Geometric model extraction from 3D medical data

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Introduction

Technological advances made it possible to acquire massive sets of 3D biomedical data. The collected knowledge has to be formalized, organized and combined in many ways. Furthermore, simulations and interactive explorations are needed.

This paperwork is aimed to describe model extraction from 3D medical images and visualization using the LAR+ViSUS framework.

LAR framework

The Linear Algebraic Representation(LAR) scheme* uses Combinatorial Cellular Complexes (CCC) as its mathematical domain, and various compressed representations of sparse matrices as its codomain.

The LAR framework provides a wide set of operations, each based on the representation scheme.

* A representation scheme is a mapping between the mathematical spaces to be represented by a computer system and their symbolic representation in computer memory.

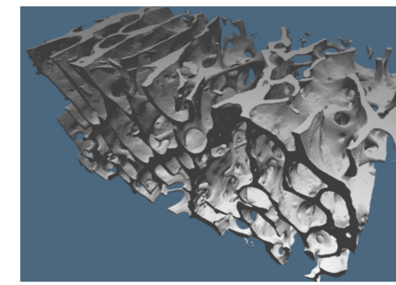
LarVolumeToObj

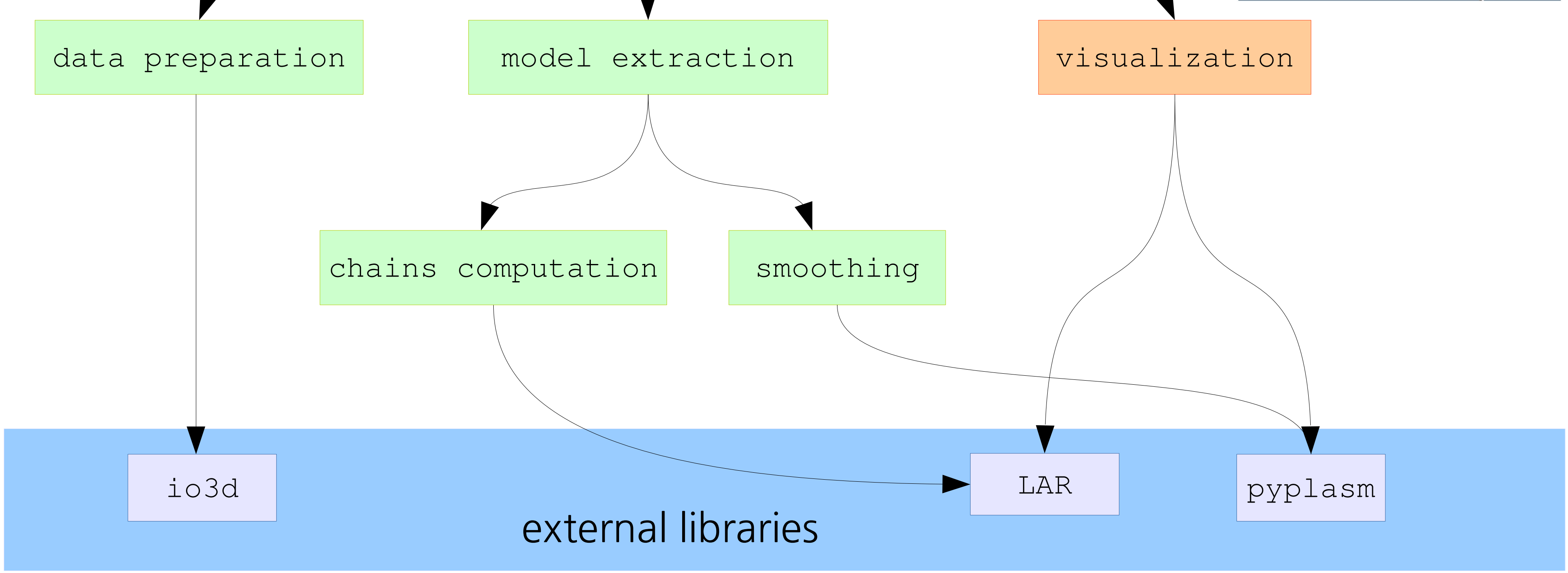
LarVolumeToObj is a software module of the LAR framework designed to generate a well-defined 3D mesh from a stack of 2D images.

Generally speaking, the structure of a d-dimensional image is mapped to a cellular complex of (d-1)-cuboids (voxel faces).

