MECH&AE 263F Homework 1 Deliverables

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***Abstract*— This electronic document contains the plots and answers to questions within the first homework assignment of the MECH&AE 263F class within UCLA. Sections were created appropriately for different problem statements to be answered.**

I. Deliverable 1

This deliverable required the creation of an executable script for simulating falling connected spheres within a liquid, both with specified physical properties. The simulation time ran for 10 seconds, had timesteps of 0.01 seconds, and simulated three connected spheres. The following were asked to have responses:

1. Plots for the position and velocity of the middle sphere at times: 0s, 0,01s, 0.05s, 0.10s, 1.0s, 10.0s.
2. The observable terminal velocity of the simulation
3. Observed behavior of the turning angle when the radii are the same
4. Benefits and downsides of solving through implicit versus explicit methods within the simulation

A. *Plots for specified times (1)*

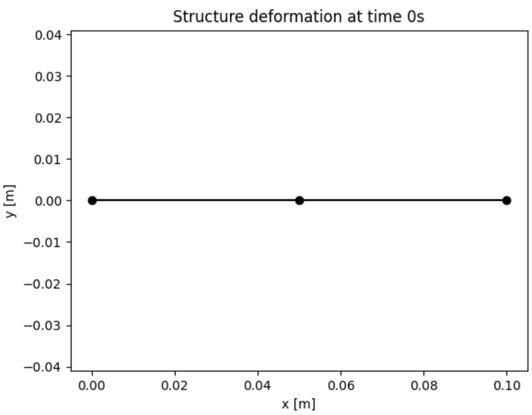

Figure 1. Plot of structure at 0s of the implicit method

*Generation of the graphs through usage of python. Algorithms for calculating energy gradients, Jacobians, and simulation code were based off scripts provided by Professor M. Khalid Jawed

