



Learning Particle Dynamics for Manipulating Rigid Bodies, Deformable Objects, and Fluids

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Introduction

- Real-life control tasks involve objects of different states, such as rigid bodies, deformable objects and fluids.
- A particle-based representation of scene dynamics is general and flexible.

We propose a method that

- Learns particle dynamics for fluids and rigid/soft bodies, and
- Performs complex manipulation tasks using the learned model both in simulation and in the **real world**.

Challenges

- Rigid objects: maintain rigidity
- Soft bodies: elastic and plastic deformation
- Fluids: enforce density and incompressibility
- Two-way coupling between different materials
- How can we use the model for control?

State-specific Treatments

Rigid Objects

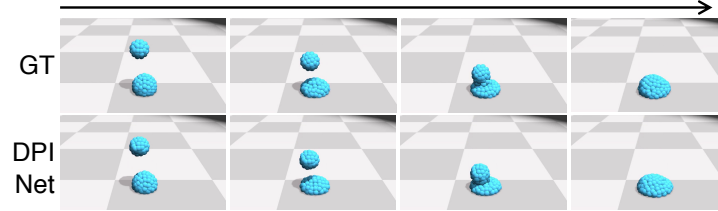
- Hierarchical graph
- Predict rigid motion
- Dynamic graph

Soft Bodies

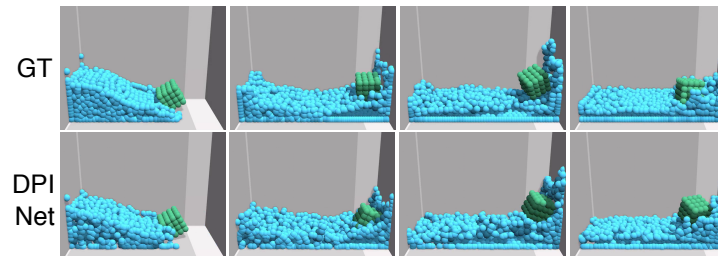
- Hierarchical graph
- Dynamic graph
- Maintain rest position for elastic deformation

Simulation

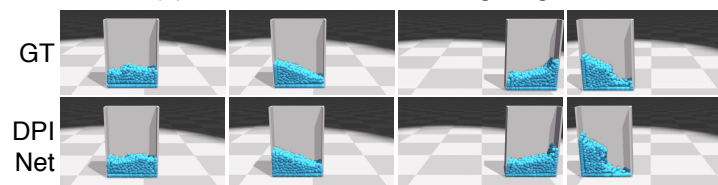
- Input the position and velocity at the first frame



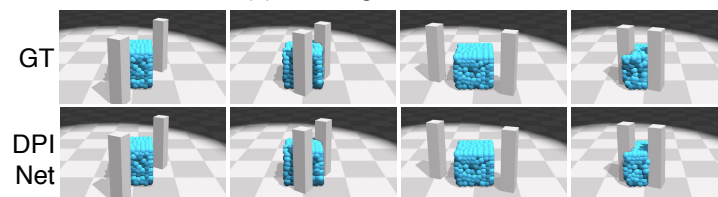
(a) Two drops of high-viscosity fluids are merging.



(b) A block of water is flushing a rigid cube.



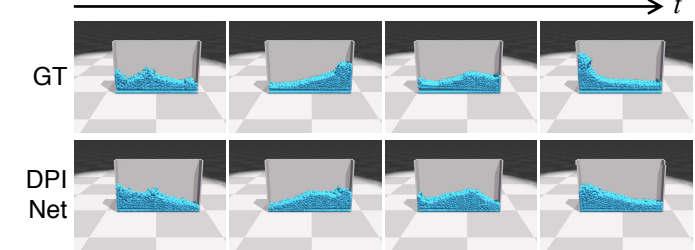
(c) Shaking a box of fluids.



