ADAPTABLE GEOMETRIC MODELS FOR HANDLING DEFORMABLE OBJECTS

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MOTIVATION

- Deformable objects appear in many robotics tasks, from manipulation to simulation. Modeling their physical behavior such as mass and stiffness is quite challenging.
- **Our goal**: create a method to adapt a physical model to match the behavior of a real object.

TAKE AWAY

- Estimate physical parameters from **real deformation data.**
- ARAP-based simulation + parameter optimization.
- Application to **robotic manipulation tasks.**

PROPOSED METHOD

- We base our approach on the dynamic **As-Rigid-As-Possible (ARAP)** [1] model implemented in C++ using Libigl [2].
- We optimize the **mass matrix and stiffness parameter (S)** by minimizing the difference with a known ground-truth deformation.
- This process enables the model to adapt to **different physical behaviors.**

SIMULATED EXPERIMENTS

Simulated objects (plane, sphere, toroid, …) deformed interactively by dragging handle points.

Non optimized mesh   Optimized mesh
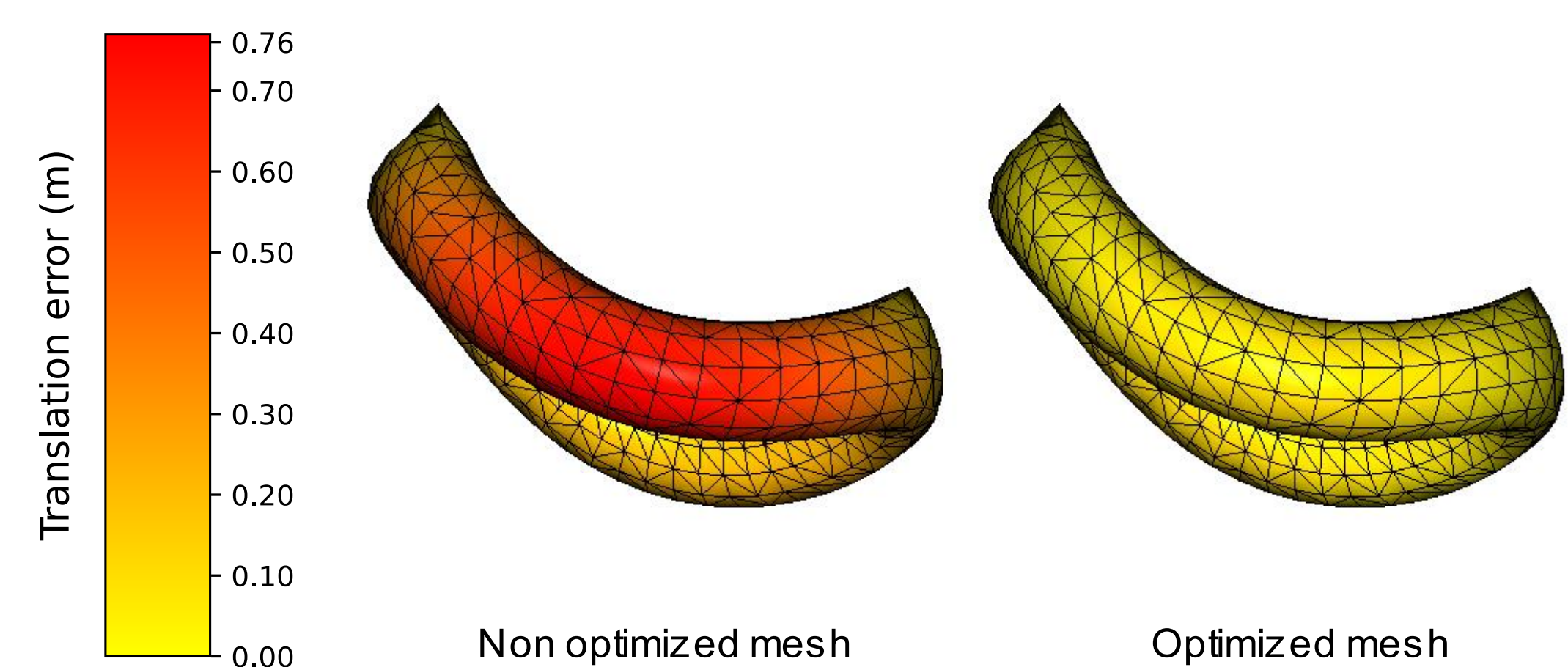
REAL EXPERIMENTS

- To validate our method, we used **pieces of fabric with ArUco markers**.
- We recorded their 3D positions before and after deformation using an RGB-D camera.
- We then ran ARAP with initial parameters and optimized them to minimize error.

