Strange Attractors

By Group 273

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INTRODUCTION

The task is to work on Interactive 3-D simulation of strange attractors.
The term 'Strange Attractor' is used to describe an attractor (a region or shape to which points are 'pulled' as the result of a certain process) that displays sensitive dependence on initial conditions (that is, points which are initially close on the attractor become exponentially separated with time).
In the simulation, we will include 12 stimulations that are-
Lorenz attractor, Thomas , Aizawa , Dadras , Chen, Lorenz83,Rossler, Halvorsen, Rabinovitch-Fabrikant, Three-Scroll chaotic system , Sprott , Four-wing.

EXISTING WORK WITH LIMITATION

While strange attractors have the potential to provide important insights into the behavior of complex systems, there are still many limitations and challenges that need to be overcome in order to fully realize their potential.

Some of these limitations are:

- Strange attractors can be highly complex
- Calculating the behavior of strange attractors can be computationally intensive and require a lot of processing power.

- The behavior of strange attractors can be highly unpredictable, which can make it difficult to make accurate predictions about their behavior over time.
- Strange attractors can only be determined from the data available, and it is possible that the data may not be representative of the true behavior of the system.

PROPOSED WORK AND METHODOLOGY

The work we proposed was that we will work on Interactive 3-D simulation of strange attractors.
In the simulation, we will include 12 stimulations that are-
Lorenz attractor, Thomas , Aizawa , Dadras , Chen, Lorenz83,Rossler, Halvorsen, Rabinovich-Fabrikant, Three-Scroll chaotic system , Sprott , Four-wing.

Methodology -
For the completion of the project, the team had to divide the work in 2 major modules which were building the frontend and building the simulations. For the frontend part the team had to learn HTML and CSS and work with that to design the structure of Website. For the simulation part, the team had to learn several JavaScript libraries to design the simulation of different attractors.

HARDWARE AND SOFTWARE REQUIREMENT

Hardware Requirement -

- Processor: A modern processor with a minimum clock speed of 2 GHz is recommended to ensure smooth performance of the simulation.

- RAM: A minimum of 4 GB of RAM is recommended to ensure that the simulation can run smoothly and handle multiple concurrent users.

- Graphics card: A dedicated graphics card with support for 3-D rendering and at least 1 GB of video memory is recommended to ensure high-quality visualizations of the strange attractors.

- Storage: A minimum of 100 GB of storage is recommended to ensure that the simulation can be installed and run without any performance issues.
- Display: A high-resolution display with a minimum resolution of 1920 x 1080 is recommended to ensure that the visualizations of the strange attractors are displayed clearly and accurately.
- Operating System: A modern operating system such as Windows 10, macOS, or Linux is required to run the simulation.

Software Requirement -

- Web browser: A modern web browser such as Google Chrome, Mozilla Firefox, or Microsoft Edge that supports WebGL and JavaScript is required to run the simulation.

- HTML and CSS: HTML is used for structuring the file and CSS is used for styling the website

- p5.js : p5.js is a JavaScript library for creating interactive graphics and animations in a web browser, and is required for the development of the simulation.

- dat.gui.min.js: dat.gui.min.js is a JavaScript library for creating graphical user interfaces, and is required for the development of the simulation.

- Text editor: A text editor such as Visual Studio Code, Sublime Text, or Atom is required for writing and editing the code for the simulation.
- Git: Git is a version control system that is used to manage and track changes to the code for the simulation.
- Web server: A web server such as Apache or Nginx is required to host the simulation and make it accessible to users.

