COV877: Special Module on Visual Computing:

∇SIM: DIFFERENTIABLE SIMULATION FOR SYSTEM IDENTIFICATION AND VISUOMOTOR CONTROL

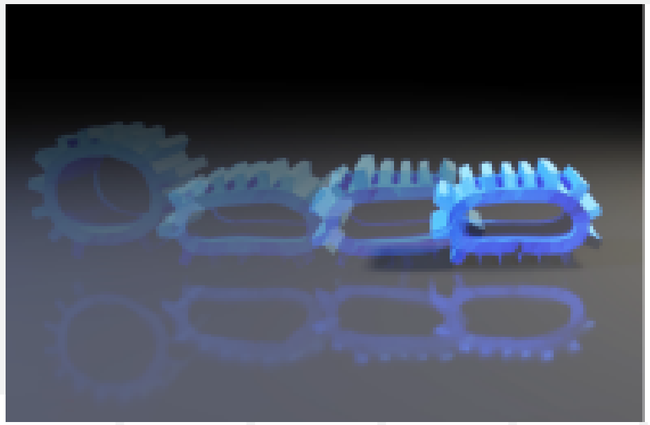
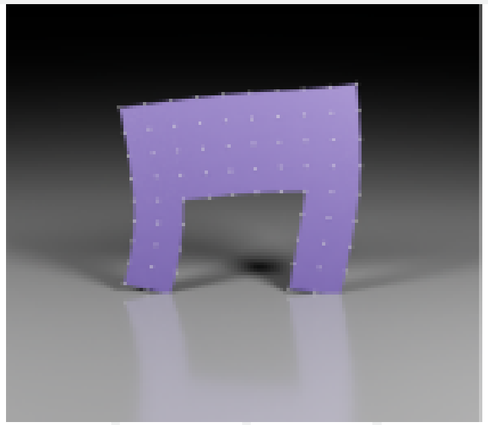
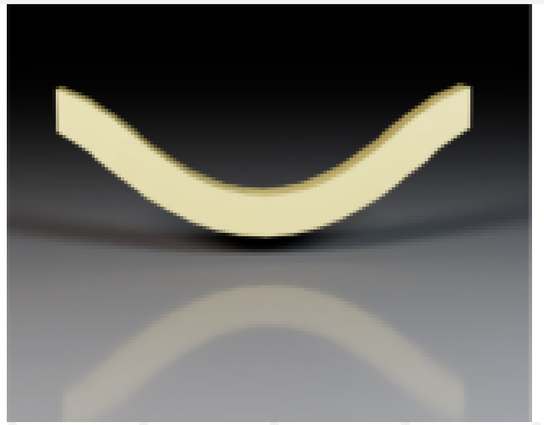
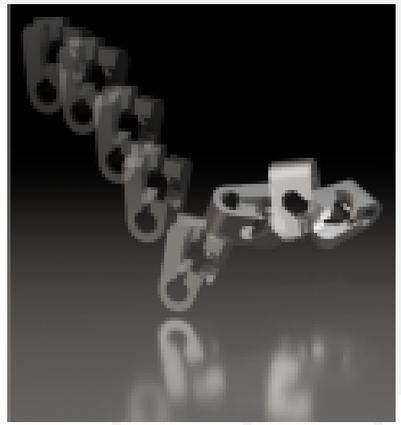
Presented by Roshan Raj

