Haptic Modeling of Inhomogeneous Viscoelastic Objects

Gautam Kumar[1], Shashi Prakash[1], Hojun Cha[2], Amit Bhardwaj[1] And Seungmoon Choi[2]

kumar.156@iitj.ac.in prakash.8@iitj.ac.in hersammc@postech.ac.kr amitb@iitj.ac.in choism@postech.ac.kr

[1] Indian Institute of Technology Jodhpur

[2] Pohang University of Science and Technology

Introduction

- This work provides a new approach for modeling of inhomogeneous viscoelastic deformable objects.
- Employs the principles of feature-based learning and perceptual adaptive sampling mechanisms to reduce the dataset.
- A single random forest-fractional derivative (RF-FD) based data-driven model is trained on the reduced dataset.
- The existing clustering based solution in the literature where one model is trained for each cluster.
- Results demonstrate that the proposed approach provides a better prediction accuracy in estimating the responses on inhomogeneous objects as compared to the existing solution in the literature.

Data Collection

- Data is collected using a force-feedback device and a load cell, recording position-force measurements with an inverted cosine force control signal.
- Three physical mockups made of soft silicone (Ecoflex 0010 from SmoothOn Inc.) are used for the experiments, referred to as Object O_1, Object O_2 and Object O_3.
- For each object, data is collected from 200 randomly selected contact locations within a 60 mm by 50 mm modeling area that exhibits a high level of inhomogeneity.

