Geodesic Neighborhoods for piecewise affine interpolation of sparse data

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Objective

Interpolate range measurements (LIDAR or sparse disparity data) incorporating information provided by a photo u of the scene.

Height samples (5%)

Reference image u

Piecewise affine
interpolation

Previous Work

Smoothness Prior

- Polynomial interpolation [Shepard '68]
- Piecewise affine [Preciozzi '05]
- Minimal surface [Facciolo et al. '06]
- AMLE [Almansa et al. '02]

Parametric models

- Semantic models [Karantzas & Paragios '09] [Van Gool et al. '02]

Geodesic Voronoi Cells

- *Reference Image* $u(x) : \Omega \rightarrow \mathbb{R}^+$, with $\Omega \subset \mathbb{R}^2$
- *Curve* $C(p) : [0, 1] \rightarrow \Omega$, and $C_{s,t}$ curve connecting s and t
- *Geodesic distance* between s and t

$$d(s, t) = \min_{C_{s,t}} \int_0^1 |\nabla u \cdot \dot{C}_{s,t}(p)| + \varepsilon |\dot{C}_{s,t}(p)| dp$$

discourages paths **across high gradients**

- *Positions of the samples* $\Lambda \subset \Omega$
- *Depth values of samples* $G(\lambda) : \Lambda \rightarrow \mathbb{R}$, $\lambda \in \Lambda$
- *Geodesic Voronoi diagram* of the sites in Λ is defined with the geodesic distance
- Computed with fast marching [Yatziv, Bai, Sapiro '06-'07]

Geodesic Voronoi Cells

Geodesic Voronoi diagram of the sites in Λ , successfully accounts for discontinuities in the image.

Reference images

Samples & Voronoi cells

Geodesic Voronoi Cells

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Reference images

Geodesic Voronoi cells

Piecewise Affine Interpolation

- **Lambertian hypothesis:** *a uniform surface with a constant angle has a constant intensity in the image*
- Extrapolate information across uniform regions
- Only one sample per cell: Piecewise constant

Geodesic neighborhood

$GN_K(p)$ of p , set of K -nearest (geodesic) samples of Λ to p .

Obs: Samples in $GN_K(p)$ likely to have the same model as p .

Geodesic neighborhood

Piecewise Affine Interpolation

Robust affine plane interpolation using GN_K

Linear blend with 5 GNN

Affine estim. same 5
GNN

- $\forall p \in \Lambda$ use RANSAC to fit an affine plane through $GN_K(p)$
- Then extended the model to the entire cell
- We call H the piecewise affine model union of all the cells
- Attention: this is noiseless data

Constrained Region Merging

Oversegmentation problems

- The model of each cell is independently estimated
- Adjacent cells may end up with different models

Merge regions with compatible models using Mumford-Shah:

$$E(B, f) = \sum_{R \in \mathcal{P}(\Omega, B)} R\text{Err}(R, f) + \lambda \int_B g(s) ds, \quad \lambda \geq 0$$

- **Error term:** $R\text{Err}(X, f) = \sum_{x \in X \cap \Lambda} |f_X(x) - H(x)|^2$
 H : initial plane interpolation,
 f_X : affine model for region X
- **Boundary length:** $g(s)$ big at poorly contrasted boundaries, small at well contrasted ones
- Constrained with LSD segments [Grompone et al. '10]
- Computed with greedy algorithm [Morel & Solimini '95]

Region Merging

Before merging

Region Merging

Before merging

After merging

Segment constraints

Results

Results

More results at <http://gpi.upf.edu/static/geoint>

Conclusions

- Method for interpolating range data that incorporates geometric information from an image of the scene
- Geodesic neighborhoods: tool for modelling the local information, can be adapted to other (non-affine) models
- Poor results for badly contrasted edges between strongly textured regions

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Future work?

- Incorporate texture descriptors to geodesic distance [Bai & Sapiro '07]
- Improve region merging, tree of mergings [Cardelino '10]

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Thank you for your attention

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