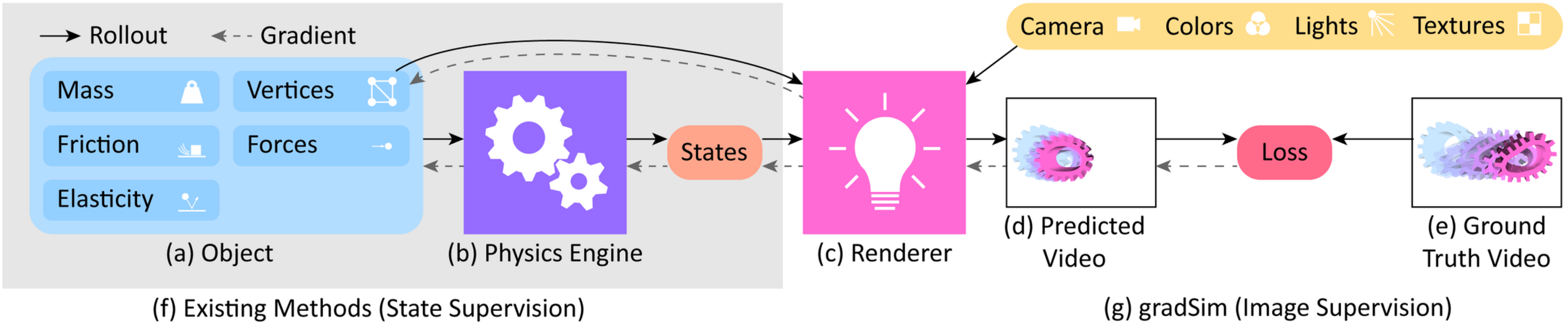
AGENDA

- Introduction
- Differentiable Physics Engine
- Differentiable Rendering Engine
- Experiments
- Physical Parameter Estimation from Video
- Visuomotor Control
- Conclusion

INTRODUCTION

∇Sim is a unified differentiable rendering and multiphysics framework that allows solving a range of control and parameter estimation tasks (rigid bodies, deformable solids, and cloth) directly from images/video


Rollout
Gradient
Mass
Vertices
Friction
Forces
Elasticity
(a) Object
(b) Physics Engine
States
(c) Renderer
Camera
Colors
Lights
Textures
(d) Predicted Video
Loss
(e) Ground Truth Video
(f) Existing Methods (State Supervision)
(g) gradSim (Image Supervision)

DIFFERENTIABLE PHYSICS ENGINE

A differentiable physics engine is the heart of ∇Sim.

- At the core of this engine:
    - Generalized Coordinates:
    - Parameters:
    - Second-Order Differential Equations (ODEs):

DIFFERENTIABLE RENDERING ENGINE

- A crucial component in ∇Sim is the differentiable rendering engine.
- It plays a significant role in bridging the gap between physical simulations and image observations.