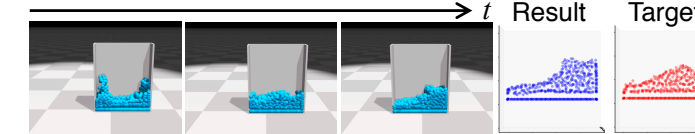
(d) Gripping a deformable object (e.g., sticky rice).

Generalization

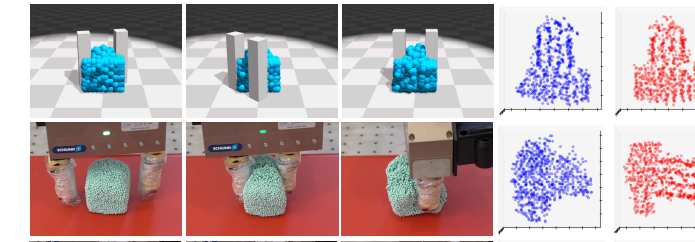
- Two times more fluid particles than training



Control



Shake the box so that water reaches the target configuration.



Plan grips to mold the deformable foam to a target shape.

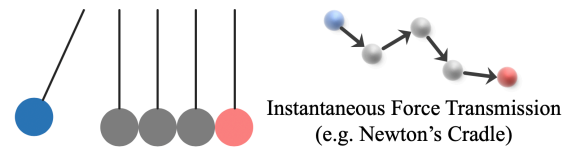
References

- Damian Mrowca, et al.
Flexible Neural Representation for Physics Prediction
NeurIPS 2018
- Peter W. Battaglia et al.
Interaction Networks for Learning about Objects, Relations and Physics
NeurIPS 2016

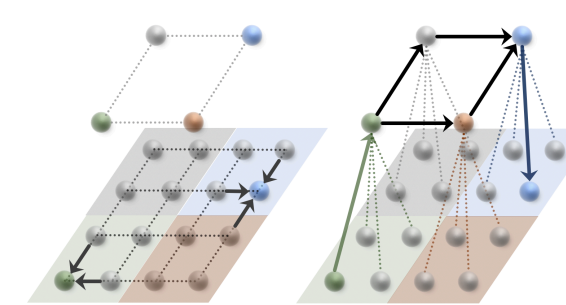
Website
(video & code)



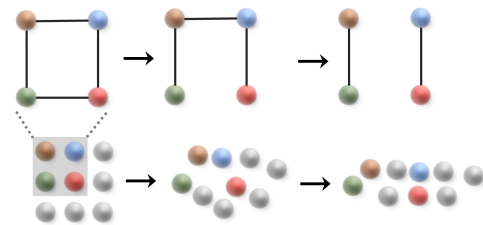
Dynamic Particle Interaction Networks (DPI-Nets)



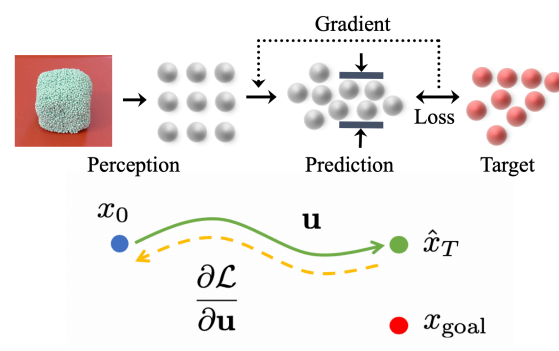
(a) Multi-Step Effect Propagation



(b) Local Propagation Hierarchical Propagation



(c) Dynamic Interaction Graph



(d) Gradient-based Control

| Methods | (a) | (b) | (c) | (d) |
|-----------------------------|-------------|-------------|-------------|-------------|
| IN (Battaglia et al., 2016) | 2.74 | N/A | N/A | N/A |
| HRN (Mrowca et al., 2018) | 0.21 | 3.62 | 3.58 | 0.17 |
| DPI-Net | 0.15 | 2.03 | 1.89 | 0.13 |