Hackathon Task 2

Lorenz System Simulation and Visualization

I used Runge Kutta 4th order (RK4) numerical integration method algorithm to detect the defect, in that problem I will use the algorithm step by steps

Algorithm

The chosen algorithm is the **Runge Kutta 4th order (RK4) numerical integration method**.

Reasons for choosing RK4:

- **Accuracy:** RK4 provides higher accuracy compared to simpler methods like Eulers method, especially important for chaotic systems like the Lorenz system.
- **Stability:** Chaotic systems are highly sensitive to initial conditions, and RK4 minimizes numerical errors that would otherwise distort the trajectory.
- **Efficiency:** RK4 balances computational cost and precision, making it suitable for simulating continuous dynamical systems.
- **Applicability:** RK4 is a general-purpose ODE solver and works well for both linear and non-linear systems.

The is a well-known example of deterministic chaos. By comparing the standard Lorenz equations with the custom as-written equations, the algorithm demonstrates how slight differences in formulation can lead to very different trajectories.

Results and Accuracy Discussion

- The RK4 integrator successfully computed the 3D trajectories for both systems.
- The standard Lorenz system produced the expected chaotic butterfly-shaped attractor, which is a hallmark of chaotic dynamics.
- The as-written system generated a different trajectory, highlighting how sensitive such systems are to parameter changes and model formulation.
- The accuracy of the simulation was confirmed by the smoothness and stability of the trajectories, without divergence or unrealistic oscillations.
- Since RK4 reduces numerical error significantly compared to simpler methods, the results can be trusted as a close approximation of the real system dynamics.
- The final output images visually demonstrate these differences.