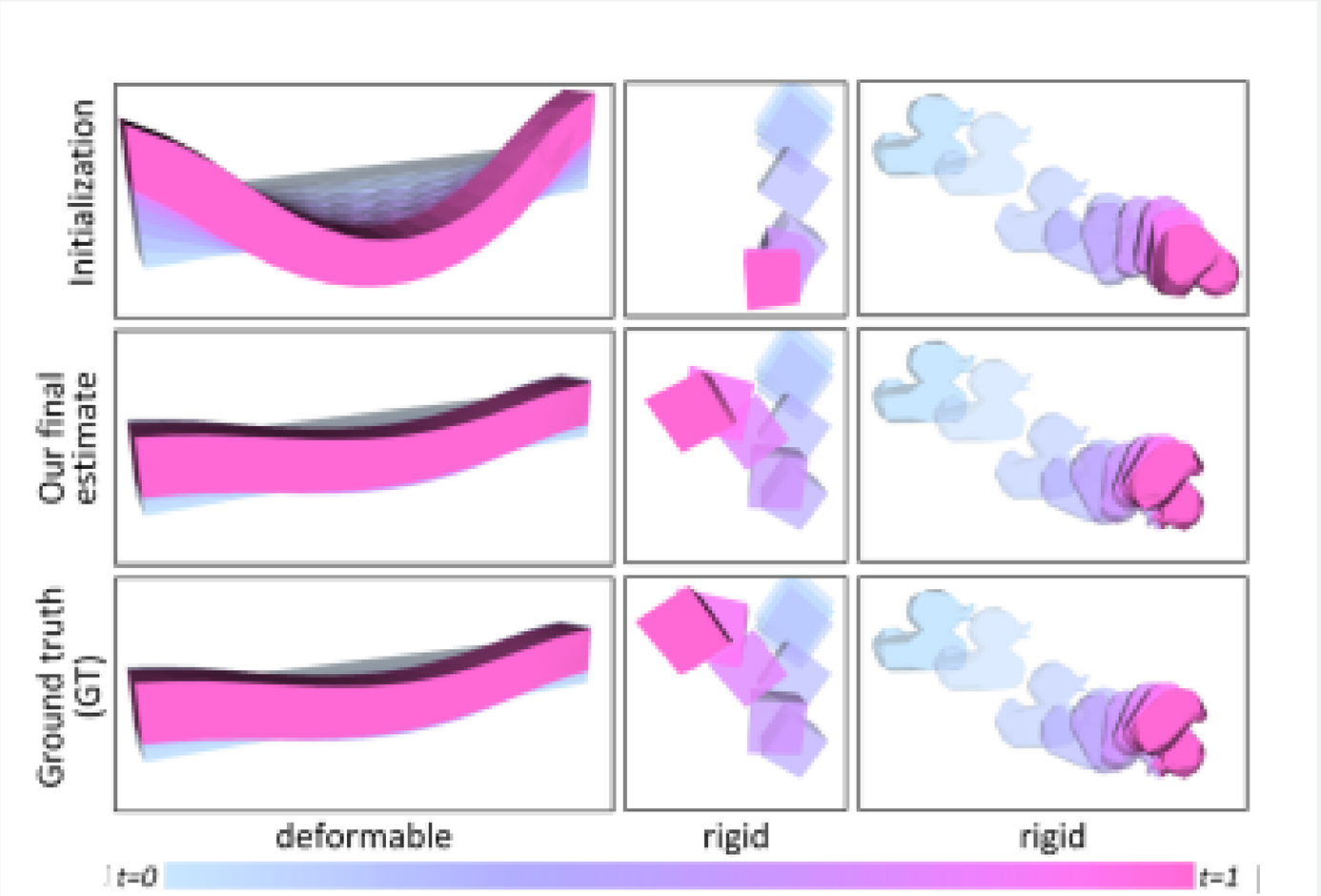
EXPERIMENTS

Multiple experiments were conducted to test the efficacy of ∇Sim on physical parameter identification from video and visuomotor control, to address the a neumerous questions.

PHYSICAL PARAMETERS

Physical Parameter Estimation from Video:

First, we assess the capabilities of ∇Sim to accurately identify a variety of physical attributes such as mass, friction, and elasticity from image/video observations.

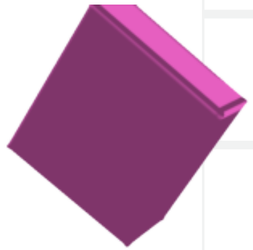

Initialization
Our final estimate
Ground truth (GT)
deformable
rigid
rigid
t=0
t=1

RIGID BODIES

- It was used to assess the accuracy of estimating physical and material attributes of rigid objects from videos.

- A dataset of 10,000 simulated videos was curated, including variations of 14 objects, such as boxes, cones, cylinders, and non-convex shapes.

MASS ESTIMATION



FRICTION ESTIMATION

DEFORMABLE BODIES

- The ability of ∇Sim to recover physical parameters of deformable solids and thin-shell solids (cloth).

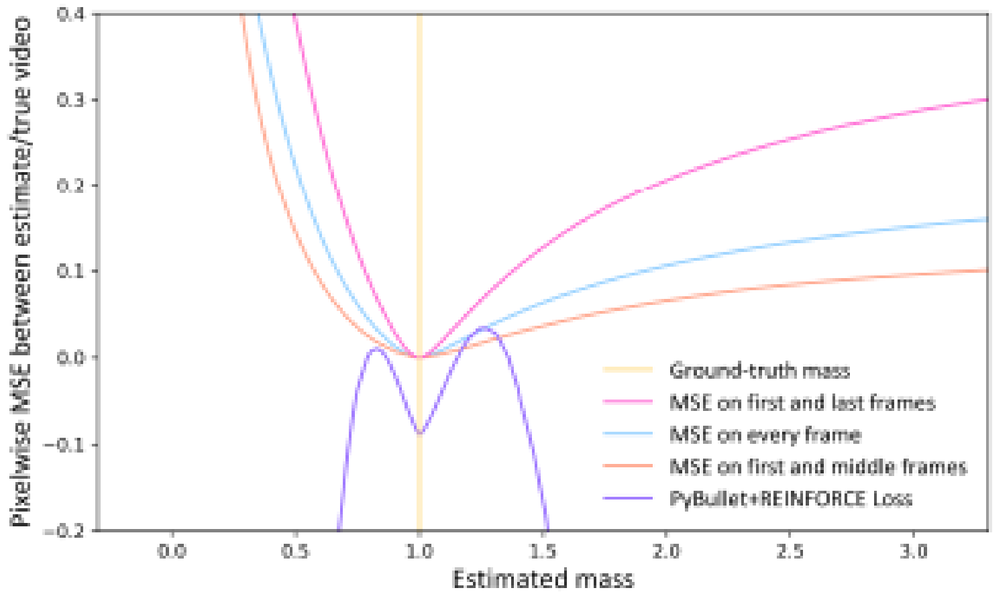
- ∇Sim accurately recovered the parameters for 100 instances of deformable objects, including cloth, balls, and beams.

