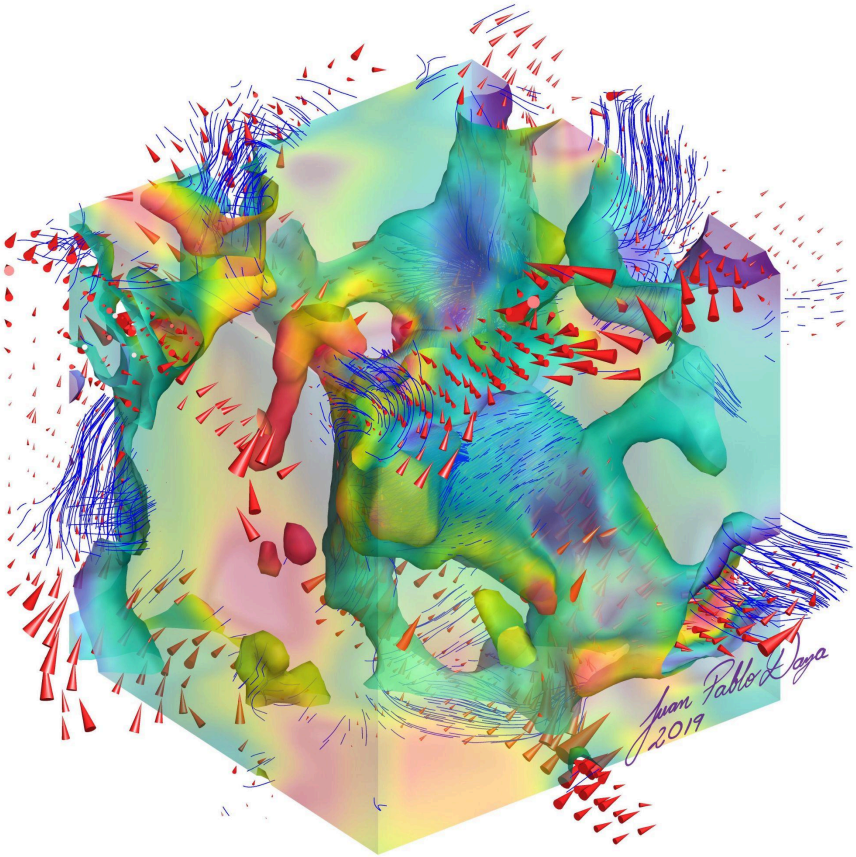
Visual Summary of Projects

Here is a sample of my motivation to graphically show the projects I worked on. Behind the images are highly elaborated mathematical principles, theories, and ideas. I processed the data and wrote the code that generated these images.

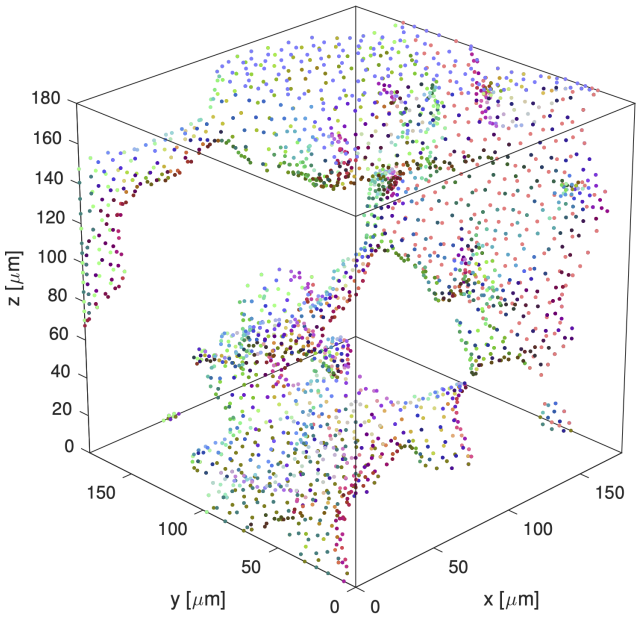
Understanding of 3D data, computer graphics and spatial data structures