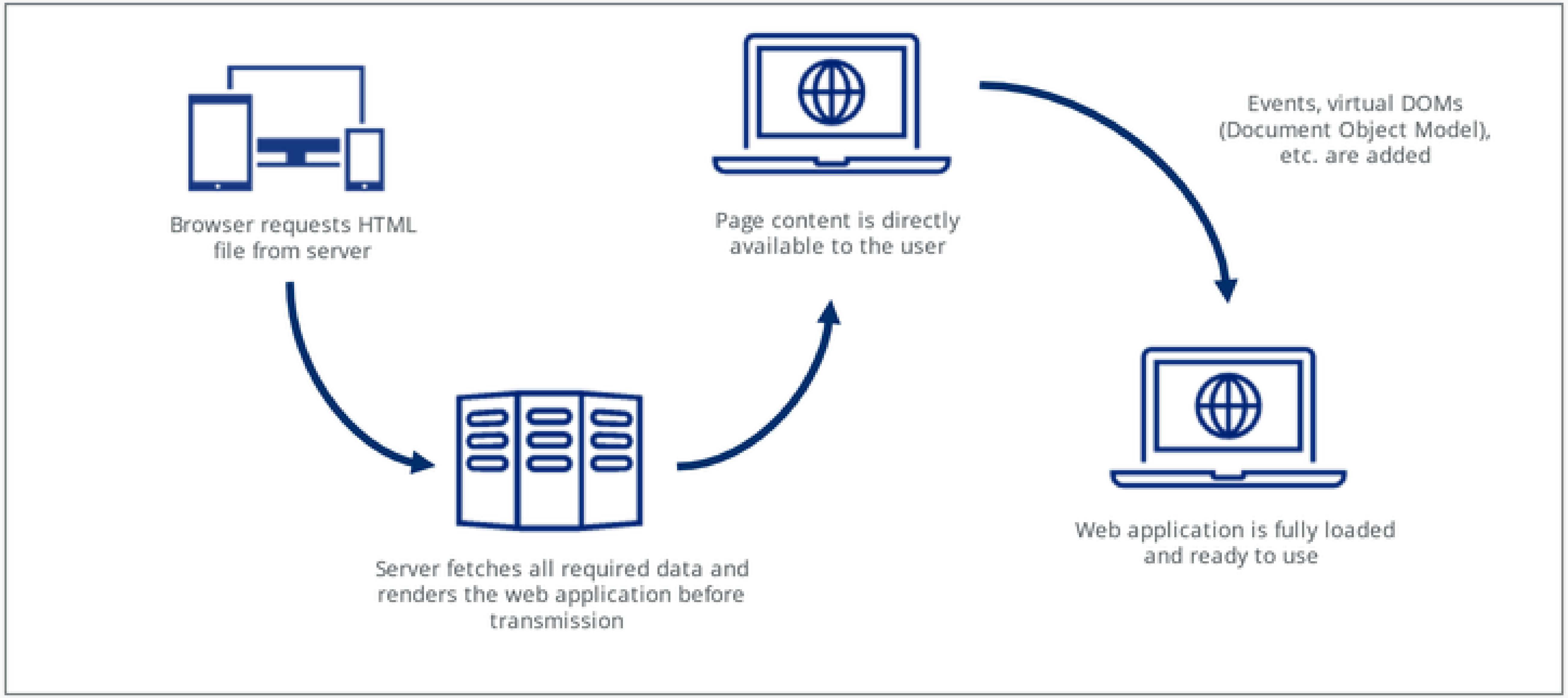
OVERALL ARCHITECTURE DIAGRAM

A typical web app architecture of the project consists of two part-

A) Client side or the frontend

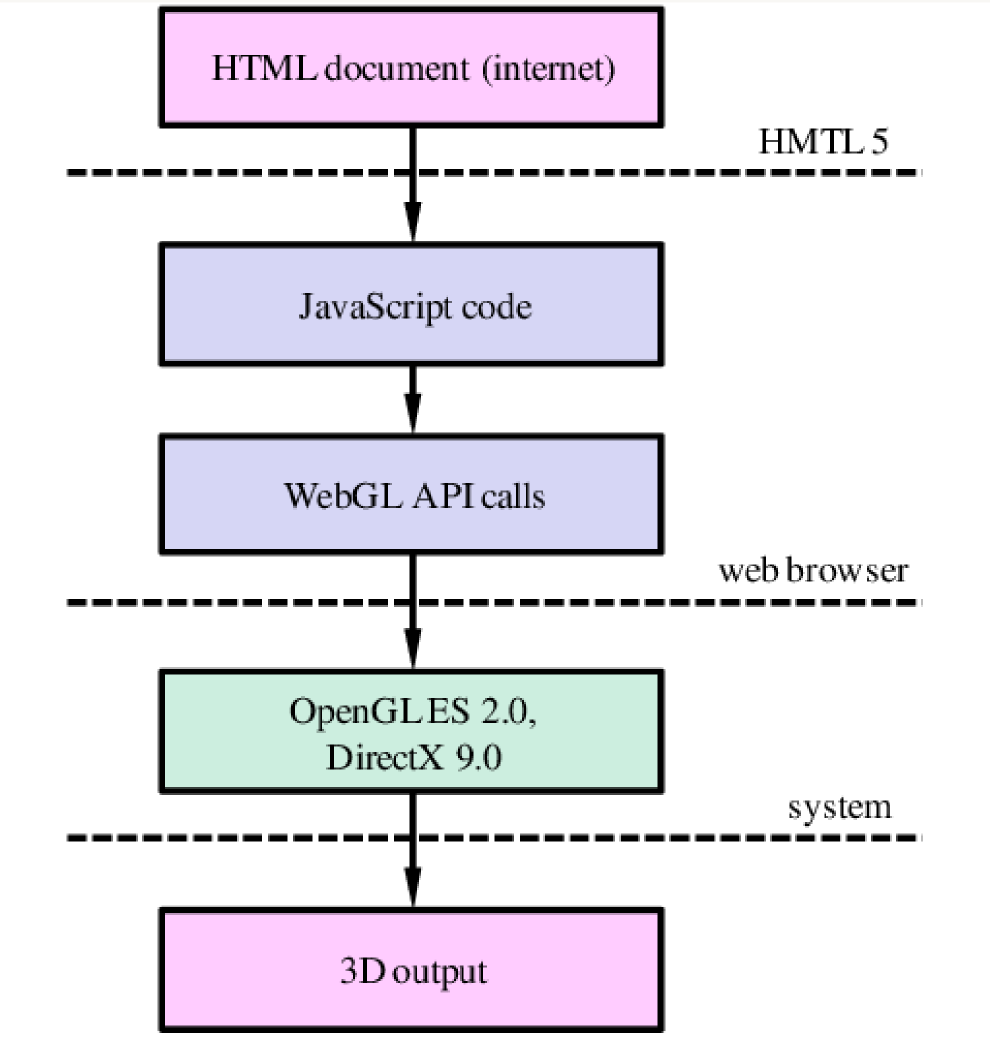
B) Visualization side

CLIENT SIDE ARCHITECHTURE (FRONTEND)



SIMULATION ARCHITECTURE

For the 3d environment, We have used the dat.GUI library for the controls. The position of a particle is computed with a 4th-order Runge-Kutta method. For the 3d environment we have used the p5.EasyCam library developed by Thomas Diewald.



ig. 1 Overall flow of WebGL-based 3D graphics outp

LITERATURE REVIEW

The term "Strange Attractor" refers to a complex mathematical object that arises in dynamic systems and displays sensitive dependence on initial conditions. These objects are important in many areas of study, including physics, mathematics, and engineering. The most famous strange attractor is the Lorenz attractor, named for its discoverer Edward N. Lorenz, who discovered it in the 1960s as part of his work on mathematical models of the atmosphere.

Existing Models: There are numerous examples of strange attractors in the literature, including the Lorenz attractor, the Rössler attractor, the Chen attractor, and the Hénon attractor, among others. These objects have been studied in detail, and their properties have been analyzed using a variety of mathematical and computational technique

Observation and Analysis: The "Strange Attractors" web project provides a unique platform for exploring and visualizing strange attractors in an interactive and engaging way. By using simulations and animations, the project allows users to observe and understand the behavior of these objects, and to see how small changes in the initial conditions can lead to large differences in the final outcome.

MODULE DESCRIPTION

FRONT END

- HTML
- CSS
- JAVASCRIPT

As mentioned earlier, the Frontend is just the component that the user can directly interact with. The main purpose of the Frontend is provide a base which the user can use and navigate through easily. There is a lot of emphasis on beautification, ranging from simplistic, minimal web apps to very sophisticated, aesthetically pleasing web apps.

