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

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Motivation

Performing spatio-temporal statistical shape analysis using robust and numerically stable shape descriptors.

Challenges

Characterization of soft tissue organ deformations is challenging because of the complexity of their topology and their time dynamics [1].

Proposed Solution

A non-parametric Eulerian approach to derive a geometric descriptor from optimal geodesic lengths.

Can characterize large deformations.

Compact shape representation

Encoding large deformations with few parameters while covering the entire surface topology using the LDDMM framework.

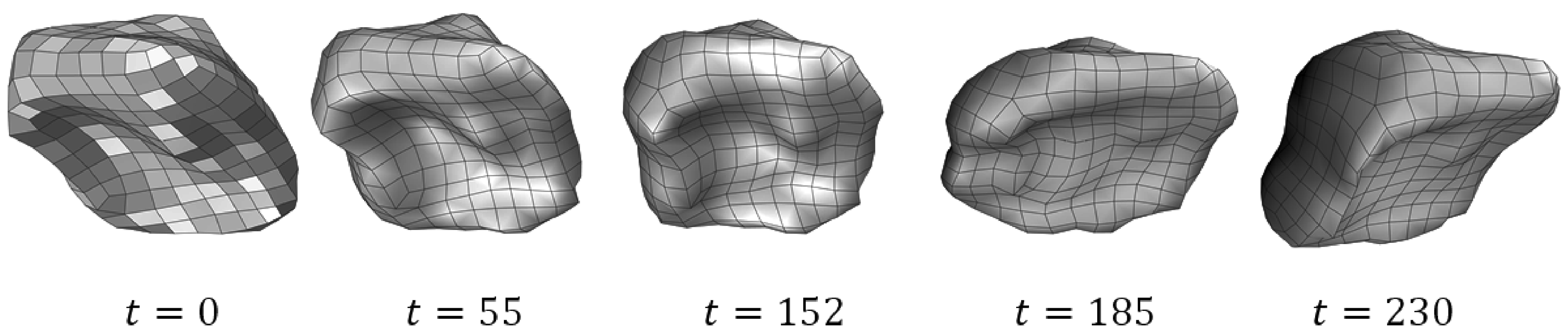

FIGURE 1. 4D reconstructed quad mesh during forced respiratory motion.

Providing an hypothesis compatible with the physics of deformations (Hamiltonian statistical mechanics).

Our descriptor

Mapping shape to a sphere by minimizing a Dirichlet energy.

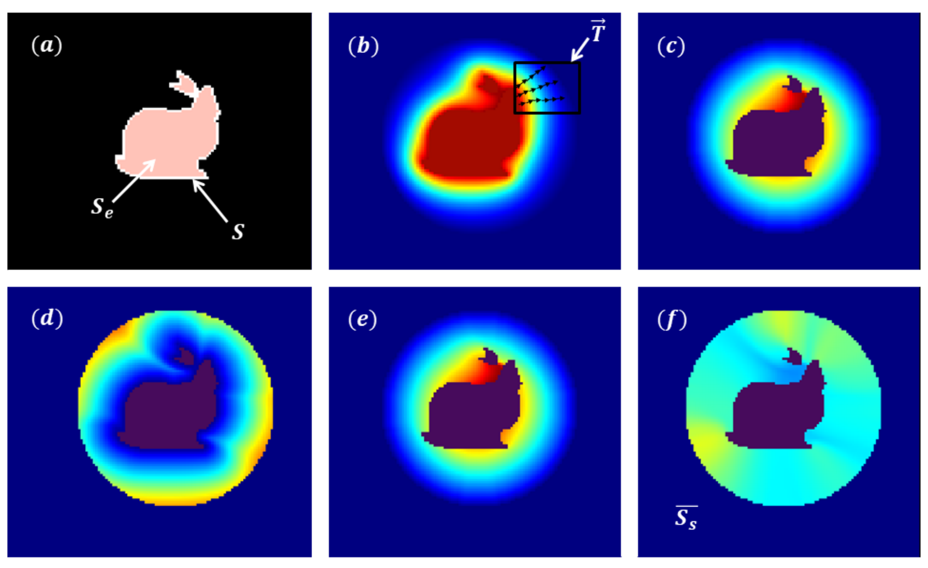

FIGURE 2. Spherical mapping and derived shape descriptor.

