A new geodesic-based feature for characterization of 3D shapes: application to soft tissue organ temporal deformations

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Introduction

- Statistical shape analysis do not cease to interest researchers in computer vision for understanding patterns in large data sets.
- Parameterize shape large deformations over time while taking into account their **non-Euclidean geometry**.
- Use of **Riemannian geometry** instead.
- Satisfy Kendall's shape space properties :
  - Define shape with k surface points
  - filtering out location, size and rotation
- **Application :** *In vivo* characterization of organ dynamics using dynamic MRI data.

Methods : surface parameterization

- The marching squares/cubes is the standard algorithm to extract iso-curves/surfaces from a discretized image/volume.

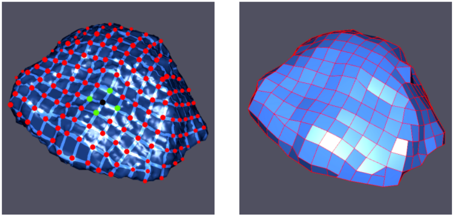
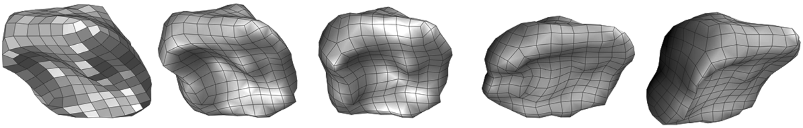


FIGURE 1 – Surface parameterization : from (x,y,z) to (F,V) mesh structure (Instant Meshes).

- Vertices form a pointcloud (points are geodesically equidistant)
- Estimating shape trajectories from pointclouds using the LDDMM.

Methods : dynamic 4D quad mesh

- Tracking vertices while keeping faces unchanged



$t = 0$ $t = 55$ $t = 152$ $t = 185$ $t = 230$

FIGURE 2 – Smooth 4D quad mesh.

- Providing an hypothesis compatible with the physics of deformations (Hamiltonian statistical mechanics).
- Useful for establishing a robust biomechanical model of organ dynamics (finite element simulations)

Methods : proposed shape descriptor

- Mapping a shape to a sphere by minimizing a "Dirichlet energy" (a *one-to-one* mapping)
- Deriving a feature to capture surface variation, with no need to compute Riemannian tensor
- Computing tensors not only incurs high computational costs but also impacts numerical stability

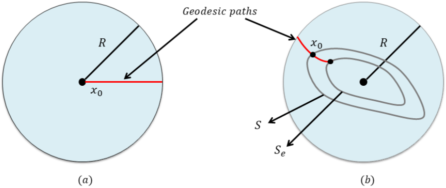


FIGURE 3 – Optimal geodesic paths.

Methods : proposed shape descriptor

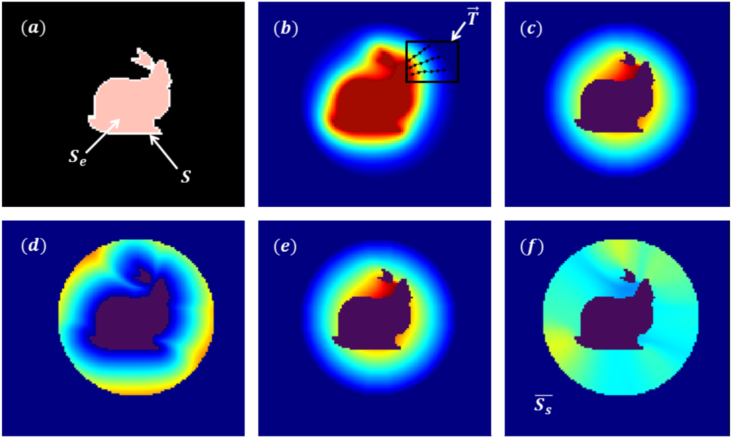


FIGURE 4 – Pipeline : the Stanford bunny example.

Results : Application to synthetic shapes

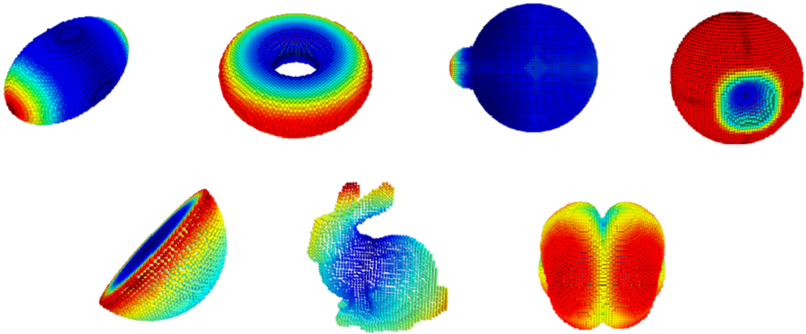


FIGURE 5 – Feature application to symmetric and non-symmetric 3D shapes.

Results : Application to bladder surface trajectories

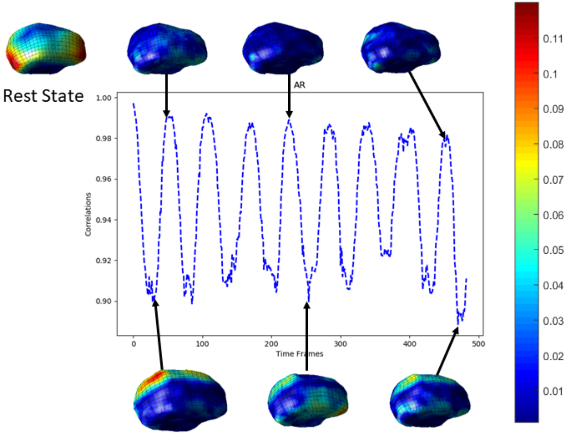


FIGURE 6 – Organ motion patterns during deep breathing exercices

Results : Application to bladder surface trajectories

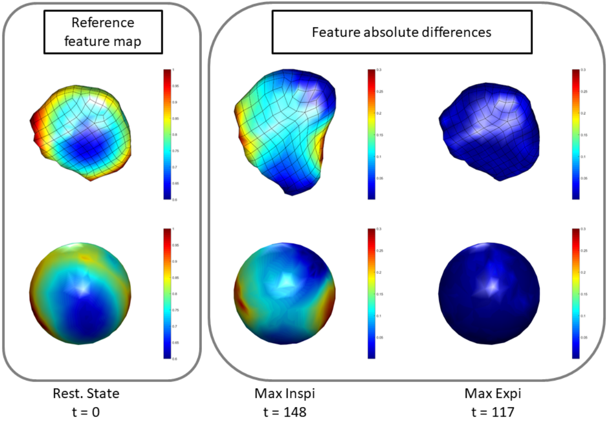


FIGURE 7 – Feature projection : 1^{st} column : reference feature map ; 2^{nd} and 3^{rd} columns : feature absolute differences w.r.t the reference (deformations).

Conclusion

Three main contributions :

- 4D quad mesh
- Novel geometric shape descriptor
- Biomedical context : application to realistic bladder volumes undergoing large deformations during forced respiratory motion
- **Perspective :** optimization of the acquisition process (determine the best geometry of the MRI acquisition plans)
- Some animations : https://amubox.univ-amu.fr/s/qPScm4wjBcRNqJ9

Thank you for your attention :)