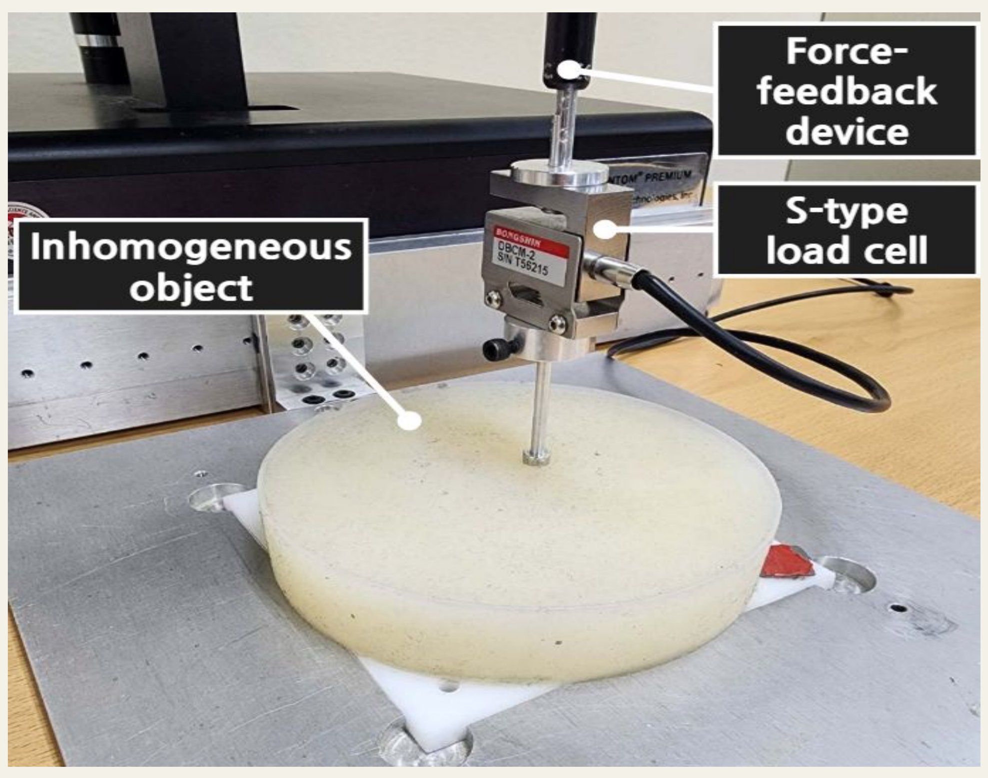
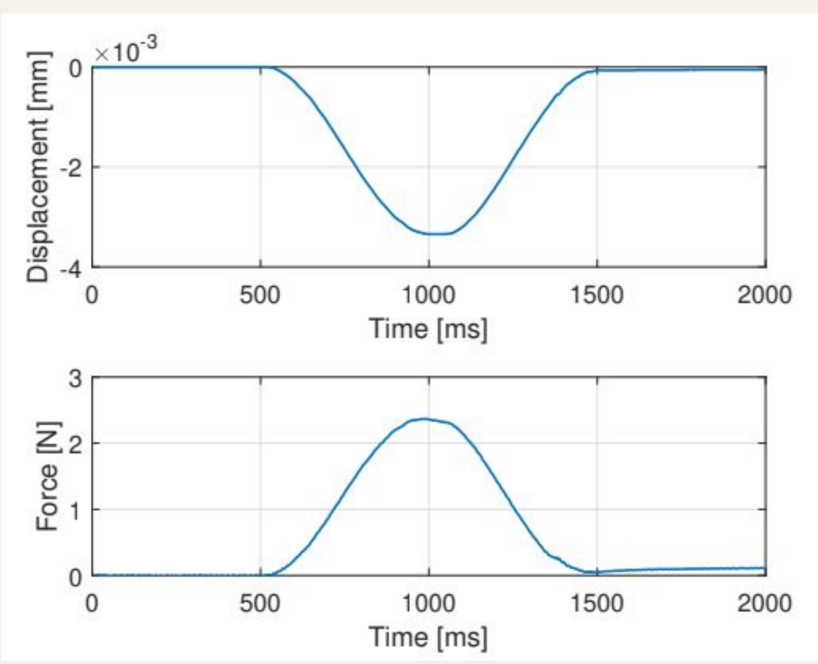
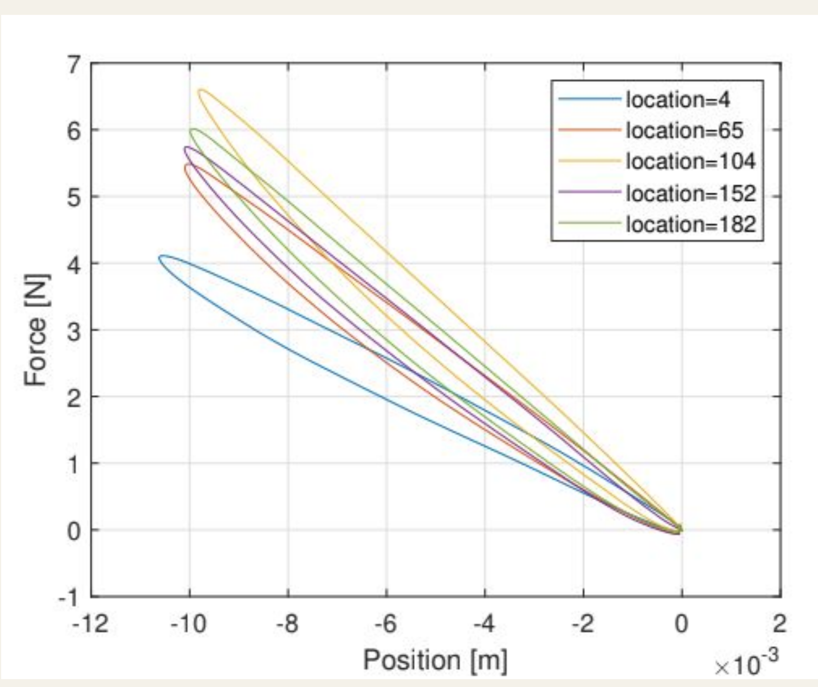


