Loosely Distinctive Features for Robust Surface Alignment

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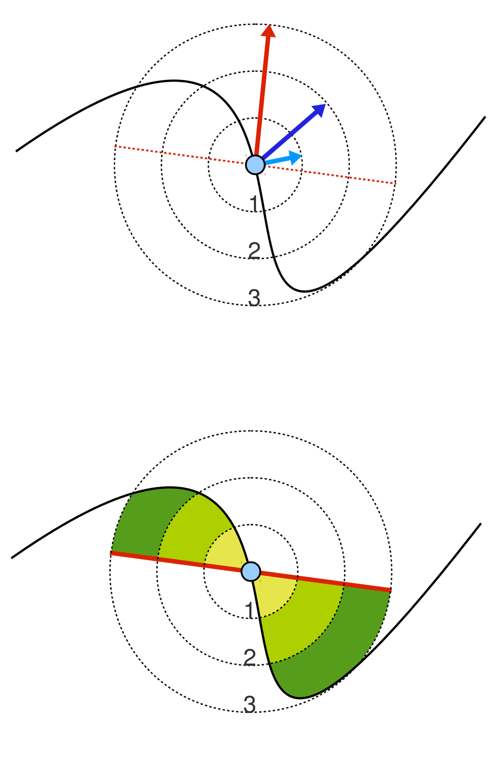
Research Goal

In this work we introduce a class of very simple multi-scale surface features called *Surface Hashes*. These features show a very low distinctiveness in isolation, but when coupled with a game-theoretic matching technique that exploits global geometric consistency they allow to attain extremely robust surface registration.

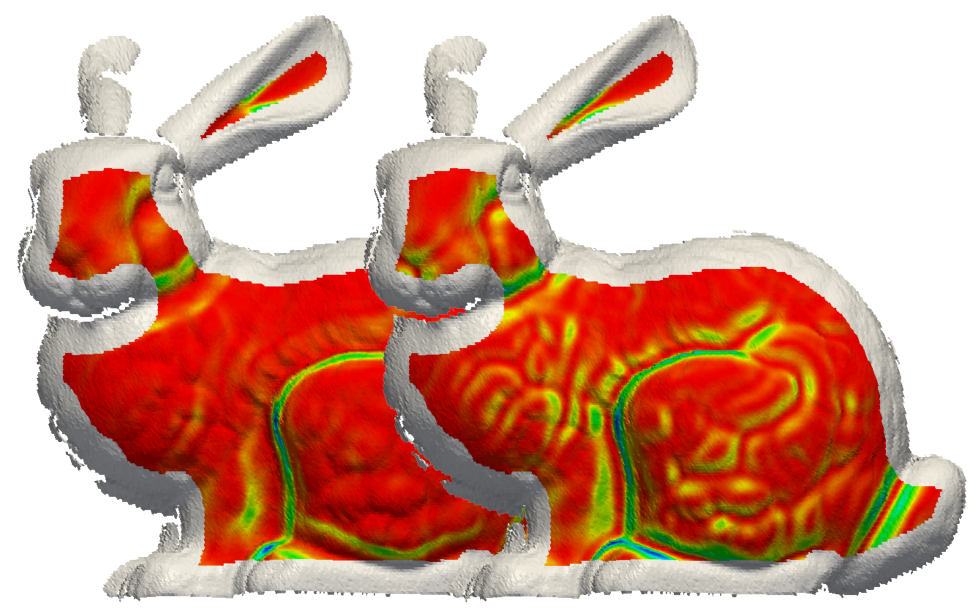
We introduce both a novel technique to detect and describe 3D interest points and a technique to use them for surface alignment.

Surface Hashes

Surface Hashes are concise, point-wise descriptors which exhibit the property of being highly repeatable at the cost of a relatively high probability of clashing.



The *Normal Hash* (on the left) is the vector of inner products between a reference normal at a large scale patch and the average normals computed at smaller scales.



The *Integral Hash* is the vector of approximated volume invariants of spheres centered at the vertex. The volume is taken as the simple sum of residuals over a fitted plane.

Interest Points Detection

We screen out features exhibiting too common descriptors over the surface.

To do this, we define a Matching Game where the strategy set S corresponds to the set of all the surface points, and the payoff matrix is defined by:

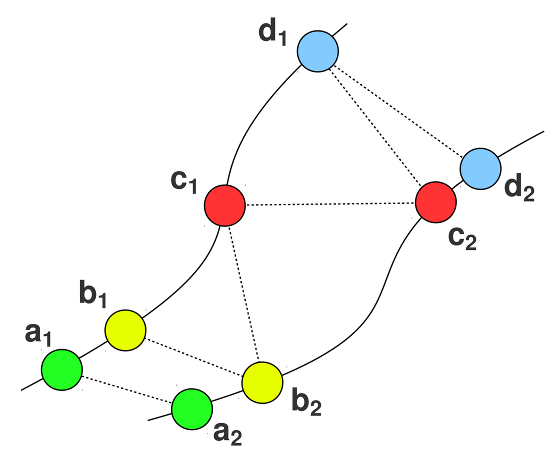
$$C(ij)=e^{-\alpha|d_i-d_j|}$$

The features that survive the evolutive process are then removed from the set of interest points.

