Geometry Description and Mesh Construction from Medical Imaging

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Our overall goal

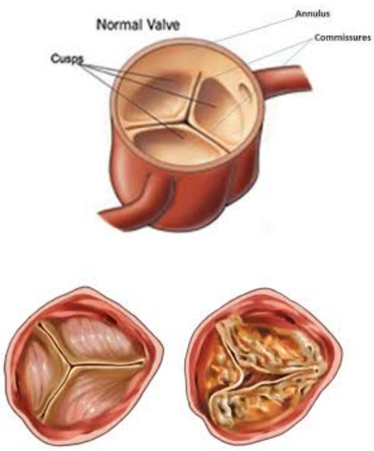
- **Co-register a biomedical atlas with the MR images of a given patient** in order to
  - infer a segmentation & semantic annotation of the patient data
  - extract geometric representations of the segmented data
  - apply PDE-based & patient-specifc simulation to single subparts
  - …

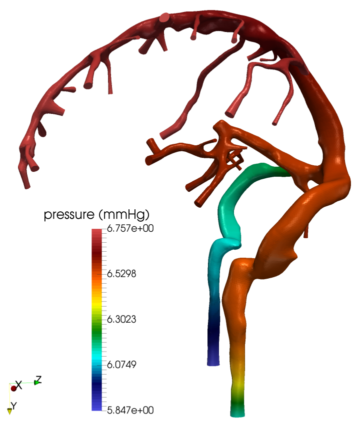
Motivations

- **Patient specific simulation**
  - Imaging ➪ Reconstruction of geometry ➪ Meshing ➪ PDE solution
  - Very complicated geometries ➪ very expensive meshing procedure
  - Mesh quality influences the quality of the solution and the reliability of the simulation

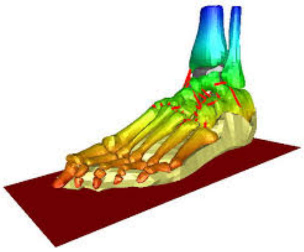
- **Examples of patient-specific simulations**
  - Haemodynamics ➪ Prevention of atherosclerosis
  - Biomechanics of the foot ➪ Reduction of diabetic ulceration risk

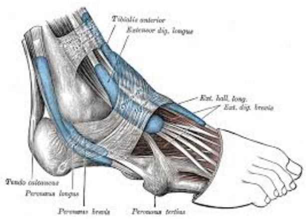
Example: haemodynamics





Example: biomechanics

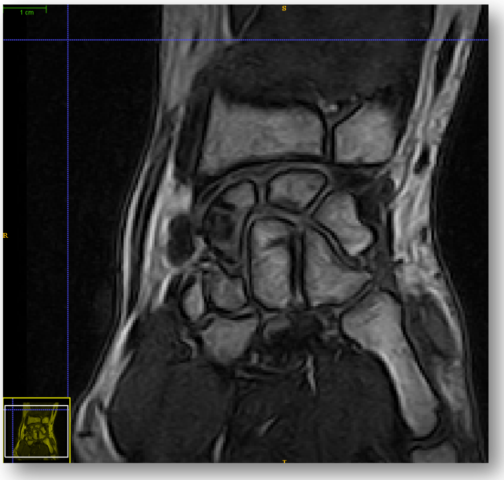




Input

- Our input/processed data will be "heterogeneous"
  - 2D images
  - volumetric bio-medical data: eg., magnetic resonance images
  - segmented volumetric 3D data
- We will work with
  - 2D and 3D regular grids (voxel grids)
  - triangle meshes
  - tetrahedral meshes

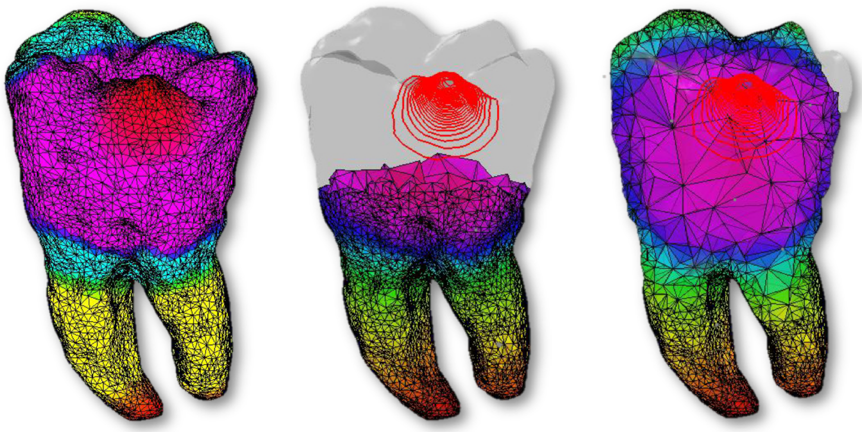
MRI images



MRI images: stack of 2D images in DICOM format

MRI image are courtesy of PLSV Ligurian Regional Hub for Life Sciences & UNIGE-DiMI, Genova