The proposed descriptor is :

- Scale/rigid motion invariant.
- Independent of surface parameterization.
- Smoothly delineate between concave and convex regions.

Determine geodesic lengths from curve shortening flow.

Feature maps for synthetic data

One can deal with genus-0 and genus-1 surfaces (*i.e.* torus example).

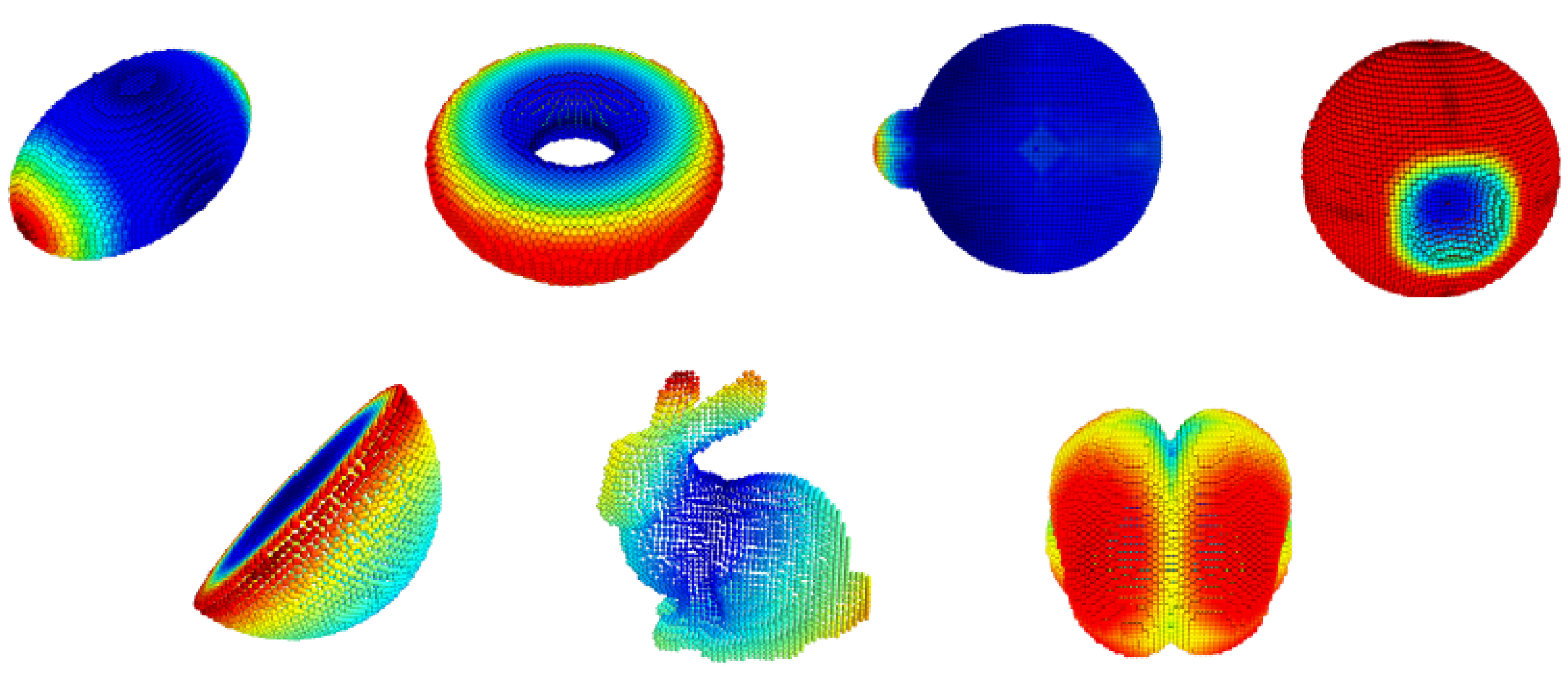

FIGURE 3. Obtained feature maps for simulated 3D surfaces.

A fast Eulerian PDE approach is used to compute the optimal geodesic lengths from curve shortening flow.

Application : Characterization of bladder deformations

Use of clinical dynamic MRI sequences : reconstructed 3D volumes [2].