Illustration of inhomogeneity





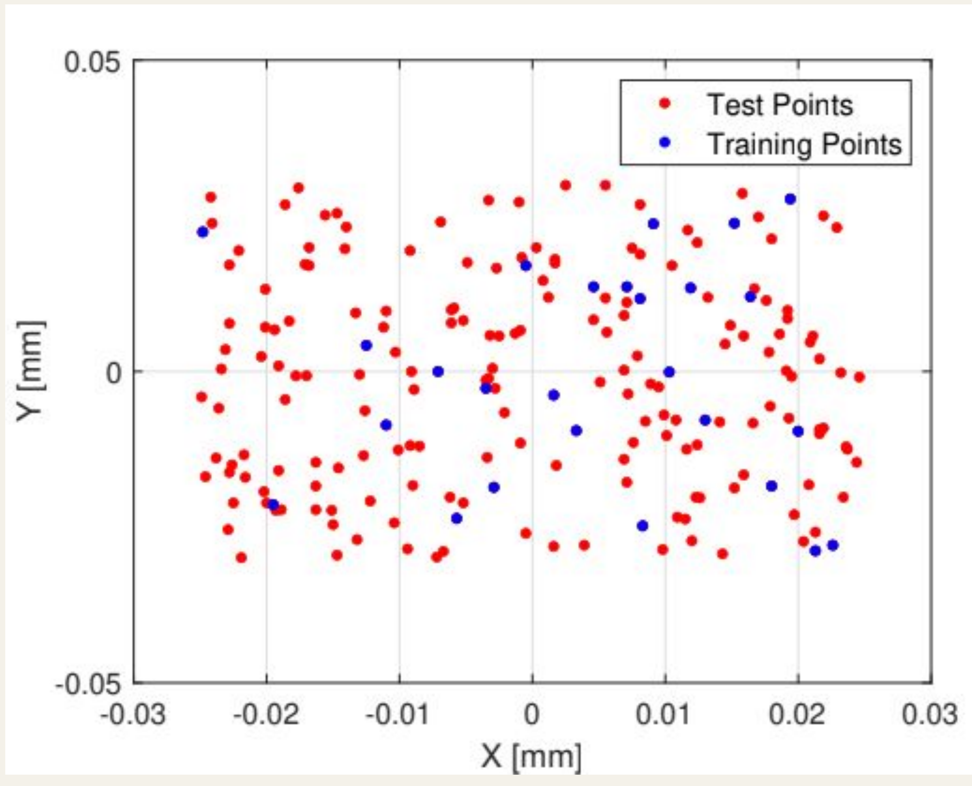
Feature-based Learning and Perceptual Sampling

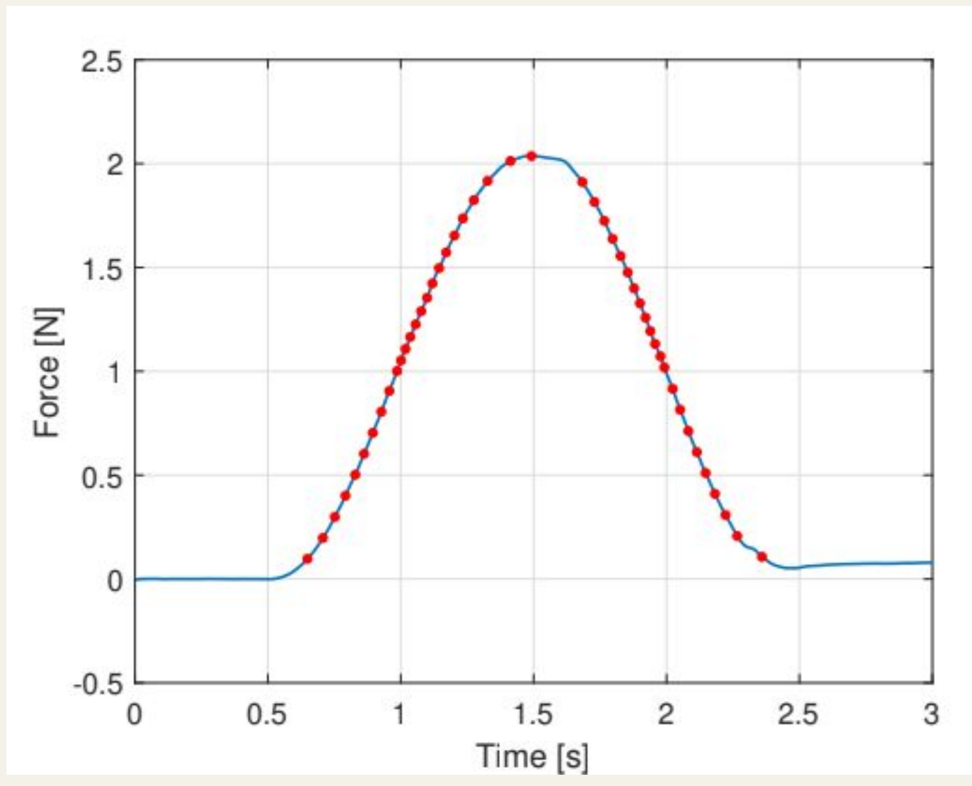
Feature-based Learning for Location Selection

$$f^l \approx c_{0,l} + \sum_{n=1}^{N} \left[c'_{n,l} \cos(n\omega t) + \mathrm{j}\, c''_{n,l} \sin(n\omega t) \right]$$

