Simulation of Deformation

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Abstract— **For homework 3, simulations are done with the combination of machine learning. Specifically, students go over the simulations for different cases: (1) deformation of a rod (2) deformation of a beam and they create neural network and machine learning models for each case.**

I. Introduction

In the last homework of MAE 259B class, students do the simulations for the motion of a sphere and a two-edge beam hanging under gravity. For each case, a neural network and machine learning model is used for a prediction.

II. Deformation of a sphere under gravity

To simplify the equation for the x and y position of the sphere, we assumed that the spring constant at each spring is the same.

A. How many input parameters do you need

With the assumption, the required input parameters to invert the mass of sphere becomes the spring constant and Y position of the sphere. The gravitational acceleration should also be considered for the model, but it can be treated as a constant. So, in my model, two input parameters are necessary.

B. What is the prediction error of your neural network model

The given template code shows that the error of neural network model should converges to 0.289. My neural network model has a problem that the batch loss does not converge, and rather, it fluctuates. The prediction error of my neural network model is about 0.15.

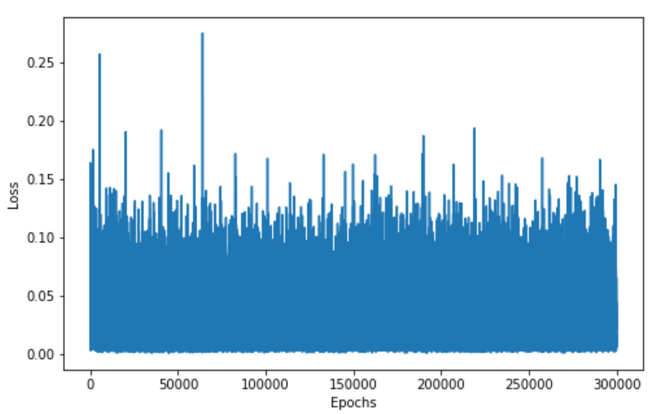

Figure 1. All loss per number of epochs

Figure 1 shows the value of all losses per number of epochs, and the graph does not converge. It is because we simplified the model with the assumption that two spring constants are the same.

III. Deformation of a two edge beam under gravity

In this section, machine learning models are used to derive the relationship between $E(t) and\ \theta(t)$. For the first part, neural network model is used and a neural ode model is used for the second part.

A. What is the performance of the neural network model

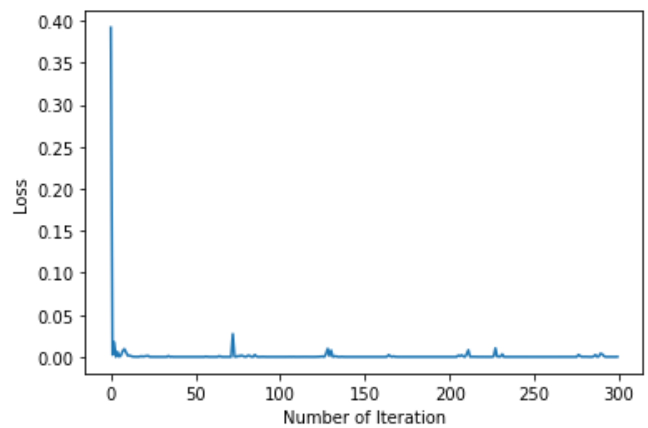

Figure 2. Loss per number of iterations

Figure 2 shows the loss per number of iterations for our neural network model. It shows that the loss declines as the number of iterations increase.

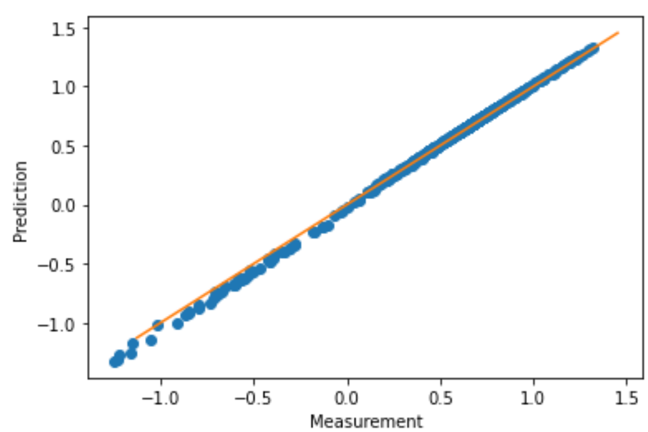

Figure 3. Prediction VS. Measurement

Figure 3 shows the performance of the neural network model, and we can see that the performance is reasonable. The prediction matches well with the real value.