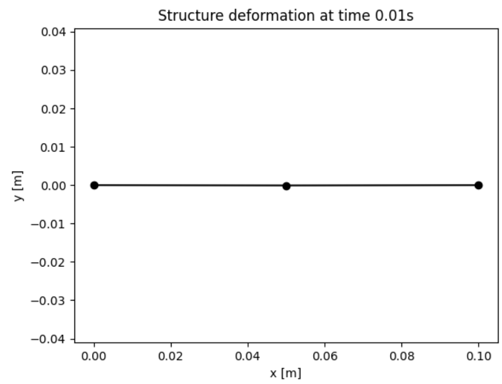

Figure 2. Plot of structure at 0.01s of the implicit method

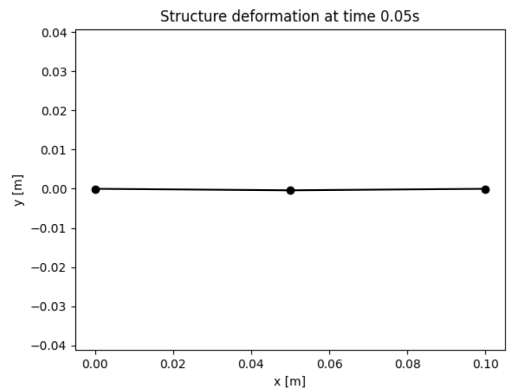

Figure 3. Plot of structure at 0.05s of the implicit method

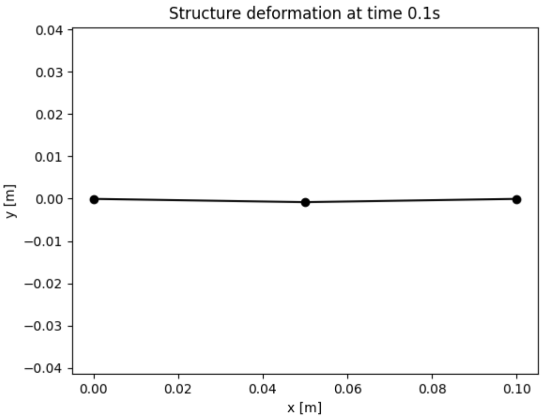

Figure 4. Plot of structure at 01s of the implicit method

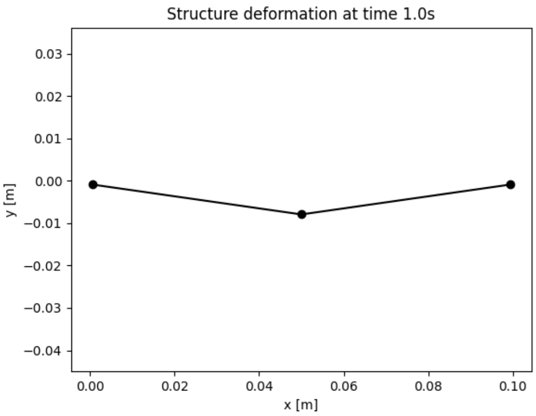

Figure 5. Plot of structure at 1.0s of the implicit method

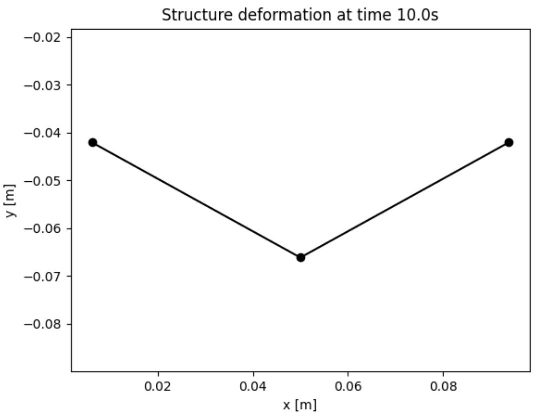

Figure 6. Plot of structure at 10.0s of the implicit method

B. Observed Terminal Velocity (2)

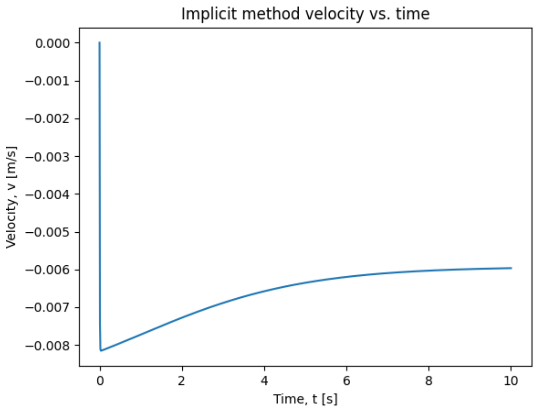

Figure 7. Plot of structure vertical velocity from the implicit method

From the above figure, the terminal velocity can be seen to be around 0.006 m/s, as it is the value the velocity plateaus at towards the end of the simulation.

C. Turning Angle Behavior (3)

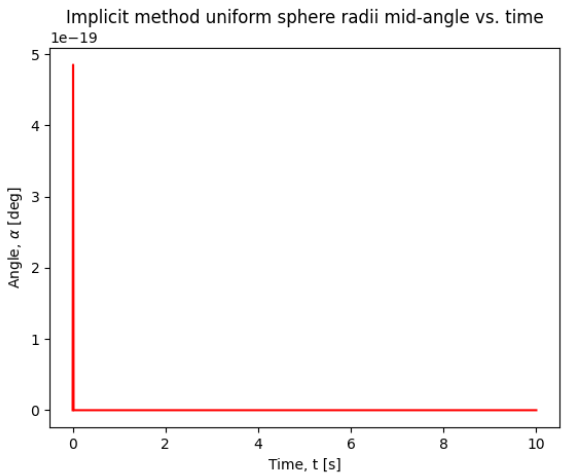

Figure 8. Plot of structure turning angle at the middle node

From the above figure, the turning angle can be seen to be 0 throughout the simulation, as the peak in the beginning has a relatively small scale. This is expected as the equal node radii gives equal amounts of viscous forces from the surrounding liquid, giving equal forces applied to all nodes or spheres, thus giving the same behavior in displacement and velocity. This then gives a resulting value of zero for the angle, as the displacement of the spheres is the same, keeping the structure in a straight line throughout the simulation.

D. Implicit versus Explicit Methods (4)

Explicit methods are prone to giving results not as representable of the actual situation if the time step isn't small enough when chosen. In cases where the time step is relatively large, the simulation may not converge. However, if too small of time steps are chosen for the method, the added time of computation of the simulation may cancel out the benefits of its simpler calculations, while also being more prone to errors from precision within the computational machine used for the simulation.

The implicit method is the more involved form of the calculation, where an exact form of the movement equation is given for the computation, requiring the use of root finding methods such as Newton-Raphson to obtain the solution of the position and velocity at specified times. The usage of this method then requires for larger computational time in exchange for better overall accuracy for a specific time step.

II. Deliverable 2

This deliverable required the creation of a simulation of 21 nodes within a time of 50s and a time step of 0.01s. The following were specifically asked for responses:

1. Plots for the position and velocity of the middle sphere, along with the observed terminal velocity
2. The final deformed shape of the system.