- HTML: HTML is basically the standard markup language for creating web pages i.e, the skeleton of a webpage. Its compatible on all popular browsers (Chrome, Firefox, Safari, IE9, and Opera)

- CSS: Cascading Style Sheets. As the name suggests, it’s used to style a web page i.e, how a site is displayed on a browser.CSS is unique in that it doesn’t create any new elements,like HTML or JavaScript. Instead, it’s a language used to style HTML elements. There are many frameworks like TailwindCSS that make this process a piece of cake.

- JAVASCRIPT: JavaScript is a scripting or programming language that allows you to implement complex features on web pages. Every time a web page does more than just sit there and display static information for you to look at — displaying timely content updates, interactive maps, animated 2D/3D graphics, scrolling video jukeboxes, etc. — you can bet that JavaScript is probably involved.

SIMULATION

- P5.js
- DAT GUI

- **P5.JS:** p5.js is a JavaScript library for creative coding, with a focus on making coding accessible and inclusive for artists, designers, educators, beginners, and anyone else. p5.js is free and open-source because we believe software, and the tools to learn it, should be accessible to everyone.Using the metaphor of a sketch, p5.js has a full set of drawing functionality. However, you're not limited to your drawing canvas. You can think of your whole browser page as your sketch, including HTML5 objects for text, input, video, webcam, and sound
.

- DAT.GUI: A lightweight graphical user interface for changing variables in JavaScript.

MODULE WORK FLOW

Module 2
Frontend & Simulation

Module 1
Frontend

Mod 3
Remaining Simulations

IMPLIMENTATION AND CODING

A detailed explanation of the progress made so far and of the module have been done here.

https://github.com/raunakk07/Stimulation-Project

SNAPSHOT OF PROJECT

STRANGE ATTRACTORS

Interactive 3D simulations

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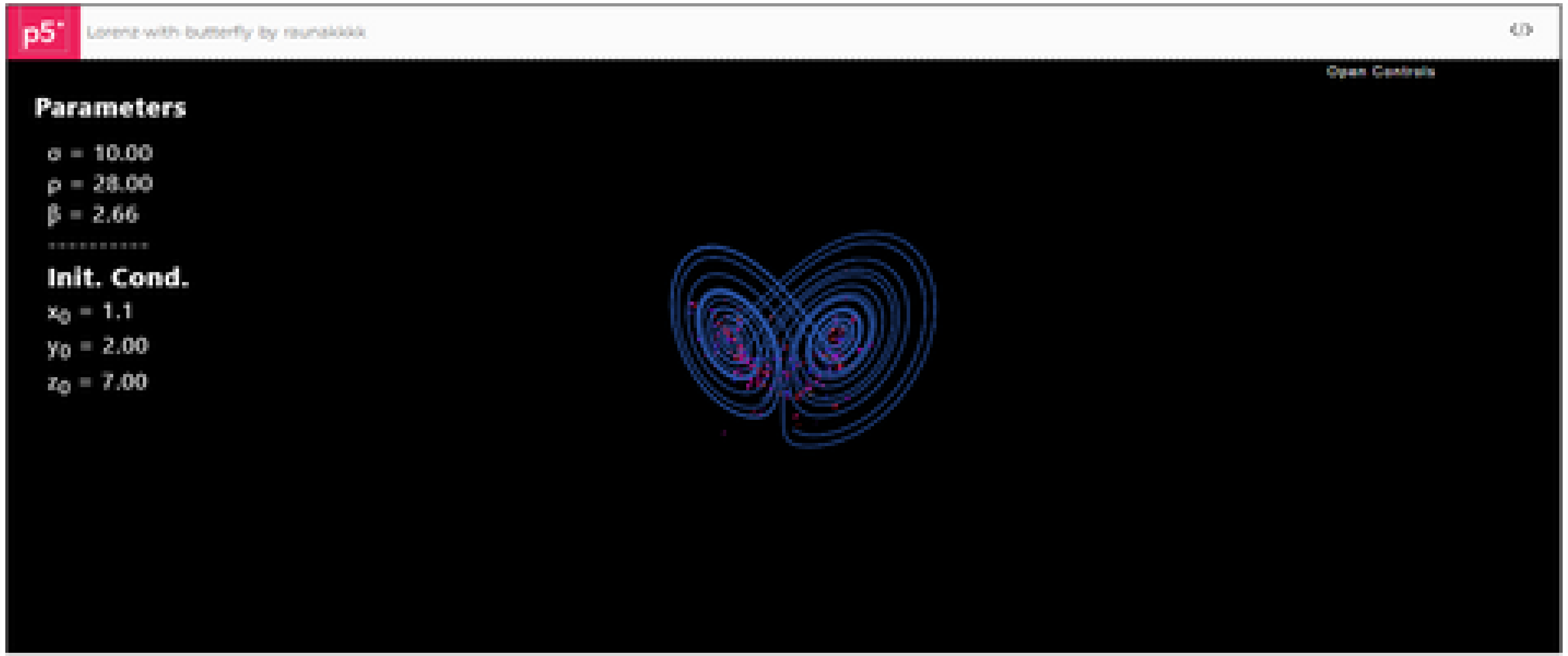
INTRODUCTION