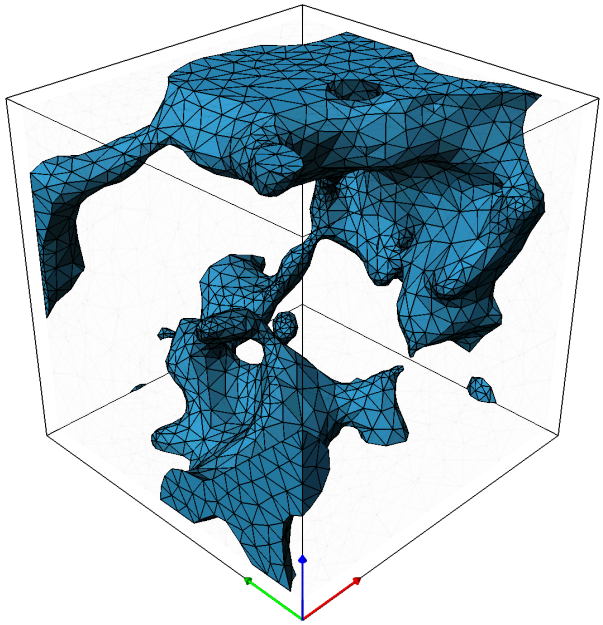
I have experience processing, visualizing and designing algorithms for different types of 3D data, I have used data from 9 degrees of freedom Inertial Measurement Units for designing control systems. I processed 3D CT-scan data for physical simulation using advanced computer graphics methods. I have the capacity and passion to work with any kind of 3D data, most examples are from porous media, but the mathematical abstractions of geometrical processing are easily translatable to any other shape.

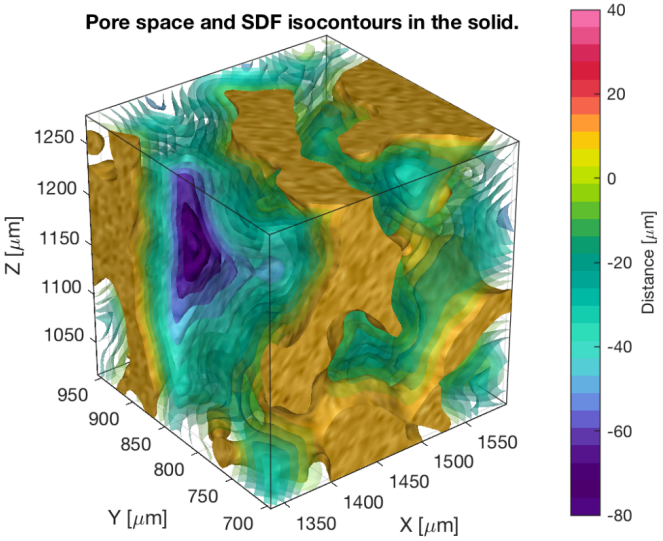
Physical simulation on a CT-scanned rock: Simulation of fluid flow computed with C++, stress and electric current computed with Fortran, in a sample of Berea Sandstone. I used Matlab to coordinate the different simulations and visualize the results. The picture shows a small fraction of the whole simulation of a cube with a side length of 270 micrometers and was used for the 3rd Edition of the Rock Physics Handbook cover. I created and designed the whole picture thanks to a complete understanding of the Computer Graphics pipeline. A rock is similar to a sponge, with solid and empty spaces; that is the structure we see in the picture.

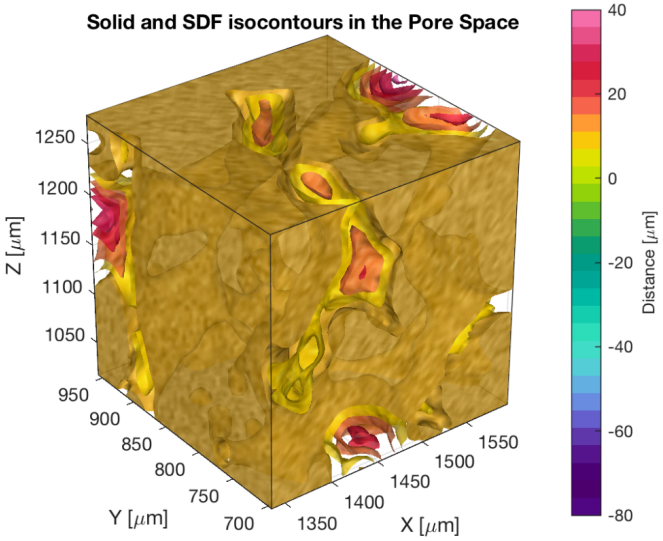


Geometrical processing of 3D Data: I studied different data structures to represent 3D data such as point clouds, tetrahedral meshes and implicit functions.