The generated model can be smoothed and visualized.

LarVolumeToObj software architecture





Data preparation (1)

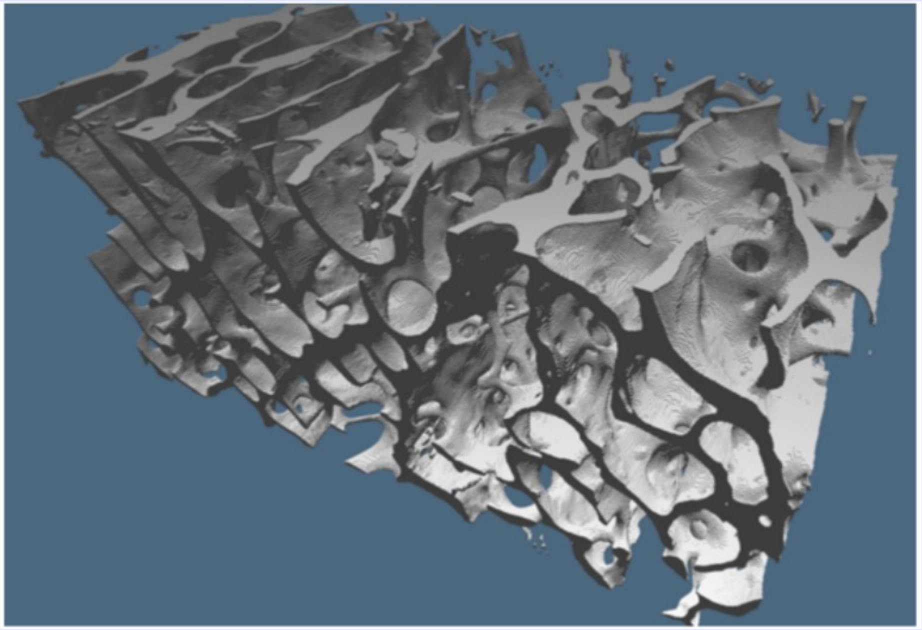
- memorization of 3D data, a stack of 2D images on a three-dimensional array;
- denoising via median filter;
- color quantization via K-means clustering;
- use of pklz, a python object serializator;
- segmentation of the pklz.

Model generation (2)

- generation of matrix [∂_3] (boundary operator);
- boundary chain computation through a SpMV multiplication;
- double facets removal via a *map-reduce* algorithm;
- laplacian smoothing;
- triangulation of the quads;
- use of json and obj formats (currently).

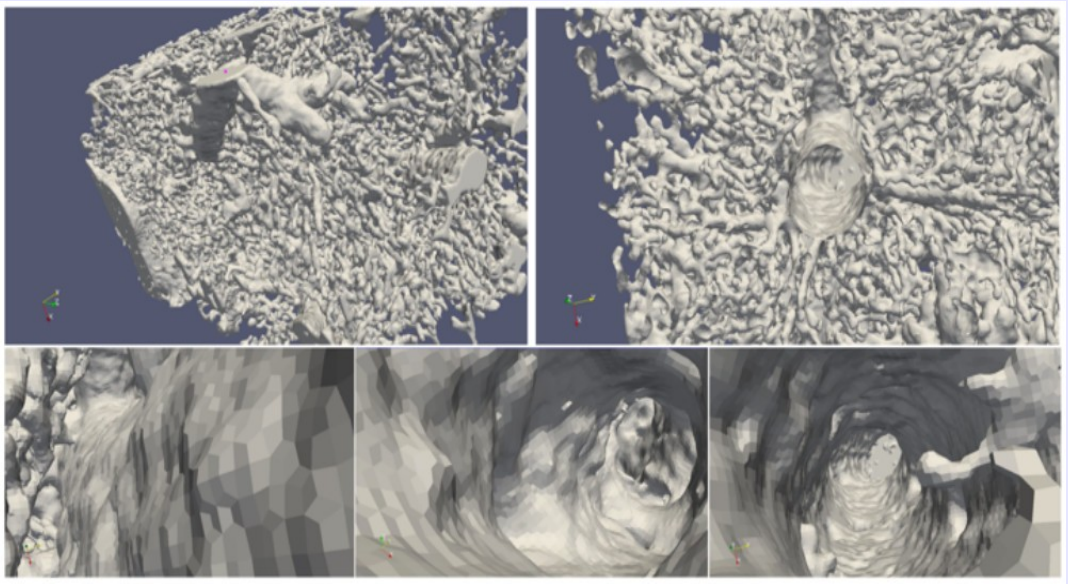
Visualization layer (3)

- lar or pyplasm visualization (currently).



