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

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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

\[ t = 0 \quad t = 55 \quad t = 152 \quad t = 185 \quad t = 230 \]

**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

![Geodesic paths](image)

**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 exercises
Results: Application to bladder surface trajectories

Figure 7 – Feature projection: 1st column: reference feature map; 2nd and 3rd 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 :)