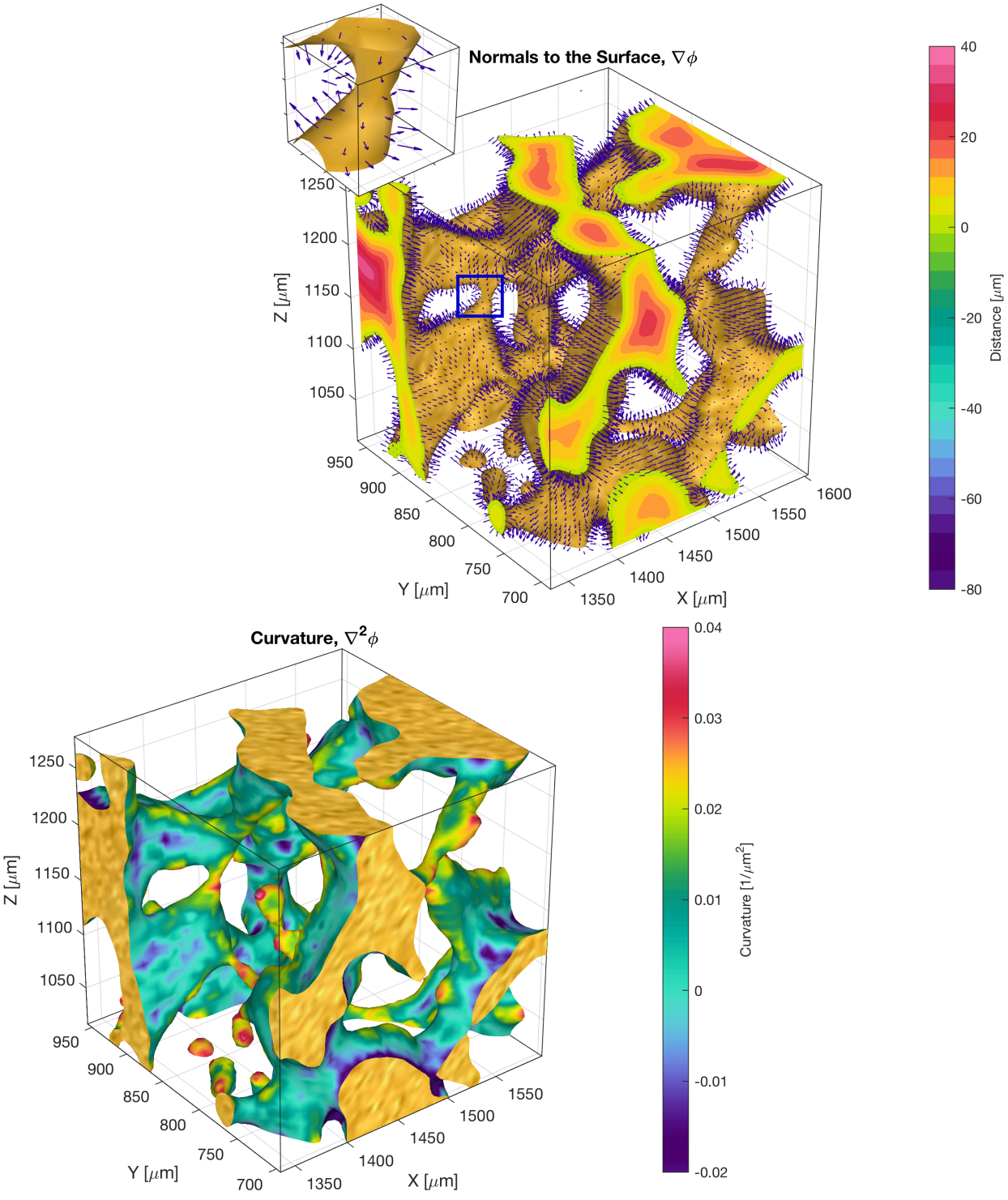




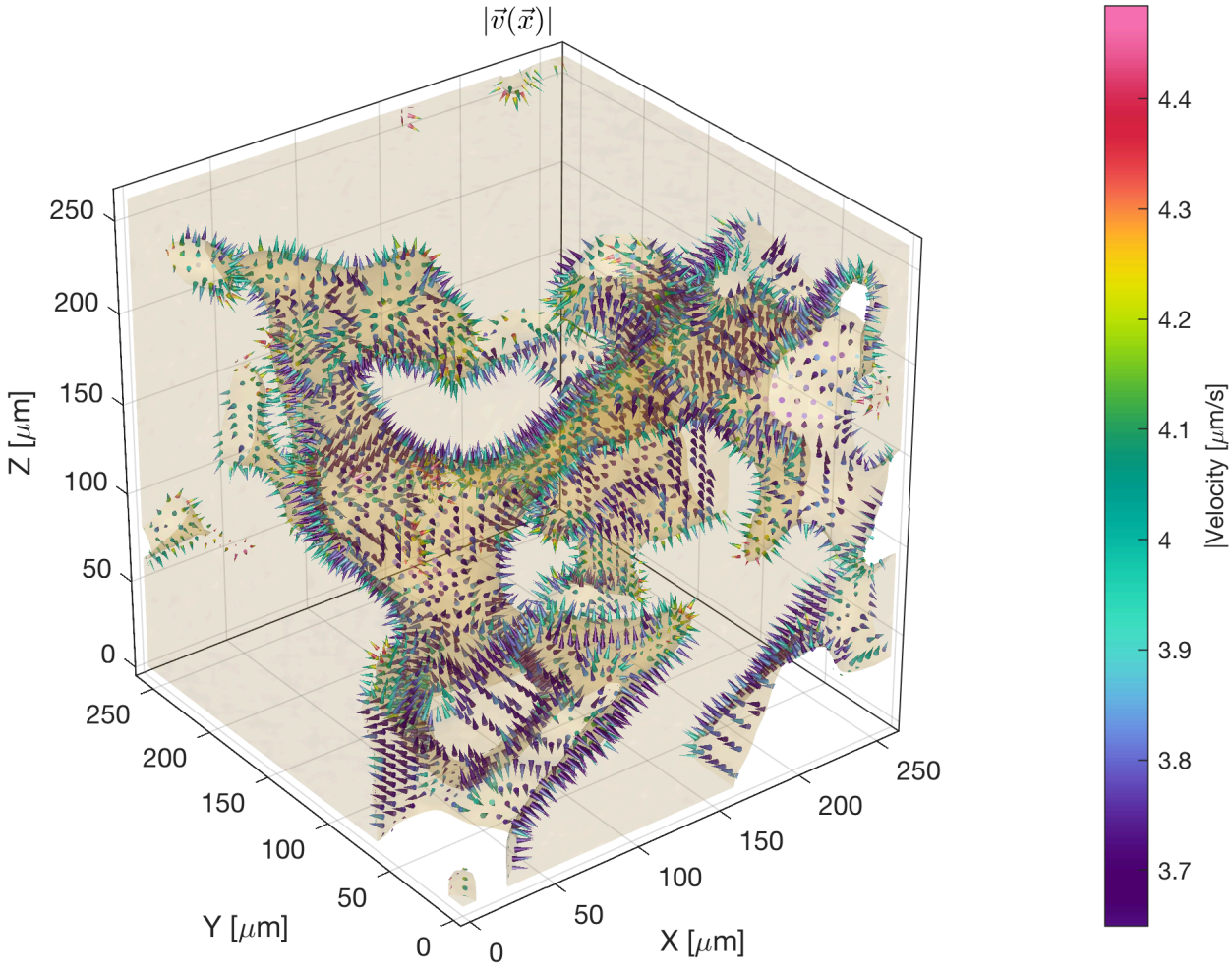




Visualization of Geometrical Properties: Here, I visualize the normals to the surface which are essential for physical simulation. I also visualize the local curvature of the surface of the internal structure of the rock, “pointy” surfaces are pictured as red/pink, “valleys” are blue, and “flat” surfaces have a turquoise color.



