Visualization of Evolving Turbulent Flow Structures

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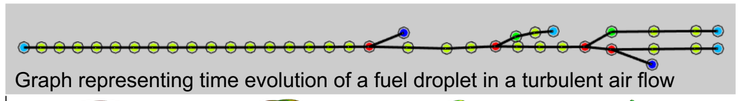
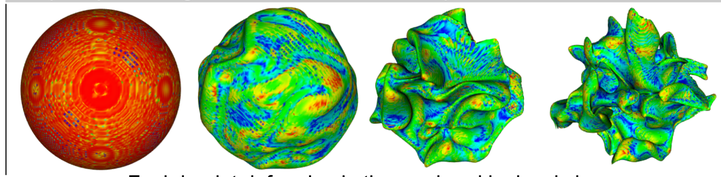
Introduction

Observing the dynamics of turbulent fluid flows has revealed several factors that can improve the power and efficiency of propulsion.

Our goal was to develop an interactive computer program to (1) visualize the deformation in time of structures extracted from turbulent flows, (2) present significant events of the structure evolution (like divisions) into a graph, (3) display relevant information of the structures chosen by the user.



Graph representing time evolution of a fuel droplet in a turbulent air flow



Fuel droplet deforming in time, colored by local shape

Objective & Impact of Professor's Research

While past research has been done to analyze the interaction between shock waves and turbulence, Professor Bermejo-Moreno's research dug deeper to quantify results given by varying relevant physical parameters:

- the **Mach number**: ratio between air speed and sound speed, larger than 1 for supersonic flow, and
- **Reynolds number**: measures how turbulent the flow is.

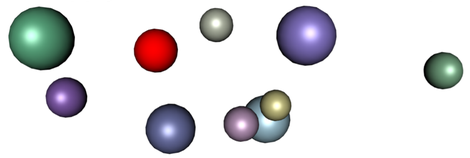
Through numerical simulations, the shape and size of the injected fuel droplets was found to affect the efficiency in which fuel and air can mix. The research proves that by optimizing these properties, the effort to propel an object at hypersonic speeds can be reduced.

The conclusion shows a promising future for supersonic flight. Finding the shapes that positively affect how fuel and air mix is critical and prompts a need to create more of this structure in the injection of fuel in a supersonic combustion engine.

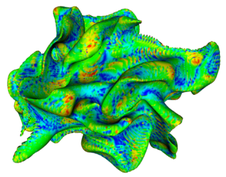
Skills Learned

- **Coding / Python**:
  - In order to work with the Python language a **Virtual Box** was needed to run a **Linux OS** on my Windows Computer.
  - While I had a very basic understanding of coding, my professor and mentor helped me get familiar with Distributed Version Control Systems. An example such as **GitLab** allowed me to learn several coding functions and properties visually and in practice.
  - When expanding the code, several coding libraries were required. to be installed: `argparse`, `libconfig`, and `pygraphviz` to name a few.
  - With each import, I had to understand how they function and what tools they offered that can be used.

- **Visualization Tool Kit (VTK)**
  - As the name implies, it is a tool kit used to visualize 3D objects.
  - In order to properly use this library, I needed to understand how to apply and combine what it is capable of.

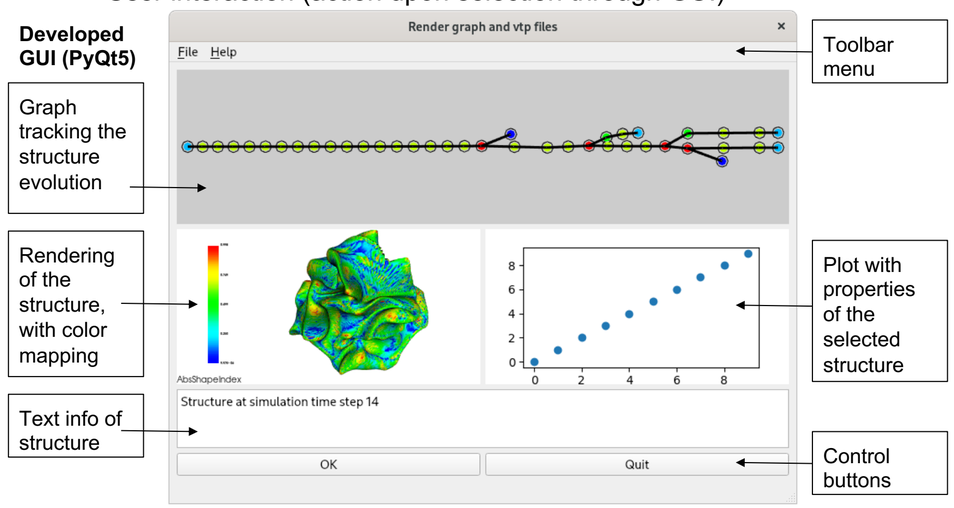


Rendering and selecting generic shapes



Rendering fuel droplet from simulation data

  - Rendering of Generic Shapes and Scientific Data
    - Setting up VTK Rendering environment.
    - Clarifying how classes are used (actors, mappers, camera).
  - User interaction (action upon selection through GUI)



Combination of Graphical User Interaction and rendering of objects to create a window tool

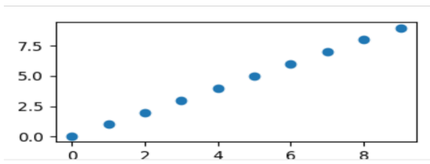
How This Relates to Your STEM Coursework

Although high school has given me the tools to further my STEM career into college, working together with my professor and mentor has shown me a tangible application for the knowledge I have.

Having seen the complex equations contained in Professor Bermejo-Moreno's research, it displays two things at once: a field of study I am yet to understand, and an instant application for a topic many others have trouble finding a purpose for. In addition, conversations with my professor and mentor allowed me to have a clearer image of what my STEM career may entail. Throughout the next years of education, my field of study may begin broaden out at first, but will naturally become highly specialized as time passes.

Next Steps

In the future I would hope to add onto the code that I currently have. While I can render the structures given from data, grabbing data and reporting in a meaningful way has proved difficult. As a result, I would hope to report properties related to specific shape on the side.



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