Continuous Global Optimization in Multiview 3D Reconstruction

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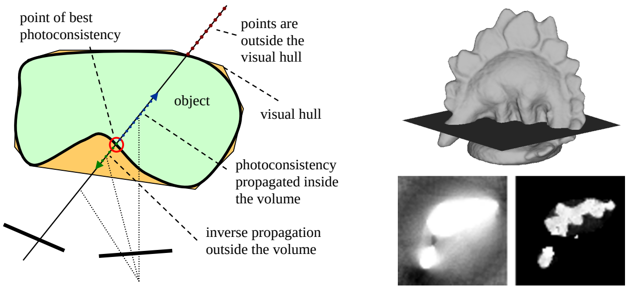
Contributions

- The first formulation for *continuous* global optimization in the context of multiview 3D reconstruction
- Introduction of an energy model based on stereo-based regional terms without preliminary per-pixel disparity estimation



Volumetric propagation of photoconsistency. *Left:* Regional terms ρ_{obj}, ρ_{bck} are defined according to the location of maximal photoconsistency along visual rays through the current point. *Right:* This leads to considerable improvements in boundary alignment compared to silhouette-based formulations.

Energy Model

The following energy functional is considered:

$$E(S) = \int_{R_{obj}^S} \rho_{obj}(x)\,dx + \int_{R_{bck}^S} \rho_{bck}(x)\,dx + \nu \int_S \rho(x)\,dx,$$

where R_{obj}^S and R_{bck}^S denote the interior and exterior region with respect to S, and ρ_{obj}, ρ_{bck} and ρ are regional and classical surface-based photoconsistency functions, respectively.

Convex Formulation

- Introducing a binary-valued function to label object and background region yields:

$$E(u) = \int_V (\rho_{bck}(x) - \rho_{obj}(x))u(x)dx + \nu \int_V \rho(x)|\nabla u|dx$$
$$\text{s. t. } u \in \{0,1\}\,.$$

- Relaxation of the above binary constraint leads to the following *convex* formulation:

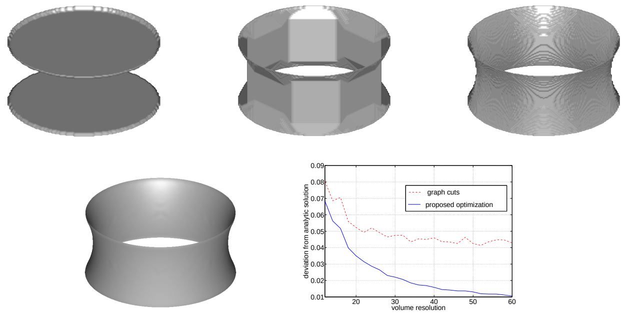
$$E(u) = \int_V (\rho_{bck}(x) - \rho_{obj}(x))u(x)dx + \nu \int_V \rho(x)|\nabla u|dx$$
$$\text{s. t. } u \in [0,1]\,.$$

- The relaxed functional is minimized by solving the respective Euler-Lagrange equation

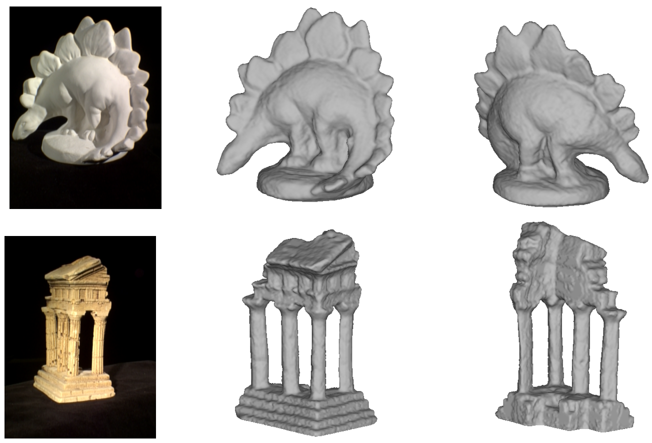
$$(\rho_{bck} - \rho_{obj}) - \nu\,\mathrm{div}\left(\rho \frac{\nabla u}{|\nabla u|}\right) = 0$$

  via linearization and Successive Over-Relaxation.

- Thresholding the result by some $\mu \in (0,1)$ leads to a *global* optimum of the original binary energy model (see [1]).

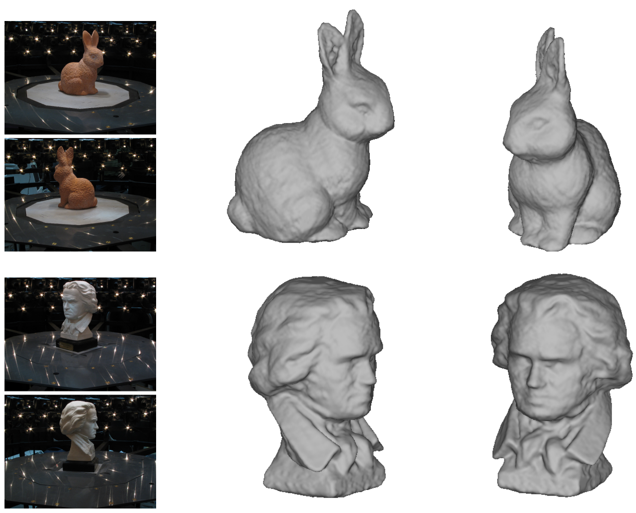


Continuous vs. discrete shape optimization. *First row:* Reconstruction of a synthetic catenoid with 6-conn., 26-conn. graph cuts and the proposed optimization, respectively. *Second row:* Analytic solution and plot of the deviation of the recovered surface (26-conn. graph cuts) from the ground-truth for increasing volume resolution.



Middlebury data sets (48/47 images). One of the input images and reconstructed surface.

data set	completeness	accuracy
dinoRing	99.4 %	0.43 mm
templeRing	97.8 %	0.72 mm



Bunny and Beethoven data sets (33 images). Two of the input images and reconstructed surface.

[1] Chan, Esedoglu, Nikolova: *Algorithms for finding global minimizers of images segmentation and denoising models*, SIAM J. Appl. Math., 2006.
[2] Kolev, Klodt, Brox, Esedoglu, Cremers: *Continuous Global Optimization in Multiview 3D Reconstruction*, EMMCVPR, 2007.
[3] Kolev, Klodt, Brox, Cremers: *Propagated Photoconsistency and Convexity in Variational Multiview 3D Reconstruction*, PACV, 2007.

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