Physics-based training method for manipulation of ropes and clothes

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https://structures.computer/roboticmanipulation

ABSTRACT

This project endows collaborative robots with the ability to intelligently manipulate ropes and clothes in the practical world by creating and using physically realistic models for robot training. Robotic manipulation of deformable objects has tremendous potential in improving quality of life for numerous aspects of daily life. Such objects are generally highly geometrically nonlinear and flexible (e.g., towels, ropes) and can undergo large deformation under moderate forces (e.g., gravity). Robots must be able to intelligently account for this deformation into their control scheme for successful manipulation. We can leverage numerical simulations to better understand the best policies for manipulation that are robust against uncertainties of real world such as friction and material defects.

CHALLENGE

(1) Slender structures can deform significantly under robotic manipulation and other external forces.

(2) Uncertainty, (e.g., friction and material defect), makes robotic manipulation of deformable objects extremely complex.

(3) For true intelligent manipulation, robots should be able to robustly manipulate a wide variety of materials without retraining.

SCIENTIFIC IMPACT

(1) Optimal policies, which are robust against uncertainties (e.g., friction), for flexible object will be developed.

(2) Efficient simulation tools, which are comparable to the real world can be used to predict the motions of deformable objects during operation.

(3) The physics behind the process of robotic manipulation will be analyzed, which when combined with data, will lead to robust robotic manipulation policies.

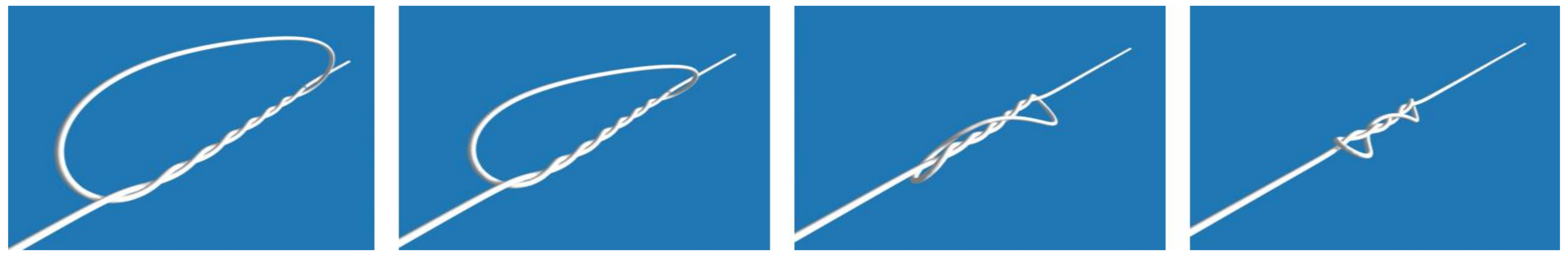
TECHNICAL APPROACH

- Efficient simulation tools based on Discrete Elastic Rods (DER), are developed, simulating the process of manipulating slender structures (e.g., tying knots, folding towels).
- The process of folding work is analyzed with simulation tools to generate a robust optimal policy.

Key innovations:

- Constructing simulation tools for simulating slender structures with contact.
- Optimal policies to folding a towel obtained from simulation can be directly translated to real experiments.
- The proposed scheme is robust against different materials and friction coefficient.

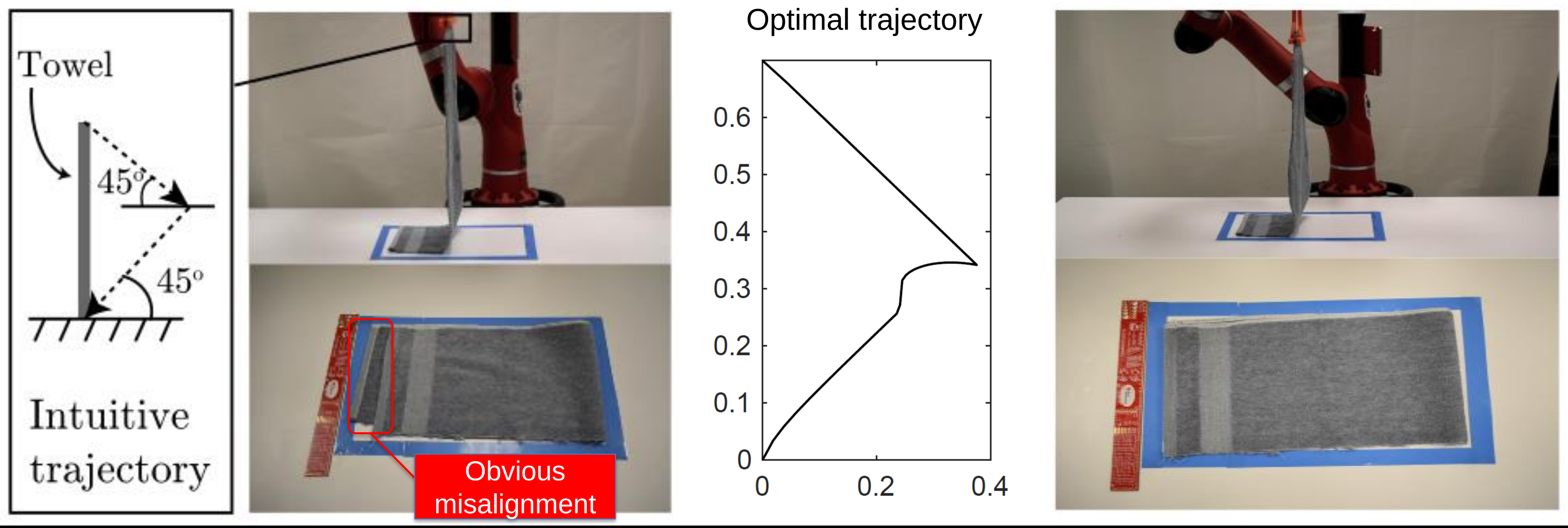
Numerical frameworks for physically realistic simulation