B. What is the performance of the neural ode model

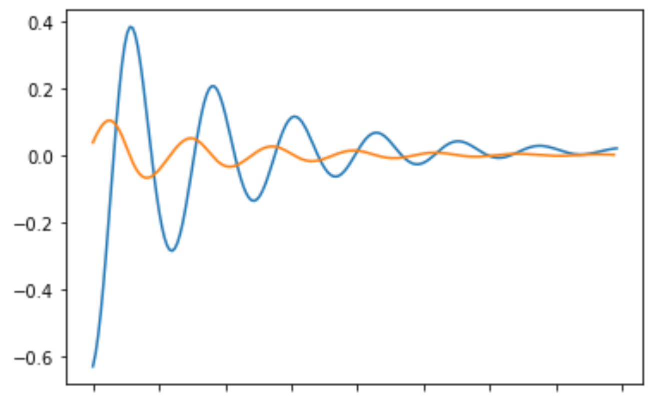

Figure 4. Displacement and velocity during the time section

The blue line graph in the figure represents the displacement and the yellowish line graph in the figure represents the velocity.

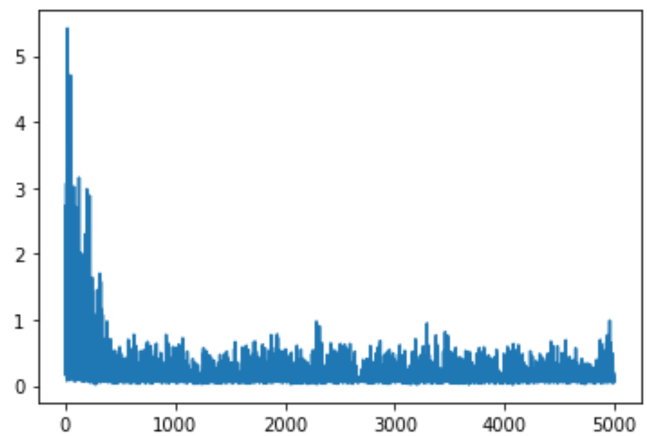

Figure 5. Lossall for ODE model

Figure 5 shows the loss for the neural ODE model. The model is trained by the given .mat files. Now the trained model is used to predict the test data

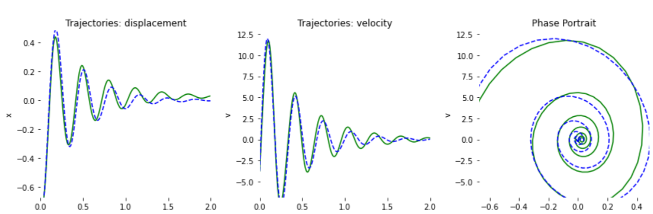

Figure 6. Trajectories for displacement and velocity, and phase portrait when test total loss = 1.621561

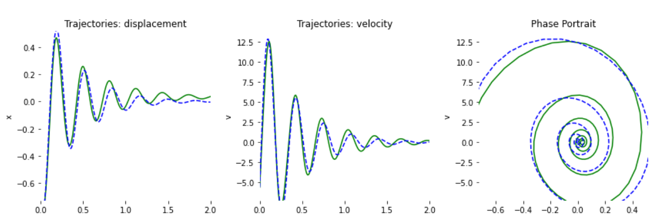

Figure 7. Trajectories for displacement and velocity, and phase portrait when test total loss = 1.751765

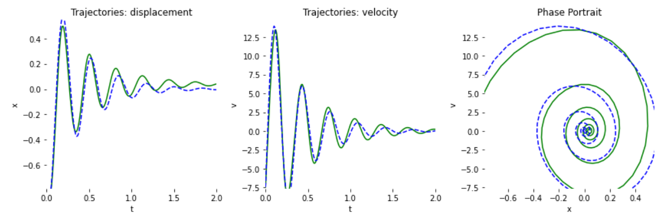

Figure 8. Trajectories for displacement and velocity, and phase portrait when test total loss = 1.897863

Figure 6,7, and 8 show the trajectories graph for displacement and velocity, and the figures also show a phase portrait graph. The difference for each graph is the value of test total loss. We can see that the range of the graph increases as the total loss increases. Also, the predicted values agree with the actual value, and we can see that the prediction from the practiced model is reasonably precise. Finally, the gradient and energy can be checked.