Perceptual Sampling for Significant Sample Selection:

$$\frac{|f_k^l(j) - f^r|}{|f^r|} > \delta.$$





Haptic Modeling: RF-FD

- A RF-FD (Random Forest with Fractional Derivatives) data-driven model is used to learn a non-parametric mapping function between input (position) and output (force) samples.
- The model's input features include fractional derivatives (FDs) of position information and the X-Y position of the contact location. Ten orders of FDs are used, ranging from 0.05 to 0.50.

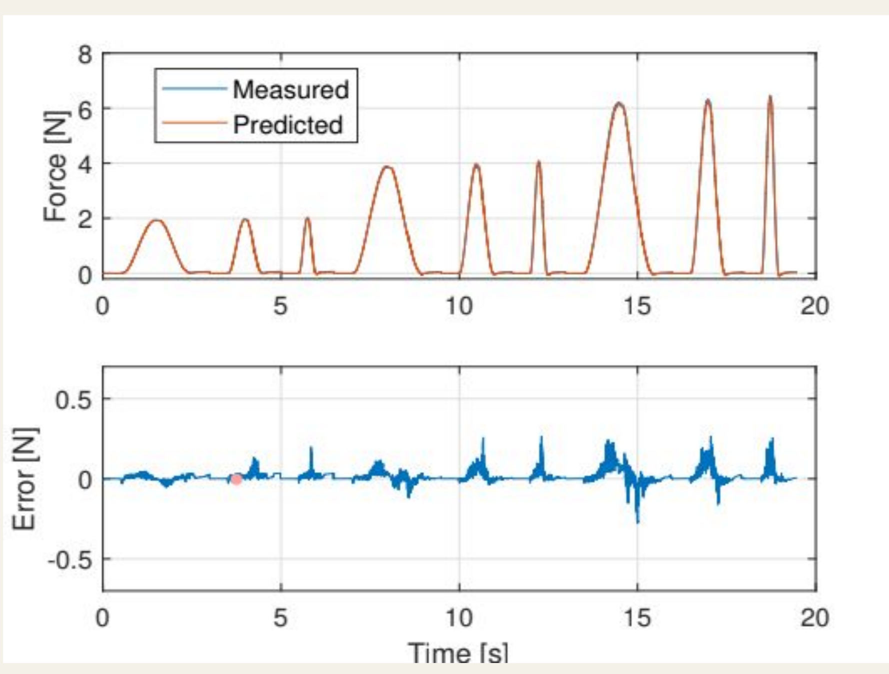
$$I[n] = \left(X, Y, D^{r1}d[n], D^{r2}d[n], \cdots, D^{r10}d[n] \right)$$

