Supplemental Material for PhysGNN: A Physics–Driven Graph Neural Network Based Model for Predicting Soft Tissue Deformation in Image–Guided Neurosurgery

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A Finite Element Volume Mesh

Table 1 provides information on the finite element (FE) volume mesh that was used for generating Datasets 1 and 2.

Table 1: Finite element volume mesh statistics.

Attribute	Value
Mesh points	9118
Mesh tetrahedra	55927
Mesh faces	112524
Mesh faces on exterior boundary	1340
Mesh faces on input facets	2992
Mesh edges on input segments	4488
Steiner points inside domain	7618

B Infrastructure Settings

The FE simulations in our study were carried out on quad-core Intel i7 @ 2.9 GHz CPU, while different PhysGNN models were trained on a Google Colab Pro server with 23GB of RAM and one NVIDIA P-100 GPU with 16 GB of video RAM.

C Additional Results

The table below represents the median of absolute error in the x, y, and z directions denoted as δx, δy, and δz respectively, Euclidean error, and absolute position error.

Table 2: Median of the evaluation metrics resulted from the best-performing PhysGNN models on Datasets 1 and 2.

Dataset	Median Absolute Error (δx) (mm)	Median Absolute Error (δy) (mm)	Median Absolute Error (δz) (mm)	Median Euclidean Error (mm)	Median Absolute Position Error (mm)
Dataset 1 Validation	0.0199	0.0228	0.0221	0.0531	0.0303
Dataset 1 Test	0.0200	0.0227	0.0224	0.0537	0.0303
Dataset 2 Validation	0.0436	0.0537	0.0538	0.1295	0.0656
Dataset 2 Test	0.0426	0.0534	0.0529	0.1285	0.0646

D   Comparison to Similar Studies

The summary table below compares our results with a few similar studies based on empirical grounds.

Table 3: Comparing our method with other studies on empirical basis.

Study	Number of Nodes in the FE Mesh	Maximum Displacement in the Dataset(s) (mm)	Mean Absolute Position Error (mm)	Mean Euclidean Error (mm)	% of Euclidean Error Below 1 mm	Average of Maximum Euclidean Error per Simulation (mm)
Tonutti et al. [2017]	1087	—	0.191	0.18	—	—
Lorente et al. [2017]	318960 – 494310	15	—	0.07	100	—
Liu et al. [2020]	1158	30	—	0.129	98	0.483
	1158	30	—	0.392	98	1.011
PhysGNN (ours)	9118	24.5864	0.1612	0.2049	95.11	2.5924
	9118	47.8233	0.2023	0.3023	94.60	4.1952

References

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