Project Proposal - Chaotic Double Pendulum Simulator & Chaos Visualizer

1. Project Overview

Short description:

A Python-based simulator that solves and visualizes the **'chaotic motion of a double pendulum'**, demonstrating extreme sensitivity to initial conditions.

Motivation:

The double pendulum is a simple mechanical system that can show chaotic behavior: two pendulums with almost identical starting angles quickly diverge into completely different motions.

This project uses **numerical ODE methods** and **visualization** to explore chaos in classical mechanics.

2. Features

Core Features

- Simulate the motion of a double pendulum with configurable:
  - Masses (m_1, m_2)
  - Rod lengths (l_1, l_2)
  - Gravity (g)
  - Initial angles and angular velocities
- Numerically solve the equations of motion using a **4th-order Runge–Kutta (RK4)** method.
- Animate the double pendulum motion using `matplotlib`.
- Plot angle vs time for both pendulum arms.

Chaos & Analysis Features (Planned / Optional)

- Chaos demo:
  - Run two simulations with a tiny difference in initial angle (e.g. \(\theta_1 + 0.001\) rad).
  - Compute and plot the separation between the two trajectories as a function of time.
- Phase-space plot:
  - Plot ω - θ (angular velocity vs angle) for one pendulum arm.
- (Optional) Estimate a simple **divergence rate** to illustrate Lyapunov-like behavior.

3. Project Structure

Term Project/

```
├─── main.py             # CLI menu and user interaction
├─── pendulum_model.py   # Equations of motion + RK4 integrator + simulation
├─── chaos_tools.py      # Two-trajectory simulation + separation analysis
├─── plotter.py          # Plotting and animation routines
├─── README.md           # Describe Function, Usage, Design, Development process, Sources, Updates
└─── dev_log.md          # Development log and notes (including AI usage)
```