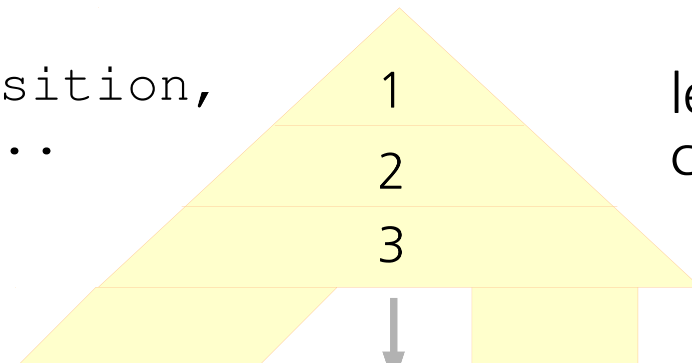
Applications

Extraction of the hepatic portal vein subsystem of a pig liver from micro-CT scans.



ViSUS Visualization Framework

PIDX DATABASE



`parameters: position, field, maxh, ...`

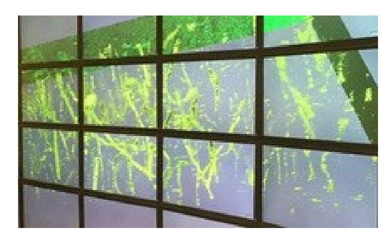
level of resolution = 1,...,n
coarse-to-fine order ↓

`query`

stream in row-major: R1, R2, R3, ...

`marching cubes algorithm`

stream of meshes: M1, M2, M3, ... →



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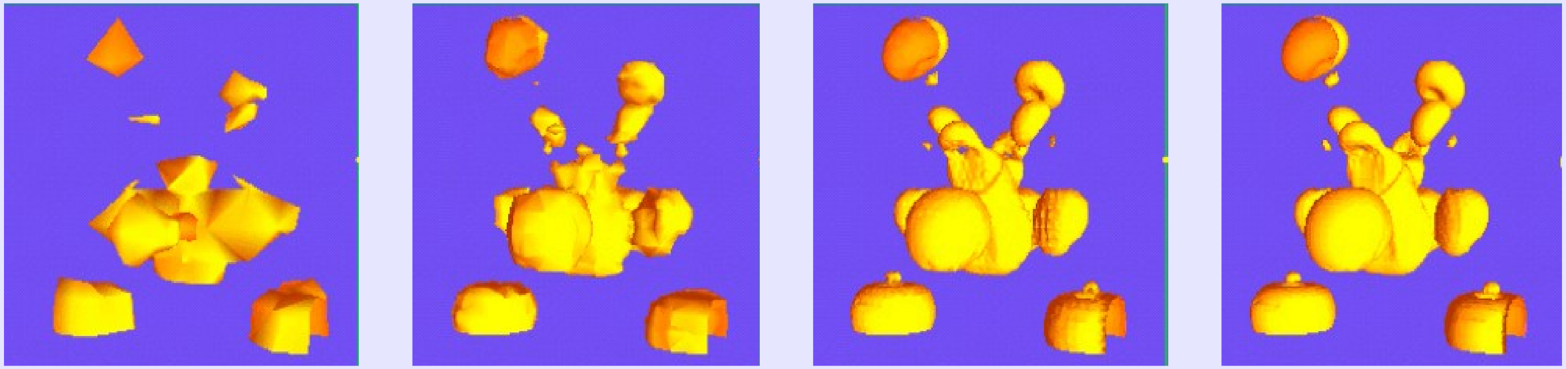
Isosurface refinement and smoothing