The term **'Strange Attractor'** is used to describe an attractor (a region or shape to which points are 'pulled' as the result of a certain process) that displays sensitive dependence on initial conditions (that is, points which are initially close on the attractor become exponentially separated with time). The most famous strange attractor is undoubtedly the Lorenz attractor - a three dimensional object whose body plan resembles a butterfly or a mask. The Lorenz attractor, named for its discoverer Edward N. Lorenz, arose from a mathematical model of the atmosphere .

Imagine a rectangular slice of air heated from below and cooled from above by edges kept at constant temperatures. This is our atmosphere in its simplest description. The bottom is heated by the earth and the top is cooled by the void of outer space. Within this slice, warm air rises and cool air sinks. The state of the atmosphere in this model can be described by three time-evolving variables

x = the convective flow
y = the horizontal temperature distribution
z = the vertical temperature distribution

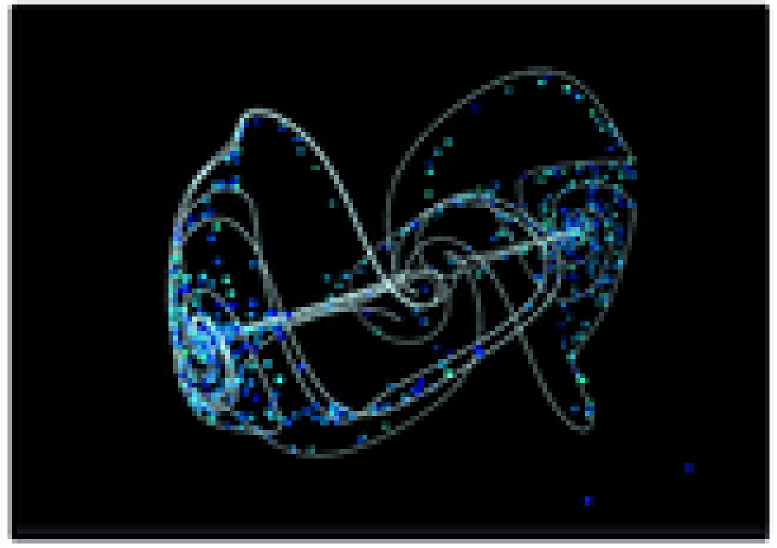
When $\rho = 28$, $\sigma = 10$, and $\beta = 8/3$, a solution curve of this system has the shape of the iconic butterfly and the position of particles will follow a similar path.



FULL SCREEN

The Lorenz attractor was the first strange attractor, but there are many systems of equations that give rise to strange attractors. In the next section you will find simulations of strange attractors with particles moving based on the given system of ordinary differential equations, including one (or two) solution curve(s). Change the parameters to observe the behaviour of the particles and the solution curve(s). To access the simulation just click on the image.