TIN & Tet meshes



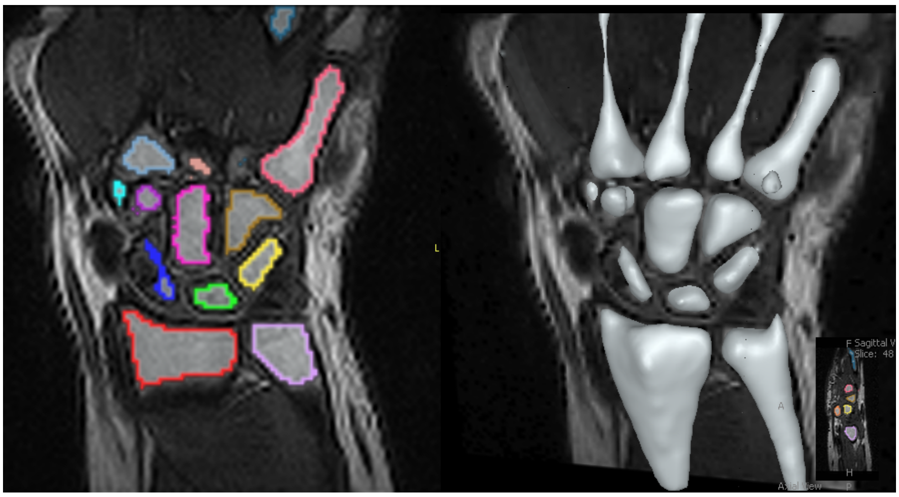
Triangle mesh

Tetrahedral meshes

“Biomedical” Atlas

- **“Biomedical” Atlas**
  - Pre-segmented image
    - by considering neighborhood relationships among different parts of an anatomical structure to be reconstructed;
    - by constructing a good quality mesh for a model structure
  - each segment is marked with a sematic label;
  - anatomical structures have intrinsic structural similarities.

“Biomedical” Atlas

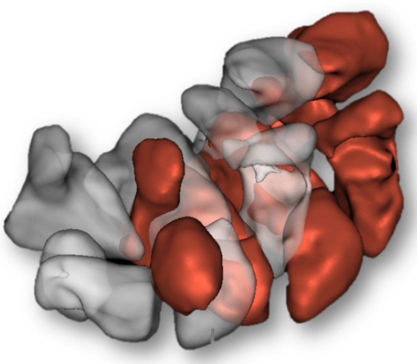


$128 \times 128 \times 51$

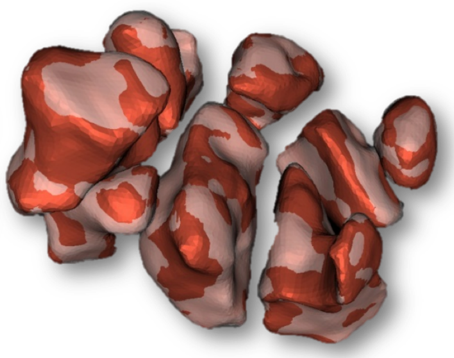
Our problem

- Two different but related co-registration problems
  - co-register a biomedical atlas with the MR images of a given patient;
  - co-register a temporal sequence of follow-up images of a given patient
    - the reference image is segmented;
    - the segmentation of the target image is unknown.

