Modeling bending direction of a Soft Arm Manipulator using Regressive Neural Networks

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Background

- Though they offer safer and diverse operation due to their compliant nature, the imperfections involved in manufacturing and the pillow-pushing structure of the Soft-Poly Limb [1] introduce a lot of unpredictable behaviour that will be impossible to model using analytical methods.
- Instead of trying to model all robot characteristics exactly, approaching the problem with machine learning tools reduces computational load and permits iterating through a larger range of modelling characteristics, aiding optimization.

Fig 1: Soft Arm Manipulator Bending: Changing the pressure in the robots' three pressure chambers allows the robot to bend.

Research Question

- The lack of rigid structures results in the actuation not linearly correlating with the bending observed in the robot.
- This study focuses on modeling said the non-linear deviation in the bending direction of the robot by regressively solving for it using neural networks.

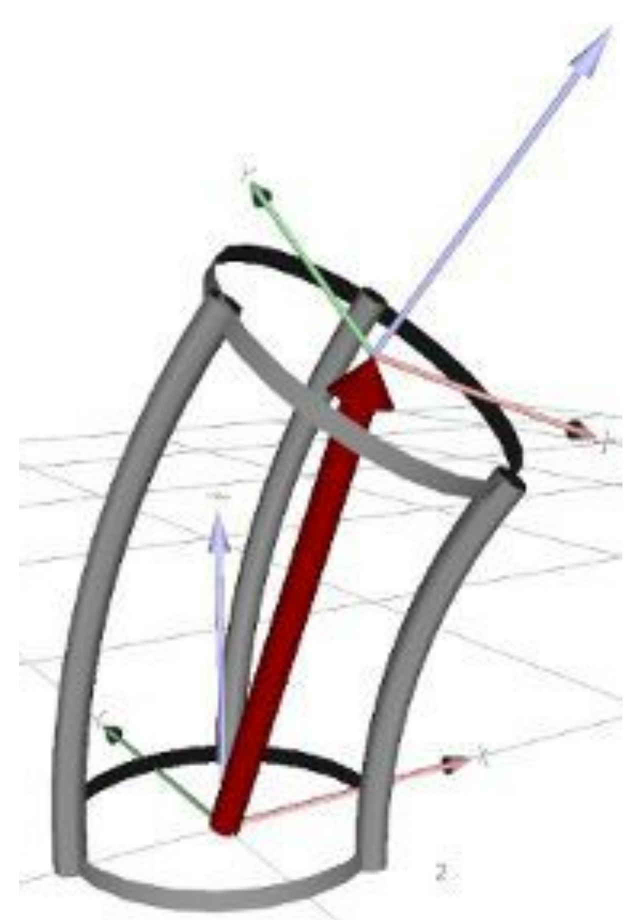

Fig 2: Motion capture model of soft arm[3]: position and orientation of the top plate, relative to the bottom plate, tracked using motion capture, can be used to calculate φ, or bending direction.

Methodology

- The routine for collecting data was designed such that the robot reaches certain predetermined poses and holds them.
- The model was iteratively tweaked as the data was conditioned until the it satisfactorily predicted the robots bending, Fig 4.