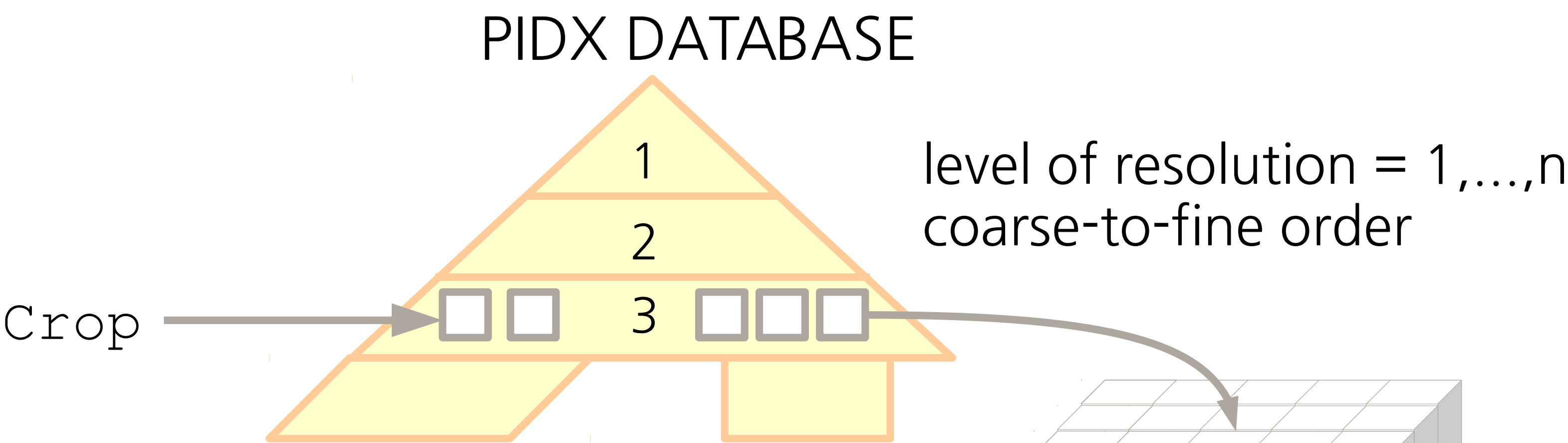
- progressive technique for on-line construction and smoothing of isosurfaces;
- input: hierarchical mesh and an isovalue;
- output: a hierarchical representation of the required isosurface.



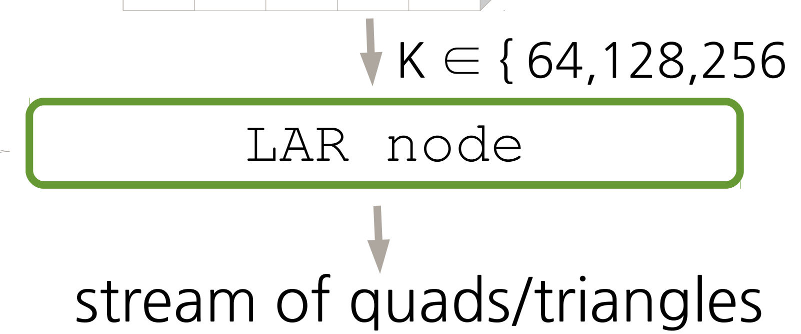
Isosurface refinement algorithm

- Vertex coloring: divide the vertices of the tetrahedra around the split edge in two classes depending of the value of the scalar field $F(\boldsymbol{x})$ compared with the isovalue w.
- Edge bisection: insert a new vertex on an edge and split the tetrahedra adjacent along such edge into two halves.
- Isosurface update: apply an appropriate sequence of eight primitives based on the intersections between isosurface and edges.

Integration solution idea



- Boundary of voxels computation through a SpMV multiplication between the CSR representation of [∂_3] of K^3 voxels and the CSC representation of the chain;
- Double facets removal;
- Laplacian smoothing, if necessary;



Comments and comparison

Some differences between the two approaches can be highlighted:

- LAR provides a correct model while marching cubes algorithm can introduce topological errors;
- high-resolution is characterized by ever smaller variability in intensity values between adjacent vertices, in this case alternatives to isosurface computation could be examined.

Project aims and conclusion

- extract geometric models from massive 3D neuronal data;
- achieve an integration between the two approaches;

References (1)

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F. FURIANI, C. PAOLUZZI, and A. PAOLUZZI, *Algebraic extraction of models and properties from images* (in Italian), GeoMedia, Volume 17, Issue 6, December 2013;

References (2)

V. PASCUCCI, G. SCORZELLI, B. SUMMA, P.T. BREMER, A. GYULASSY, C. CHRISTENSEN, S. PHILIP, S. KUMAR, *The ViSUS Visualization Framework,* in High Performance Visualization: Enabling Extreme-Scale Scientific Insight, E. W. Bethel, H. Childs, C. Hansen, Eds. Chapman & Hall/CRC Computational Science, 2012;

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