MATERIAL ESTIMATION

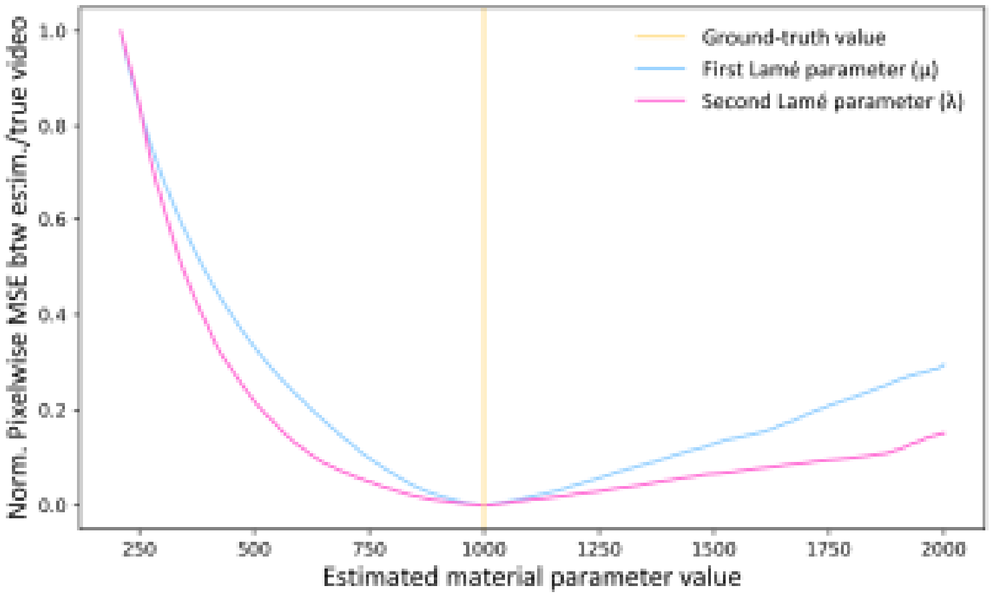
SMOOTHNESS OF LOSS LANDSCAPE

- Analysis has been made on the smoothness of the loss landscape in ∇Sim.

- The loss landscape was examined when optimizing for the mass of a rigid body with known shape while varying the initializations.