Our problem



Follow-up data



Co-registration

Our problem

- We can apply a co-registration to
  - each couple of 2D image (single slices)
  - the input and target
    - 3D volume images (stack of 2D images)
    - 3D segmented surfaces (set of 3D surfaces)
  - …

Overall procedure

- Given a set of patient MR images, we select
  - the atlas from a single image or multiple raw images
    - segmented subparts & semantic labels by hand, by automated/semi-automated techniques;
  - follow-up data
    - not necessarily in the same reference frame
    - locally deformed by pathologies (eg., musculo-skeletal diseases, inflammation, etc)

Overall procedure

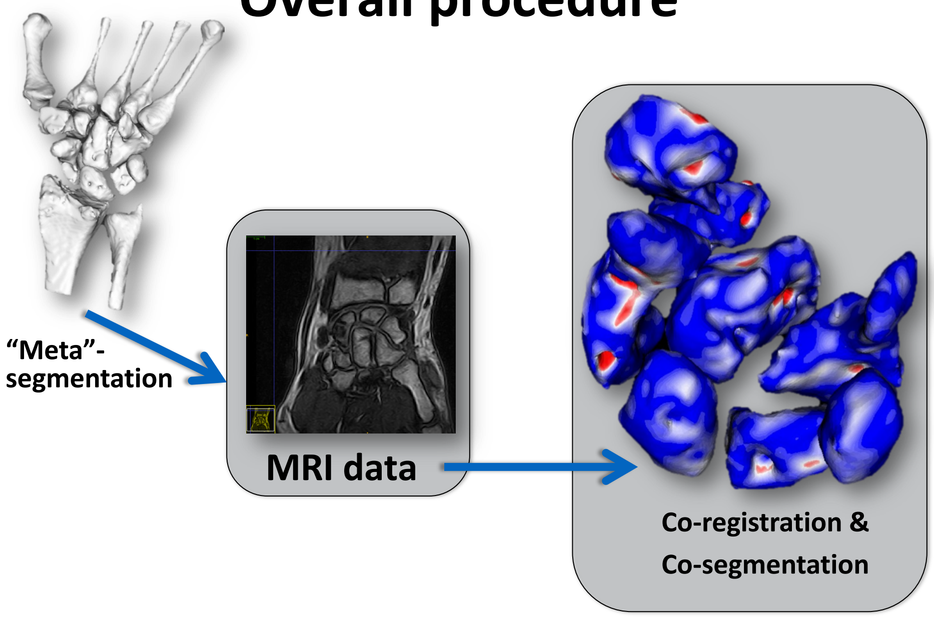
- segment the input image by performing a registration with a pre-segmented image (atlas-based segmentation);
  - the registration step yields a map from the atlas to the image to be segmented, which then inherits labels and segmentation;
  - the map allows us to obtain the labelling and segmentation (geometry&mesh) of the image;

Overall procedure

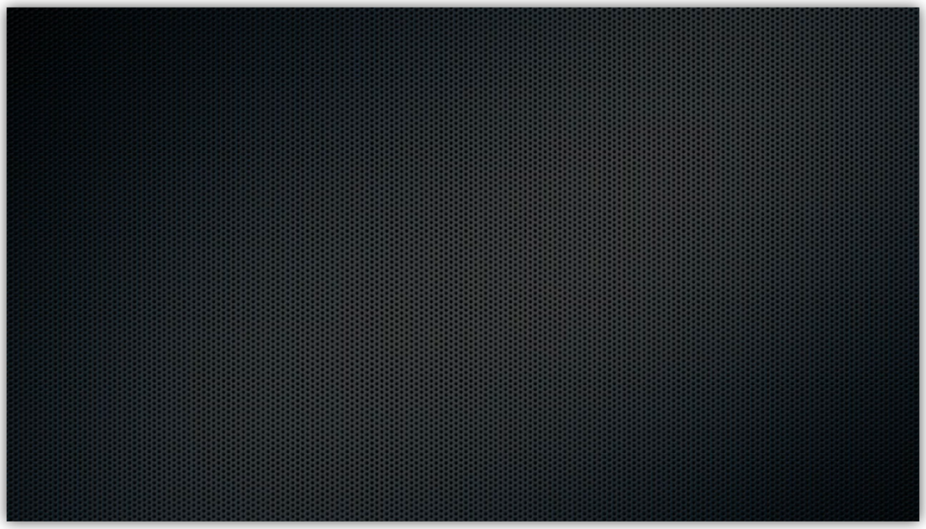
- the mapping must preserve the quality of the mesh;
- constructing the new, patient specific, geometry description and a good quality mesh of the patient;

- **Output**
  - mapping of the model structure onto the patient specific geometry
  - solving PDEs that describe a given phenomenon.

Overall procedure



Overall procedure - II



References

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- M.G. Albanesi, R. Amadeo, S. Bertoluzza, G. Maggi, *A new class of wavelet-based metrics for image similarity assessment*. Journal of Mathematical Imaging and Vision, Vol. 60, Issue 1, pp 109–127
- G. Maggi Ph.D. Thesis
- …

Project Details

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