A. *Selecting a Template (Heading 2)*

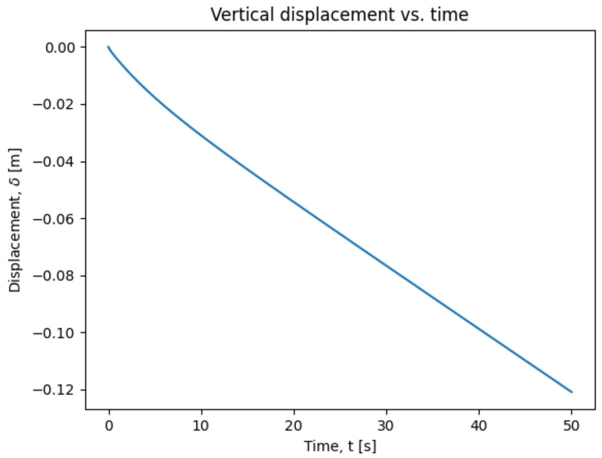

Figure 9. Vertical displacement of a 21 node system over 50s

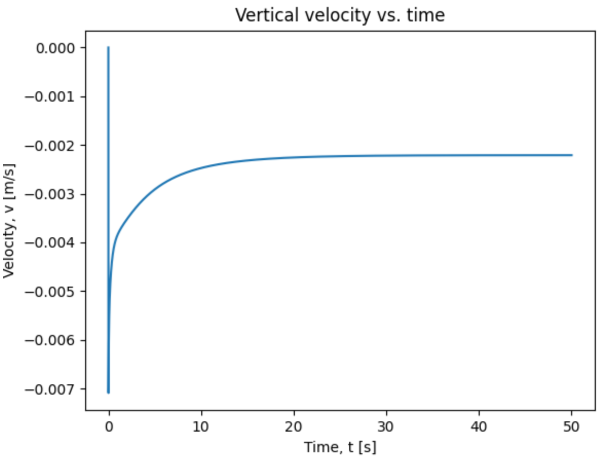

Figure 10. Vertical velocity of the 21 node system within 50s

From the plot of vertical velocity seen within figure 10, the terminal velocity of the system can then be approximated as around 0.0021 m/s, as the velocity plateaus towards the end of the simulation.

B. *Maintaining the Integrity of the Specifications*

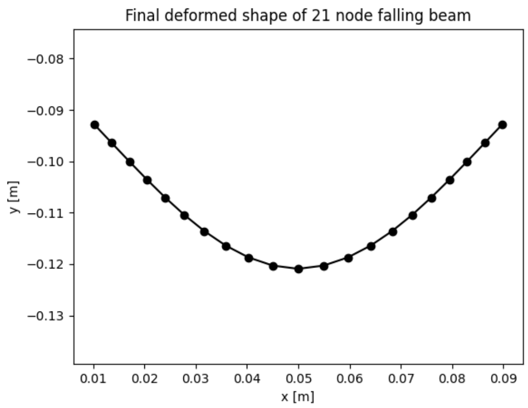

Figure 11. Final deformed shape of a 21 node system over 50s

III. Deliverable 3

This deliverable required the simulation of a 50 node beam over 1s with a time step of 0.01s. The following was asked for this deliverable:

1. Plot of the maximum vertical displacement of the system and comparison against Euler Beam theory
2. The possible benefits of the simulation compared to the beam theory

A. *Maximum Vertical Displacement Comparison to Theory (1)*

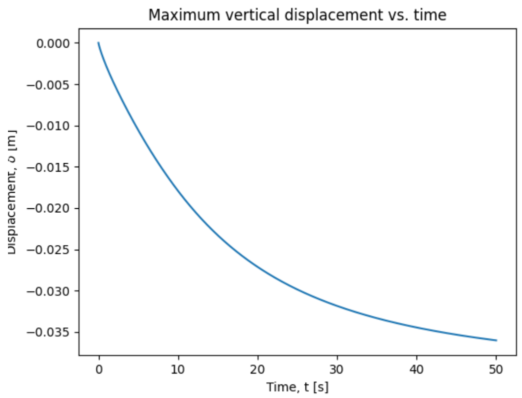

Figure 12. Maximum Vertical displacement of a 50 node system over 50s

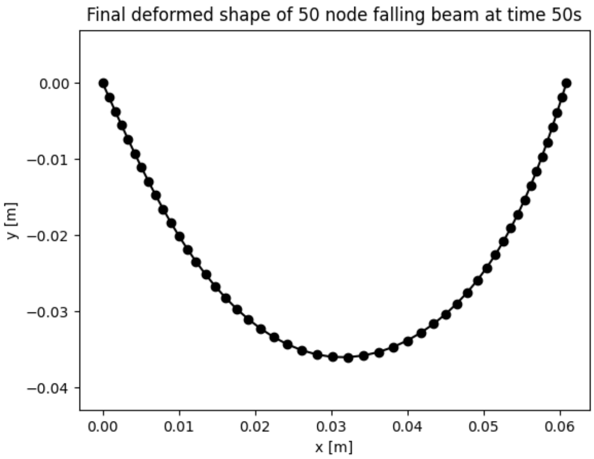

Figure 13. Final deformation of a 50 node system over 50s

As shown with figure 12 above, the maximum deformation does plateau to a value of around 0.035m over time.

B. Possible Benefits of Simulation Compared to Theory (2)

The equation shown with Euler's beam theory assumes a small deformation within the beam to be close to the actual situation, so when larger loads are applied to the mean, the displacement values from Euler's theory would get less accurate, while the simulation results match more closely. This is because the simulation directly derives the values from the deformation and other properties without simplification.

REFERENCES

[1] M. Khalid Jawed, S. Lim, DISCRETE SIMULATION OF SLENDER STRUCTURES [p. 4-26].