INTERACTIVE SIMULATIONS



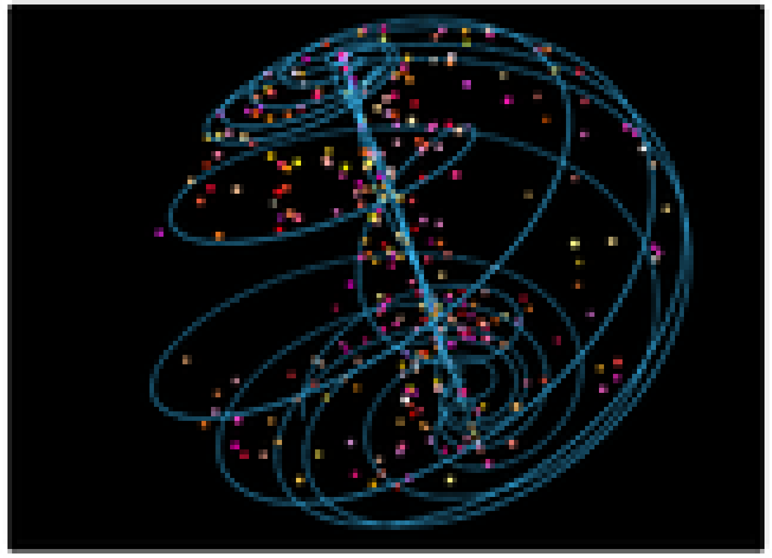
THOMAS

Parameter:

$b = 0.208186$

System:

$$\begin{cases} \frac{dx}{dt} = \sin y - bx \\ \frac{dy}{dt} = \sin z - by \\ \frac{dz}{dt} = \sin x - bz \end{cases}$$



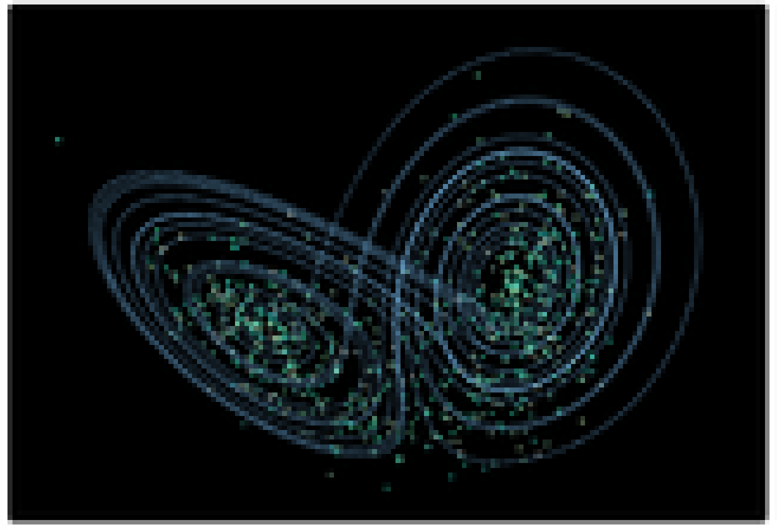
AIZAWA

Parameters:

$a = 0.95,\ b = 0.7,\ c = 0.6,$
$d = 3.5,\ e = 0.25,\ f = 0.1$

System:

$$\begin{cases} \frac{dx}{dt} = (z - b)x - dy \\ \frac{dy}{dt} = dx + (z - b)y \\ \frac{dz}{dt} = c + az - \frac{z^3}{3} - \\ \qquad (x^2 + y^2)(1 + ez) + fzx^3 \end{cases}$$



LORENZ

Parameters:

$\sigma = 10,\ \rho = 28,\ \beta = 8/3$

System:

$$\begin{cases} \frac{dx}{dt} = \sigma(-x + y) \\ \frac{dy}{dt} = -xz + \rho x - y \\ \frac{dz}{dt} = xy - \beta z \end{cases}$$