- Correlation curves between temporal feature maps.
- Shape dynamics w.r.t the resting state (reference).

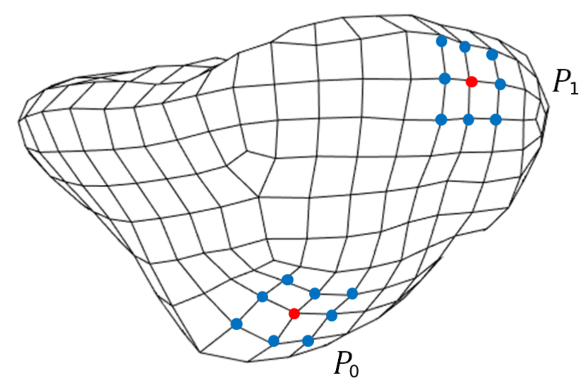

FIGURE 4. Significant points.

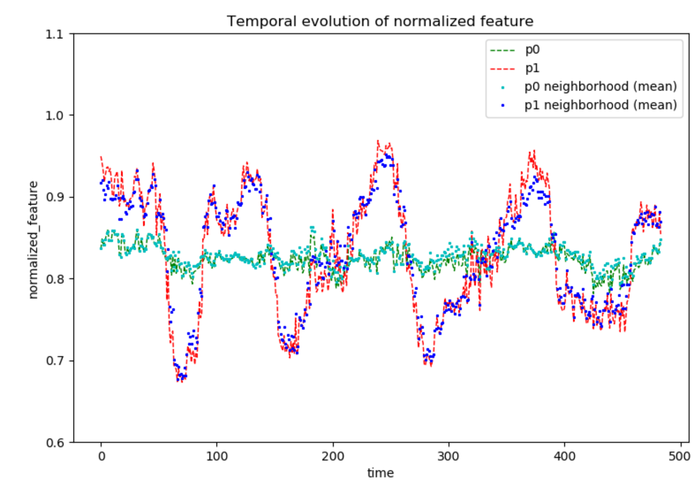

FIGURE 6. Local characterization of surface dynamics.

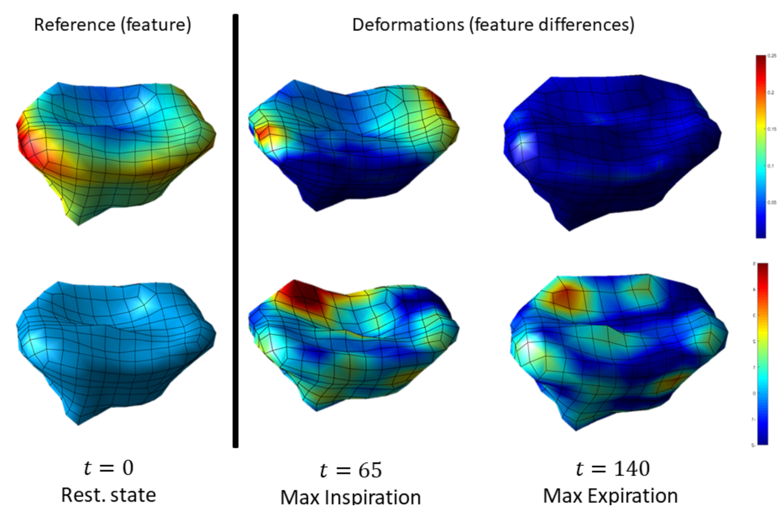

FIGURE 5. Surface motion patterns : 1^{st} row, using our descriptor ; and 2^{nd} row, using mesh elongations.

Algorithms were tested for data from 3 healthy women.

Results :

- The organ was highly deformed by maximum of inspiration.
- Deformations occured essentially on the top lateral regions.

Perspectives

A non-invasive characterization of surface motion patterns in highly deformable soft tissue organs from dynamic MRI.

- Use of different features (e.g. Riemannian curvature).
- Perform statistics at the population level.

Feasibility of characterizing cardiac motion patterns with a full volume coverage.

Acknowledgements

This work is funded, in part, by the AMIDEX - Institut Carnot STAR.

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[2] Ogier et al. 3D Dynamic MRI for Pelvis Observation-a First Step, ISBI 2019.