$$\mathbf{I}_k = \{ I[i] | I \in \mathbb{R}^{12}, i \in S_k \}$$

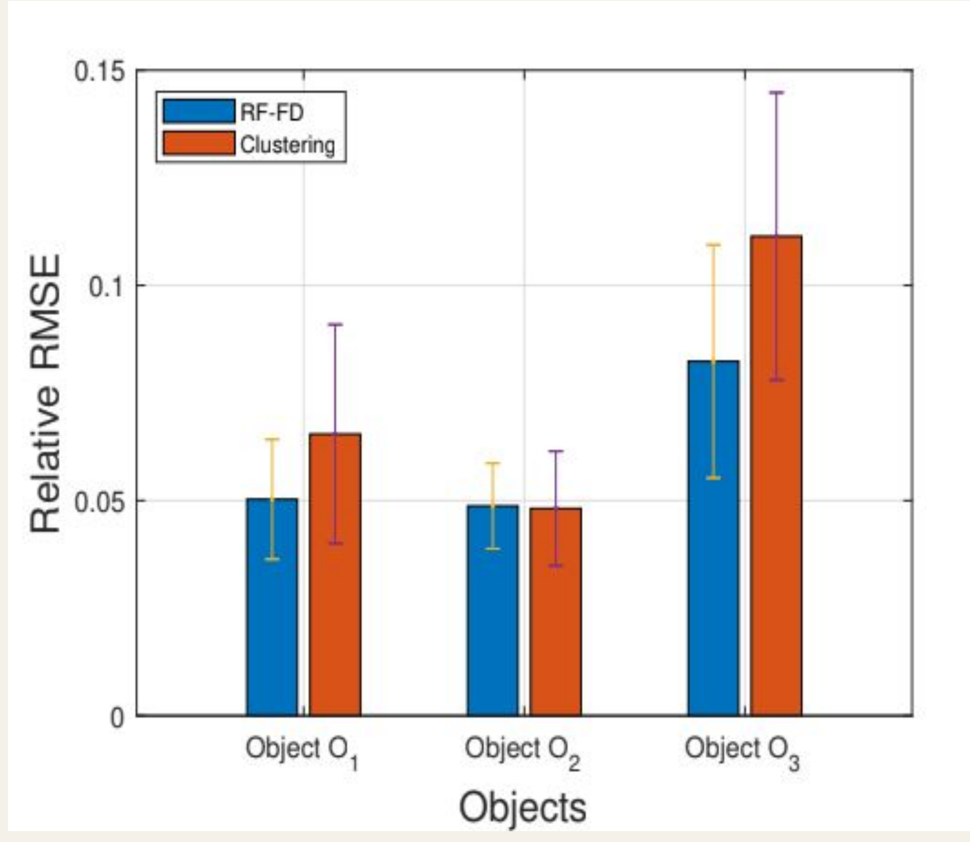
$$\mathbf{f}_k = \{ f_k[i] | f_k \in \mathbb{R}, i \in S_k \}$$

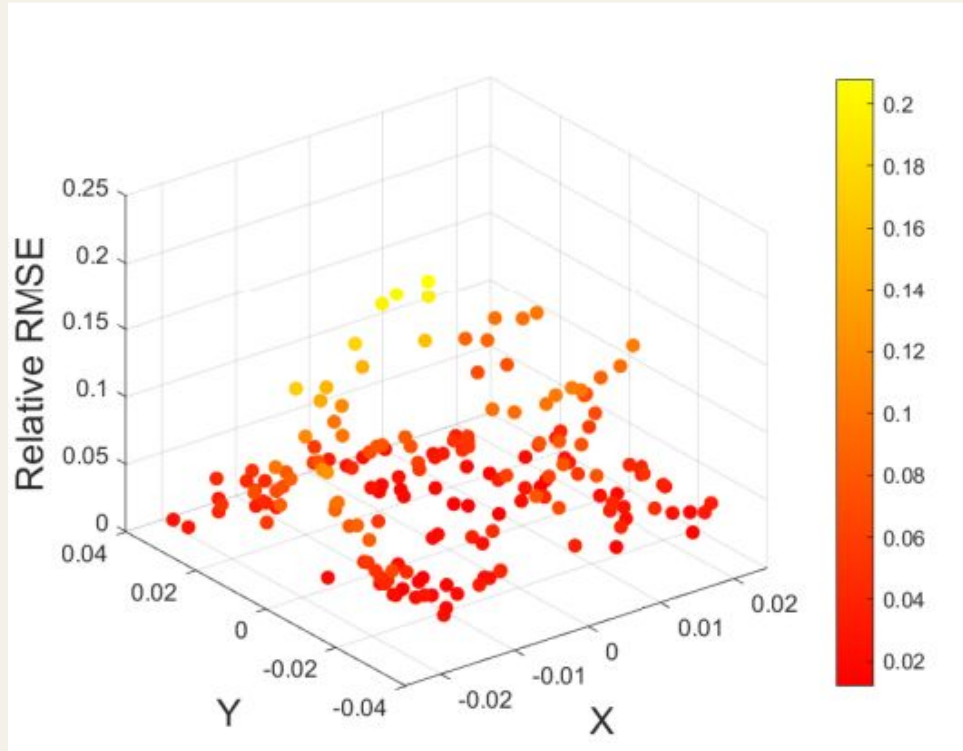
$$\mathbf{I}_g = \{ \mathbf{I}_k | \mathbf{I}_k \in \mathbb{R}^{12 \times \bar{T}_k}, k = 1, 2, \cdots, T_r \}$$