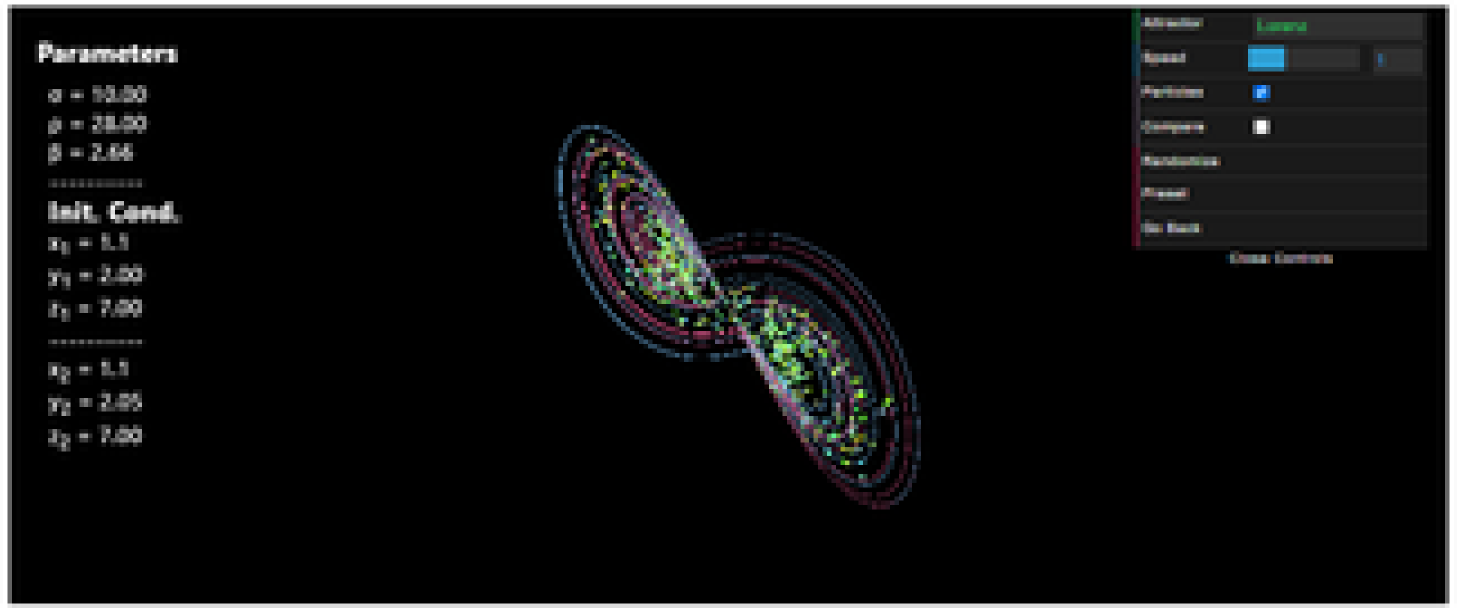
LORENZ ATTRACTOR

The Lorenz system is a system of ordinary differential equations first studied by mathematician and meteorologist Edward Lorenz. It is notable for having chaotic solutions for certain parameter values and initial conditions. In particular, the Lorenz attractor is a set of chaotic solutions of the Lorenz system. In popular media the "butterfly effect" stems from the real-world implications of the Lorenz attractor, namely that in a chaotic physical system, in the absence of perfect knowledge of the initial conditions (even the minuscule disturbance of the air due to a butterfly flapping its wings), our ability to predict its future course will always fail. This underscores that physical systems can be completely deterministic and yet still be inherently unpredictable. The shape of the Lorenz attractor itself, when plotted in phase space, may also be seen to resemble a butterfly.