Surface Registration

We define another Matching Game that ignores the information given by the descriptors and takes advantage of the rigidity constraint to be enforced in the surface registration problem.

Given a set of model points M and a set of data points D we call a *mating strategy* any pair (a_1, a_2) with $a_1 \in M$ and $a_2 \in D$. We assign to each pair of mating strategies a payoff that is inversely proportional to a measure of violation of a rigidity constraint.



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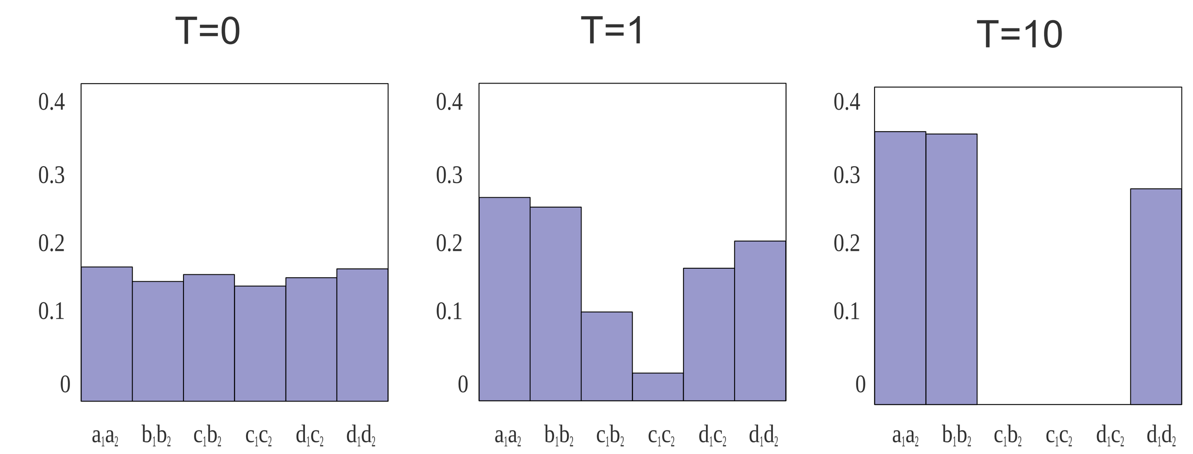
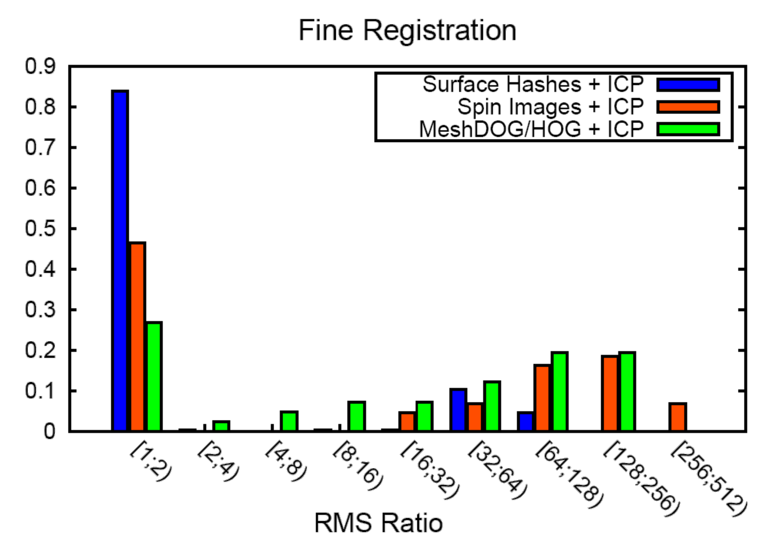
	a_1a_2	b_1b_2	c_1b_2	c_1c_2	d_1c_2	d_1d_2
a_1a_2	0	1	0.1	0.1	0.7	0.9
b_1b_2	1	0	0	0.1	0.7	0.9
c_1b_2	0.1	0	0	0	0.6	0.4
c_1c_2	0.1	0.1	0	0	0	0.1
d_1c_2	0.7	0.7	0.6	0	0	0
d_1d_2	0.9	0.9	0.4	0.1	0	0