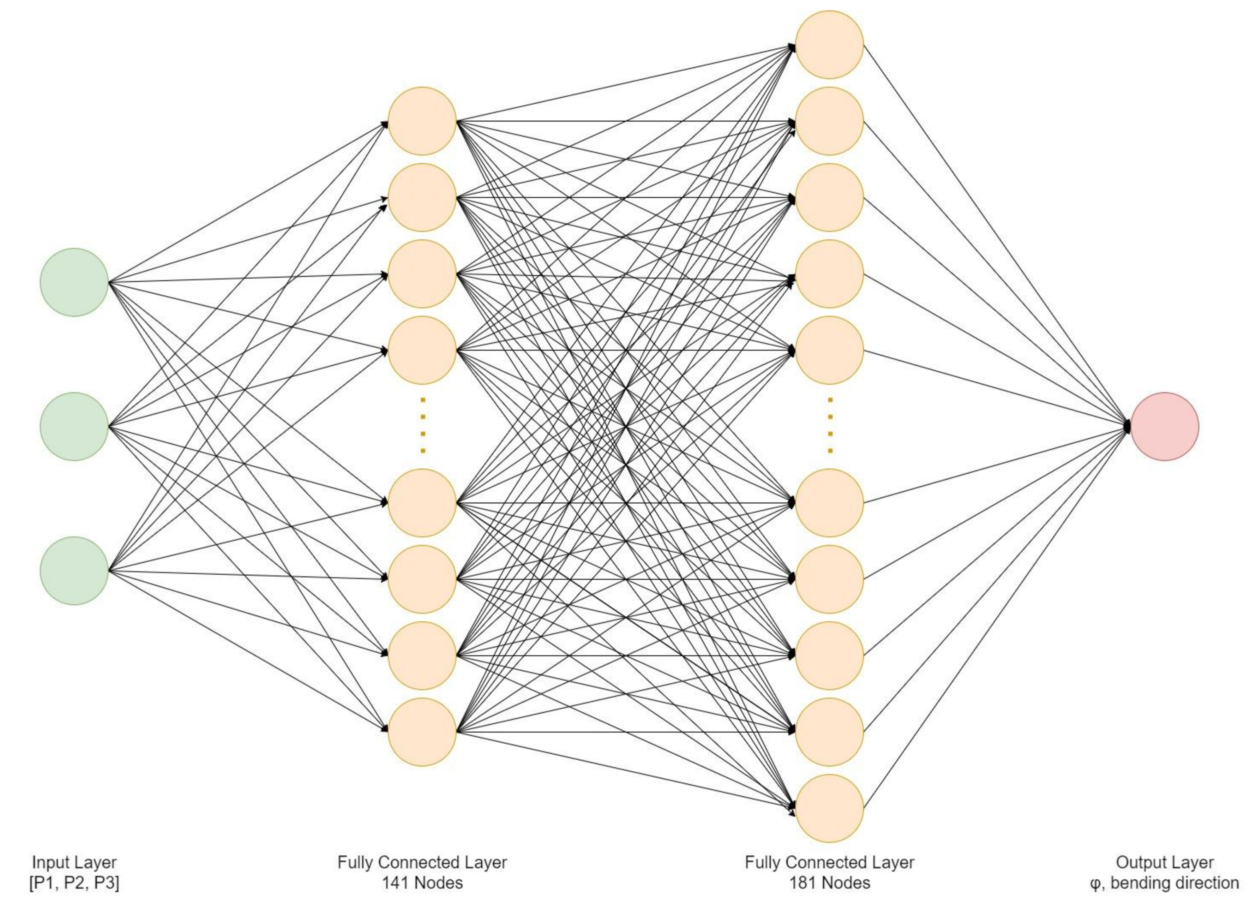

Fig 3: Final Neural Network model structure: using the 3 chambers pressures as input and the bending direction as output, the current best NN model as 141 and 181 nodes on its fully-connected layers.

Machine Learning Framework	RMSE	% error
Gaussian Process Regression	0.2346	15.2220
Support Vector Machines	0.2513	16.3032
Neural Network	0.0747	2.9048

Table 1: Comparing frameworks: Before finalizing on Neural Network, multiple machine learning frameworks were explored, like Gaussian Process Regression and Support Vector Machines.