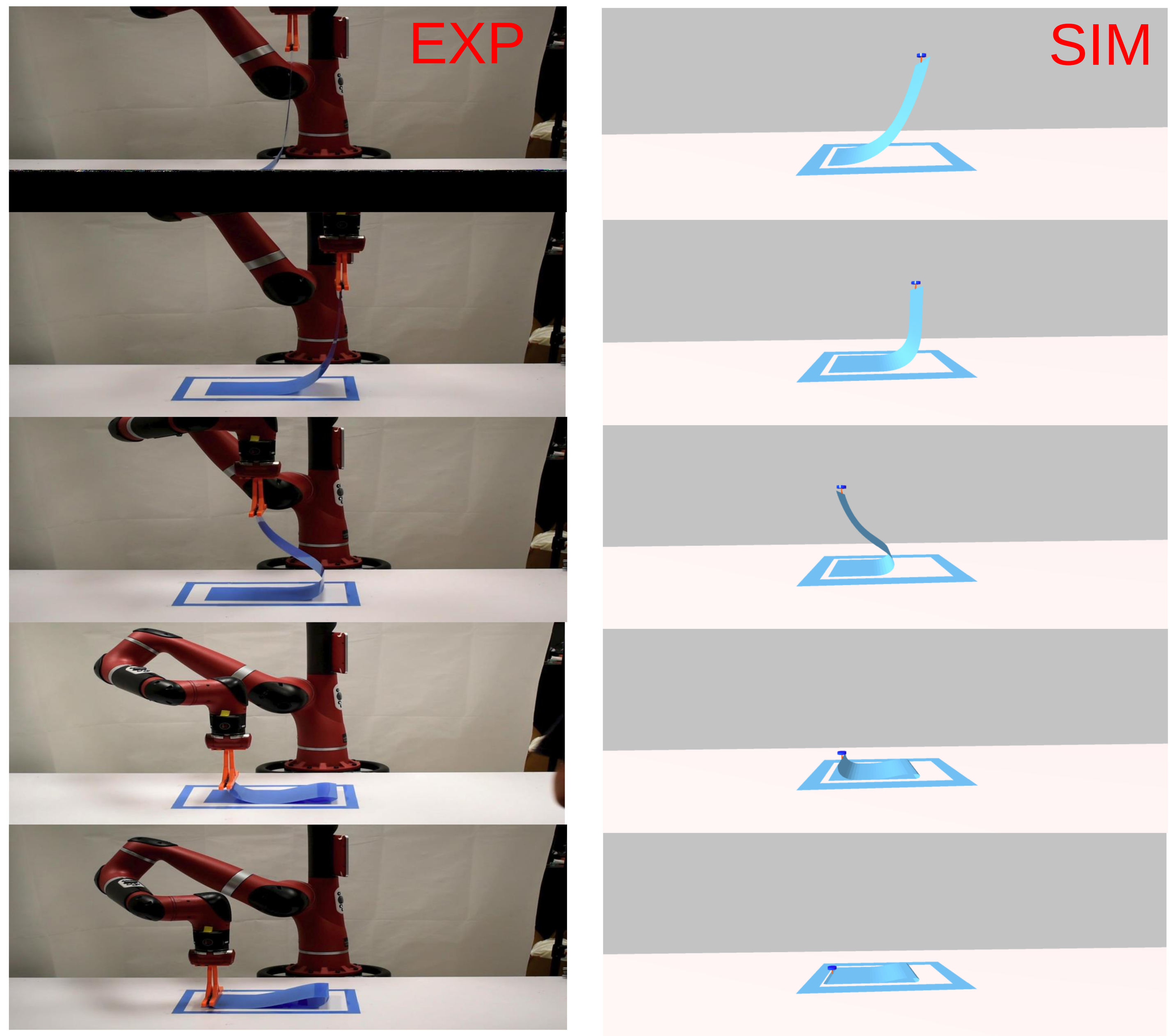
Folding a sheet into multiple layers

Intuition can fail

Physics based policy can fold a towel without misalignment



Experiment snapshot



BROADER IMPACT ON SOCIETY

(1) Physics-based training for robot manipulation enables robots to handle complex tasks, such as tying knots, folding towels and clothes, etc.

(2) Robotics manufacturing, assistance, and service can greatly benefit from robust physics-based manipulation policies.

BROADER IMPACT ON EDUCATION

(1) Training of 1 postdoctoral scholar and 2 graduate students.

(2) New graduate level course on physics-based simulations that uses this project as a case study.

(3) Open-source tools made available for further research or teaching purposes.

QUANTIFIABLE IMPACT

(1) Robust physics-based policies for folding towels without misalignment for a variety of materials.

(2) Direct transfer of learned policies from simulation to robots in the real world.

(3) Development of realistic simulation tools for knot tying and towel folding.

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