(a) **Loss landscape (rigid)**

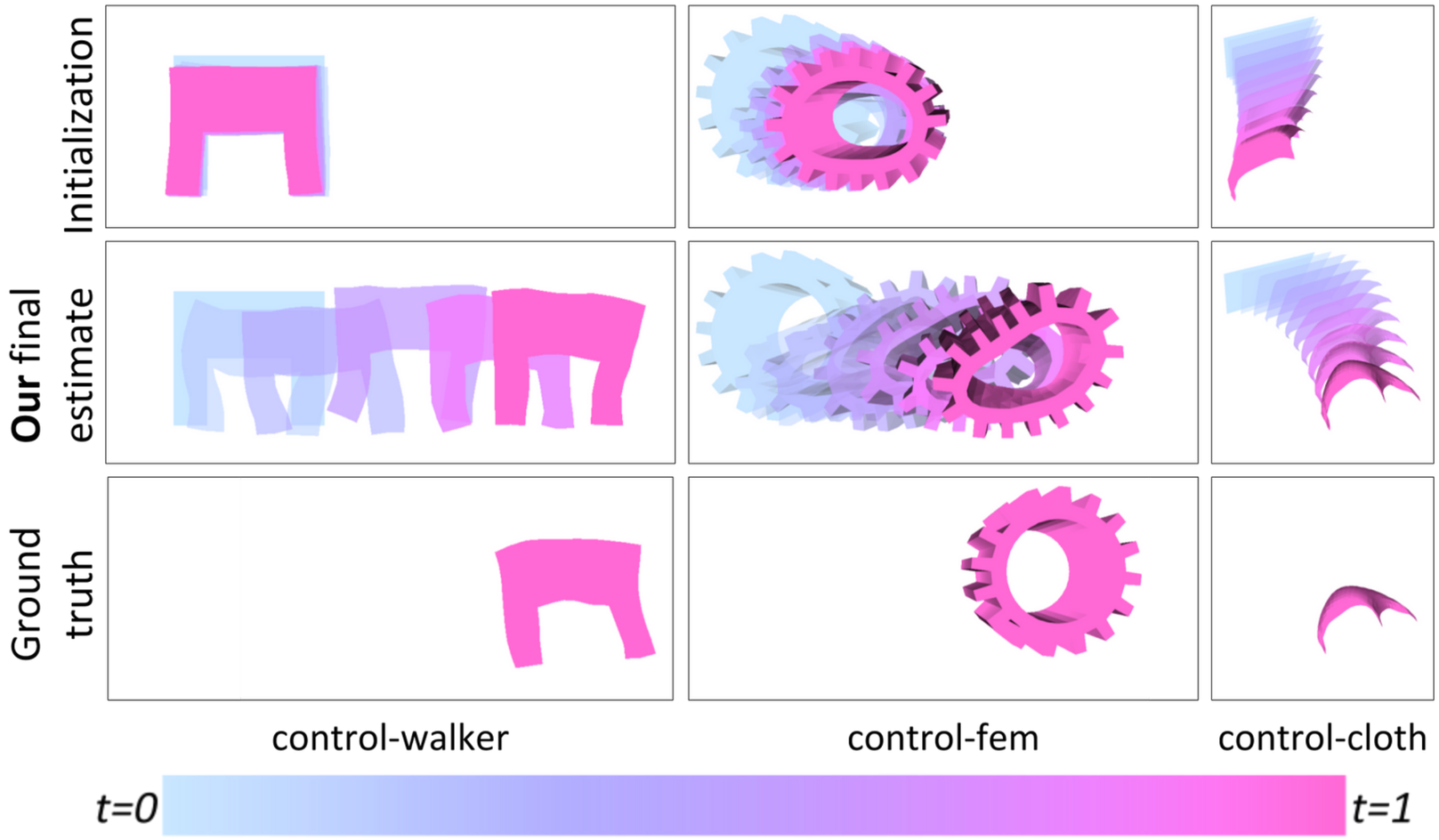


(b) **Loss landscape (deformable)**

VISUOMOTOR CONTROL

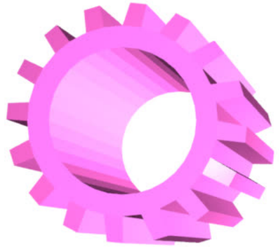
- To investigate whether the gradients computed by ∇Sim are meaningful for vision-based visuomotor control tasks

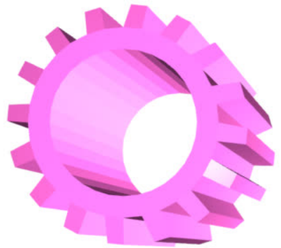
- Two key experiments:
  - Control-Walker
  - Control-FEM.

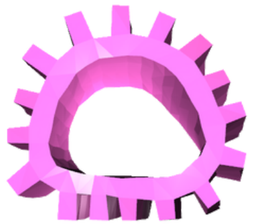

Initialization
Our final estimate
Ground truth
control-walker
control-fem
control-cloth
t=0
t=1

2D WALKER

3D GEAR







CONCLUSION

- ∇Sim is a versatile framework that enables system identification and control from raw video observations.

- We discussed the significance of ∇Sim in addressing complex dynamics and deformations in time-evolving scenes.

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ACKNOWLEDMENTS

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Thank You!