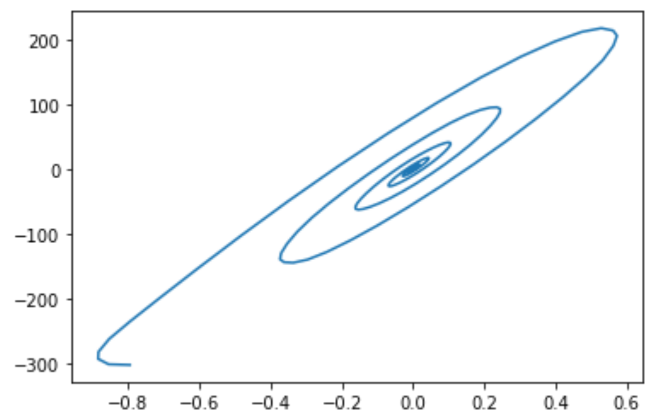

Figure 9. Displacement VS. spring force

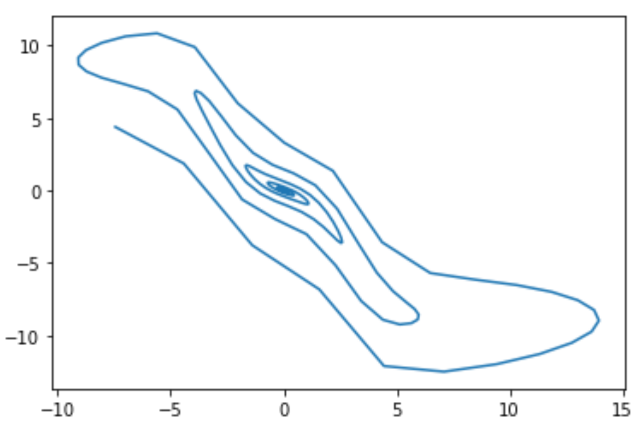

Figure 10. Displacement VS. spring force

Figure 9 and 10 shows the graphs of displacement per spring force. The difference between two graphs is that the range for all the forces are different.

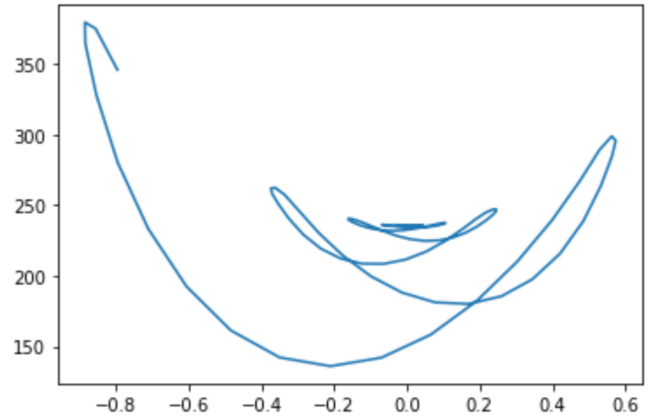

Figure 11. Velocity VS. Damping force

Figure 11 shows the velocity data per damping force.

IV. Conclusion

In this homework, students did the simulations for a sphere and two edge beam hanging under gravity using neural network and machine learning model. For the simulation of a sphere, they also showed the prediction error of neural network model. Through this assignment, students got more familiar with machine learning modeling using Python and how to use the it for a simulation. For the first part of the homework, the result I got was different with what it supposed to me, and it means that my neural network model. I need to find out a way to make the batch loss converges.

Acknowledgment

I would like to express my gratitude to Professor Khalid and Doctor Leixin Ma who guided students this homework during the class.

References

[1] HW3_Q1.ipynb
[2] HW3_Q21.ipynb
[3] HW3_Q22.ipynb