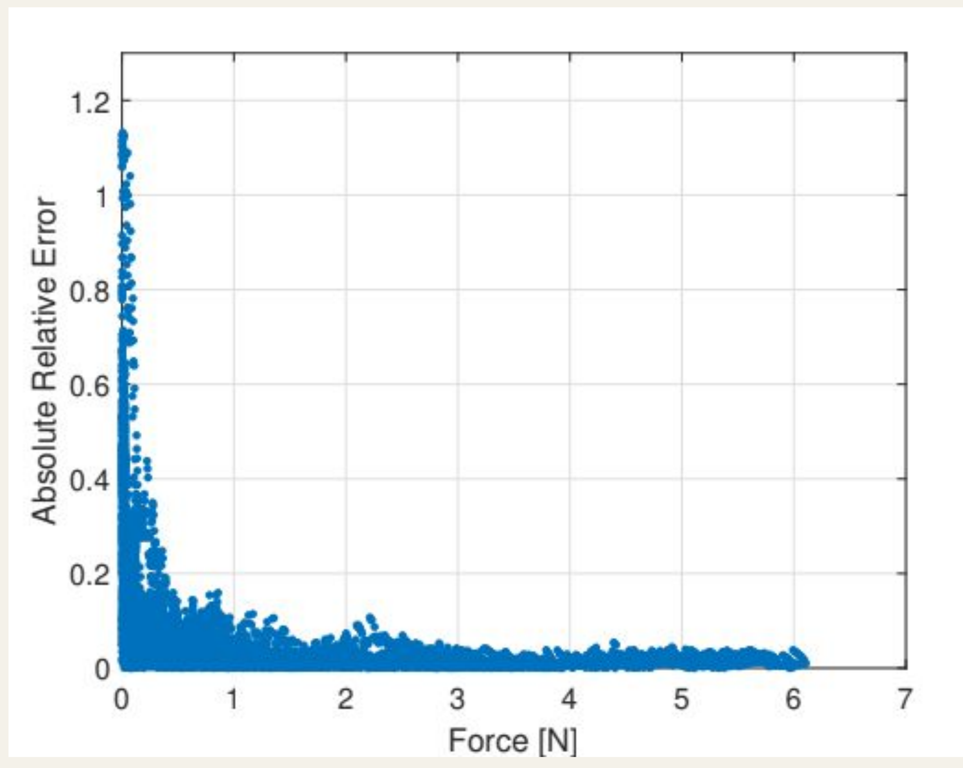
$$\mathbf{f}_g = \{ \mathbf{f}_k | \mathbf{f}_k \in \mathbb{R}^{1 \times \bar{T}_k}, k = 1, 2, \cdots, T_r \}$$



Results







Conclusion

- The approach required to train just one RF-FD based data-driven model on the reduced dataset for modeling an inhomogeneous deformable object.
- Single trained model predicts interactions at unknown locations of the objects with good accuracy.
- Requires a much lesser number of trained models as compared to the existing clustering based solution.
- Provides better prediction accuracy in terms of the RMSE and maximum error..

Acknowledgement

This work was supported in part by a grant from i-HUb Drishti, TIH Jodhpur for a project titled as "Haptics based Medical Simulator for Abdomen Palpation and Pulse Behavior" and in part by a grant from IHFC, TIH IIT Delhi for a project titled as "Telepresence and Teleaction System for Robot Assisted Dentistry"

References

- Sianov, A., Harders, M.: Exploring feature-based learning for data-driven haptic rendering. IEEE Transactions on Haptics 11(3), 388–399 (2018)
- Data-driven haptic modeling of normal interactions on viscoelastic deformable objects using a random forest. IEEE Robotics and Automation Letters 4(2), 1379–1386 (2019)
- Breiman, L.: Machine Learning, chap. 1, pp. 5–32. Springer (2001)
- Haptic codecs for the tactile internet. Proceedings of the IEEE 107(2), 447–470 (2018)

Poster template by ResearchPosters.co.za