Findings & Inferences

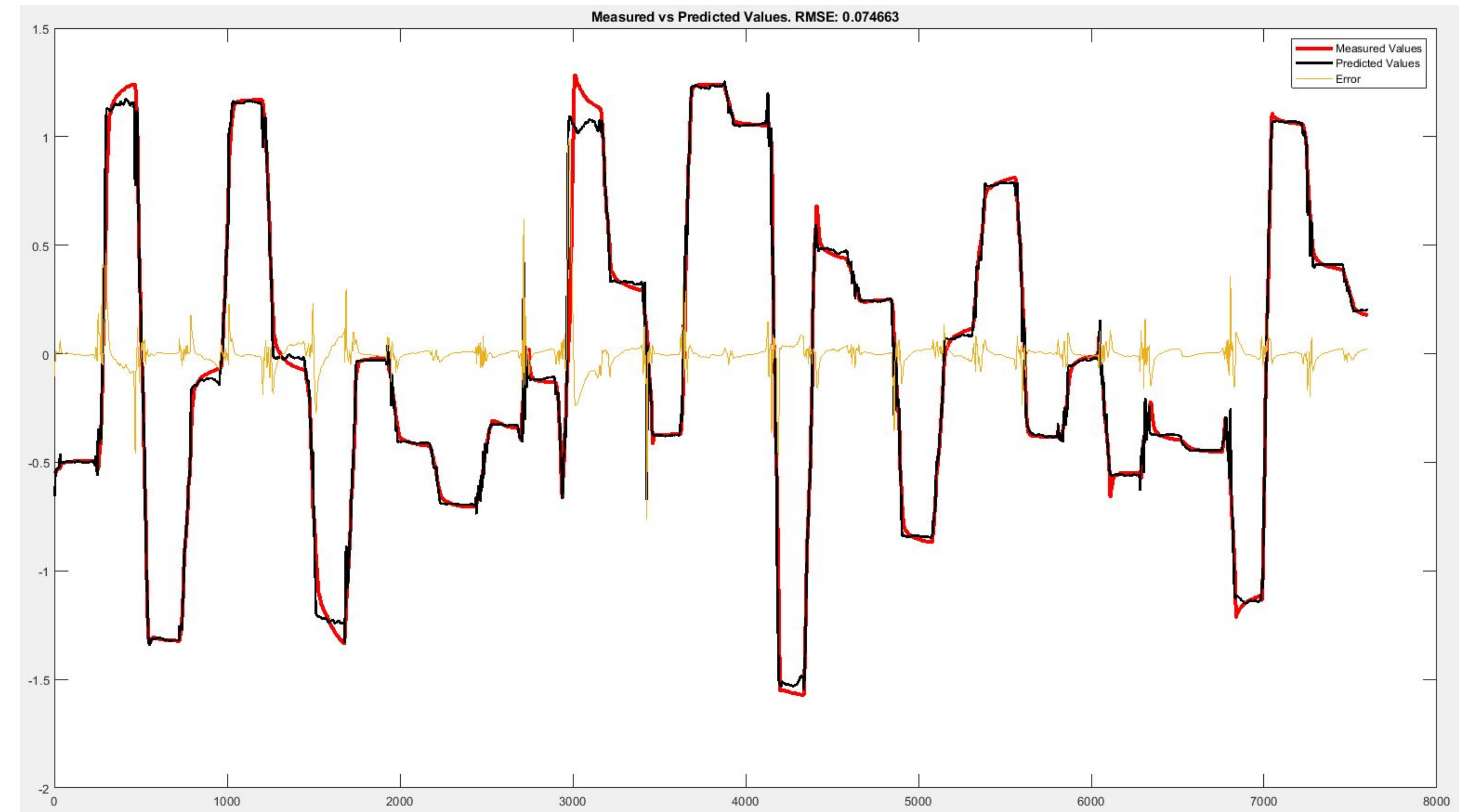

Fig 4: Measured vs Predicted Values: bending angle as measured using motion capture (red) and predicted response from current best NN model (black). Error can be observed to be small compared to φ and spikes as the robot changes direction.

- The current best model, Fig 3, with an RMSE of 0.0747 radians or a 2.9048% error is a feasible tool for further work with the soft arm manipulators, like creating a controller.
- Furthermore, the process followed for this project can be used as a framework for modeling similar behaviours observed in soft arm manipulators with different materials and constructions.
- Future work could including adding the observed bending angle as an input, reduces the RMSE to 0.0303, or a 1.1789% error.

References

[1]: Huy Nguyen, Pham & Mohd, Imran & Sparks, Curtis & Lopez Arellano, Francisco & Zhang, Wenlong & Polygerinos, Panagiotis. (2019). Fabric Soft Poly-Limbs for Physical Assistance of Daily Living Tasks.
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[3]: M. Rolf and J. J. Steil. (2012). Constant curvature continuum kinematics as fast approximate model for the Bionic Handling Assistant.

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