Non optimized mesh   Optimized mesh   Captured image
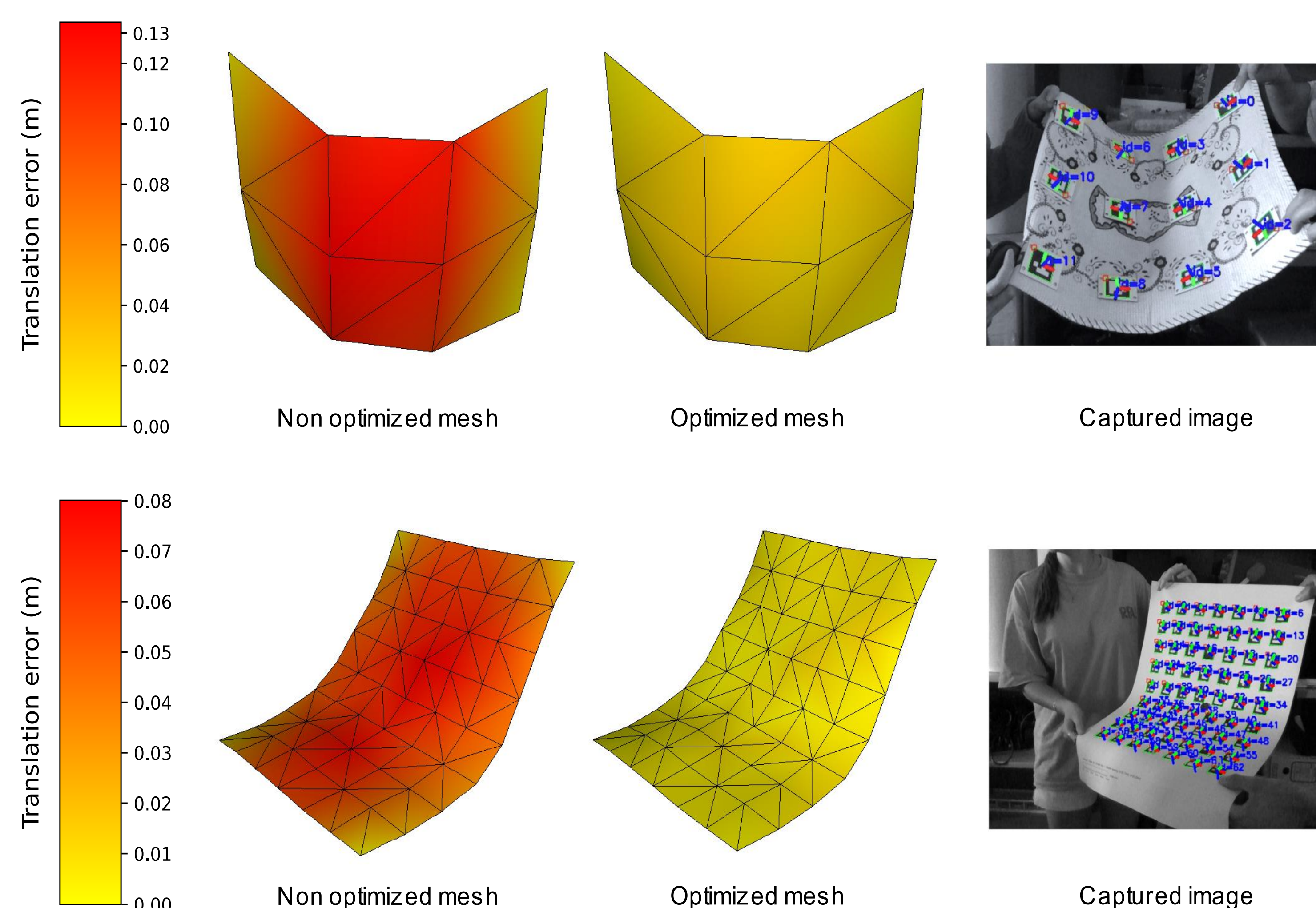
Each row corresponds to a different piece of fabric. In each case: error maps before and after optimization (left), captured image (center), and RMSE vs stiffness plot (right).
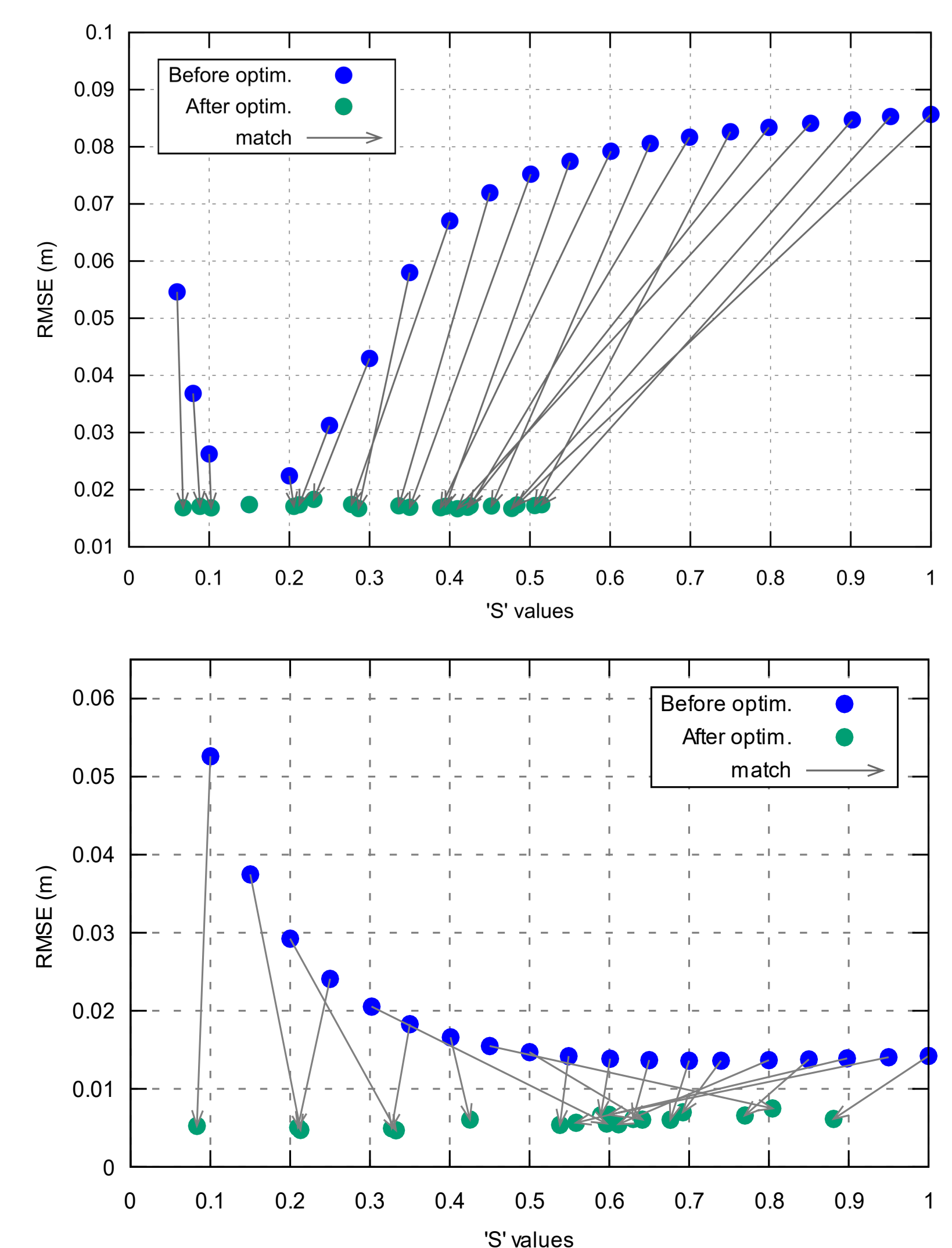
CONCLUSION

- Significant error reduction is observed after optimization in both simulation and real cases.
- Different mass and stiffness combinations can lead to similar deformations.
- **Future work** includes further validation with different objects and configurations.

SPONSORING

[1] Sorkine, O., & Alexa, M. (2007). As-Rigid-As-Possible Surface Modeling. Eurographics Symp. on Geometry Processing.
[2] Libigl. As-Rigid-As-Possible Deformation. https://libigl.github.io/tutorial/#as-rigid-as-possible.