Tracking and Motion of Dynamic Surfaces: The colored cones picture the velocity at which the rock structure will change shape when dissolution happens; this was calculated using chemical dissolution laws, depending on the geometrical structure. The picture only shows about a thousand of the whole rock sample being simulated.

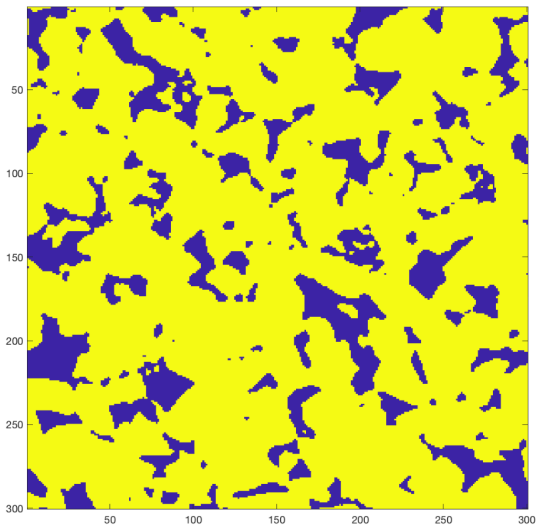


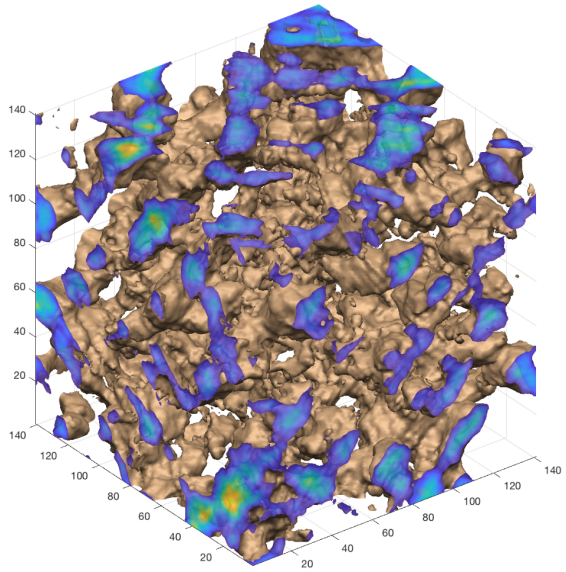
Animations of Rock Dissolution: Using High-Performance Computing, I coupled 4 physical processes, namely: Stress, Chemical Dissolution, local Curvature, and Fluid flow, to produce the deformation of the rock structure. For each stable time step(frame) of the simulation, I computed fluid flow with C++ and stress with Fortran. Then, using Matlab, I calculated curvature and chemical dissolution and deformed the rock structure using the level set method with a 5th-order WENO scheme. Additionally, I selected the perspective of the animations and the colormaps and transparency maps to highlight the processes occurring. The following 2 links contain the mentioned animations.

https://stacks.stanford.edu/file/druid:kt446xv8787/DeformationProportionalToCurvature3D.mp4

https://stacks.stanford.edu/file/druid:kt446xv8787/dissolutionDependentOnStressHighestStressInZdirection.mp4

2D to 3D transform: I created a theoretical transform that allows a whole 3D volume (right) to be generated out of a single 2D slice (left, blue is empty space, and yellow is solid). I used multidimensional signal processing to achieve it. This transform solves a fascinating problem. Can we get the transport, elastic, and electrical properties of a material using only a 2D image? With this work, the answer is yes, making this process faster and leaving exceptional cases for the expensive lab experiments.





Theoretical Design and Construction of a Quadcopter and its Flight Controller: Built a quadcopter and an exact virtual replica using 3D dynamics and precise lab measurements. Each component of the quadcopter was measured and weighed to obtain the dynamical properties (Inertia tensors); during this process, I created a full 3D rendering and measured the force of the propellers for the input voltage and rotational angular velocity. Additionally, I assembled and coded the flight controller using Arduino.