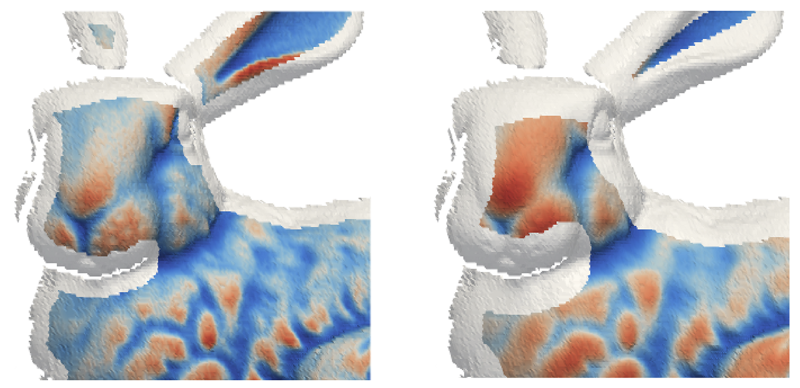


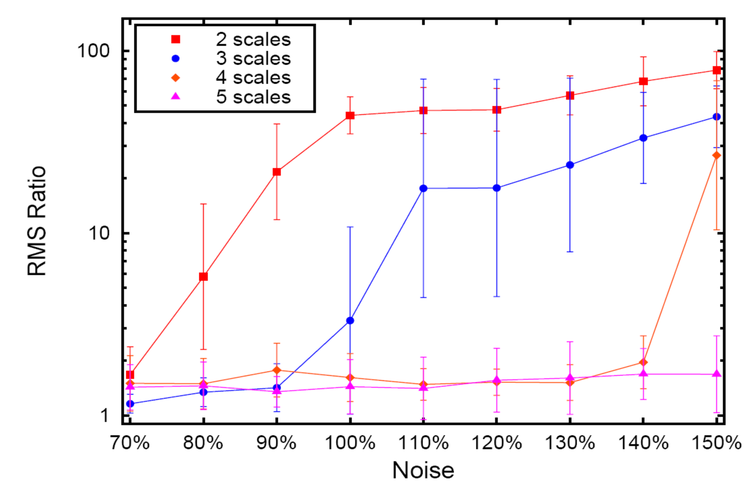
As the game is repeated, players will adapt their behavior to prefer matings that yield larger payoffs, driving all inconsistent hypotheses to extinction. The search for a stable state is performed by simulating the evolution of a natural selection process.

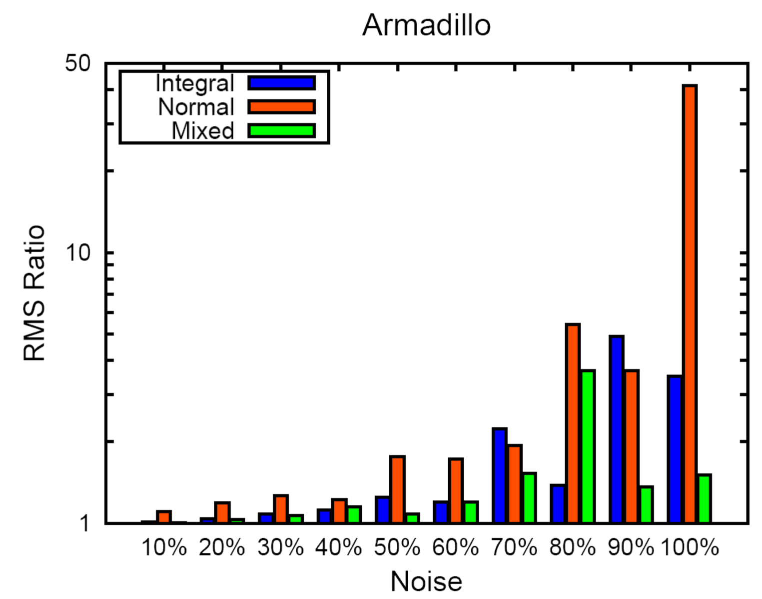
Experimental Results

- We studied the sensitivity to noise, occlusion and scale of different Surface Hashes on both real-world and synthetic objects
- RMS Ratio is the ratio between the RMS obtained after registration and the RMS of ground truth alignment, computed on the *true* correspondences
- We compared our full pipeline with DARCES and with a PROSAC-based variant taking advantage of our descriptors as a prior
- System-level comparisons were performed with the Spin Images and MeshDOG/HOG pipelines









Conclusions

We introduce a novel surface registration technique that uses very simple descriptors to create several weak correspondence hypotheses that are further optimized by a robust game-theoretic matcher. The approach is validated on a wide range of experiments showing its greater robustness with respect to noise and occlusion in comparison with other well-known techniques.