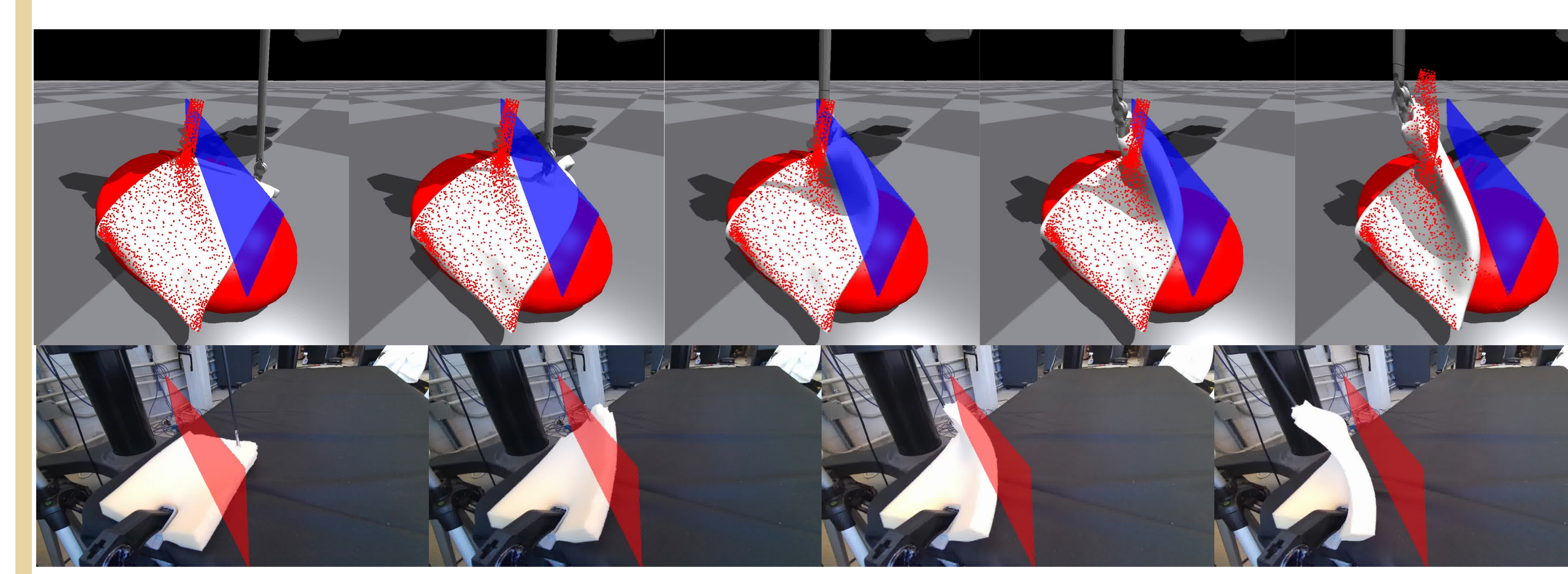


➢ On real robot, evaluate with a foam box object.

Qualitative Results



Goal-oriented shape servoing



Surgical retraction task

2022 NRI & FRR Principal Investigators' Meeting
April 19-21, 2022

[Bao Thach, Brian Y. Cho, Alan Kuntz, & Tucker Hermans. *ICRA* 2022]

Award ID#: 2024778