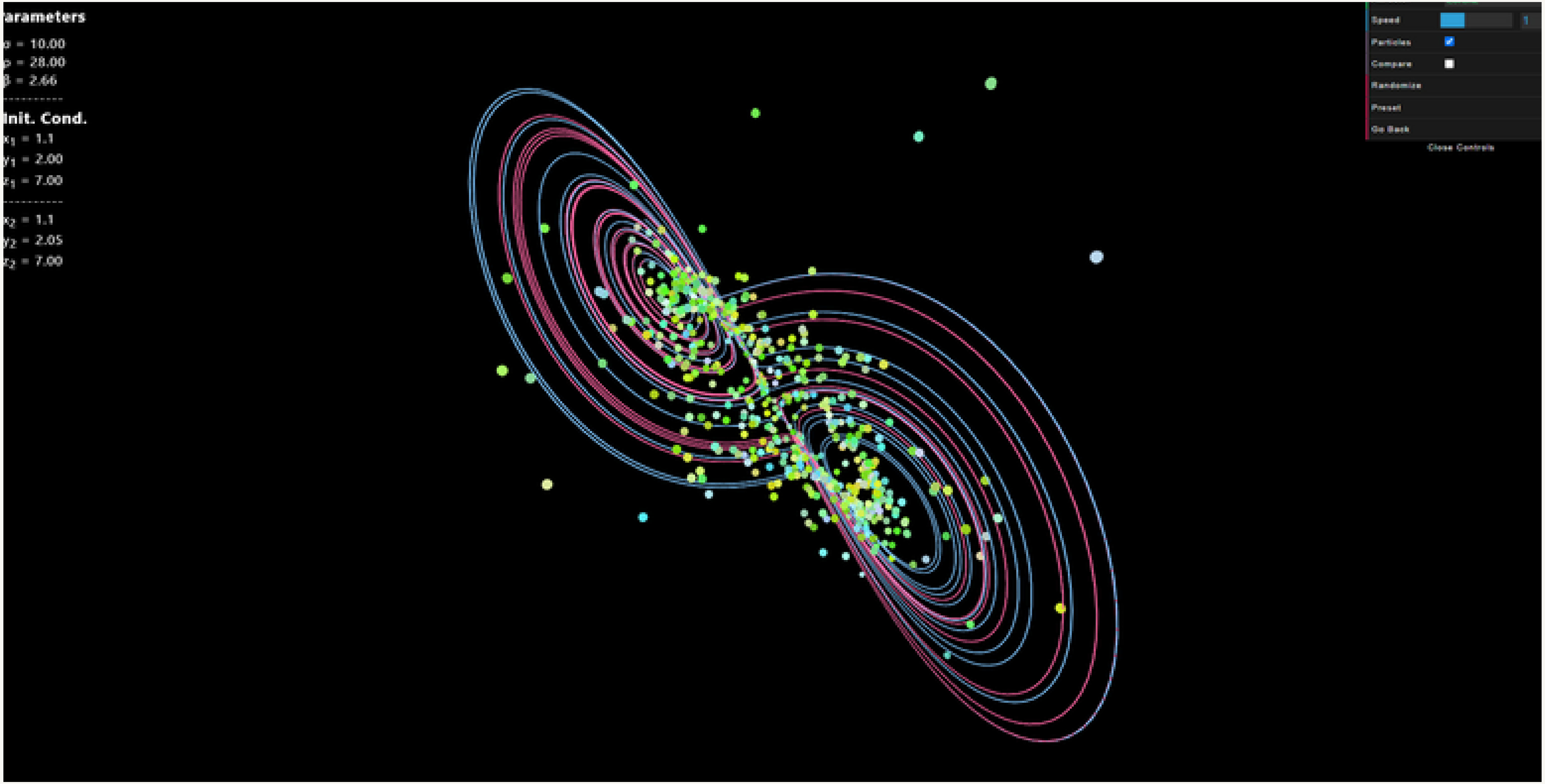
and a system of three ordinary differential equations describing the structure as-

$$\begin{cases} \frac{dx}{dt} = \sigma(-x + y) \\ \frac{dy}{dt} = -xz + \rho x - y \\ \frac{dz}{dt} = xy - \beta z \end{cases}$$

When $\sigma = 10$, $\rho = 28$, $\beta = 8/3$, a solution curve of this system has the shape of butterfly and the position of particles will follow a similar path.



FULL SCREEN


arameters
σ = 10.00
ρ = 28.00
β = 2.66
Init. Cond.
x1 = 1.1
y1 = 2.00
z1 = 7.00
x2 = 1.1
y2 = 2.05
z2 = 7.00
Speed
Particles
Compare
Randomize
Preset
Go Back
Close Controls

CONCLUSION

This project has the potential to make a significant contribution to the field of strange attractors by providing visually accessible and understandable representations of these complex systems. The project will also contribute to the advancement of visualization techniques for representing mathematical objects, which will have wider applications beyond the study of strange attractors.

REFERENCES

- https://www.stsci.edu/~lbradley/seminar/attractors.html
- https://en.wikipedia.org/wiki/Attractor
- https://p5js.org/reference/

Thank you