

# Geometry Super-Resolution by Example

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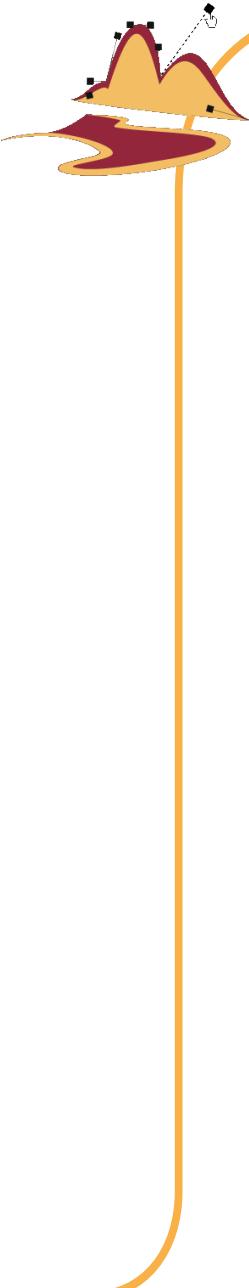
Matmídia Lab - Department of  
Mathematics - PUC-Rio



Visgraf Lab - IMPA

SIBGRAPI 2009

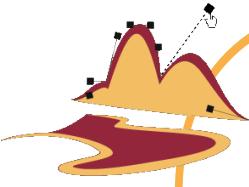




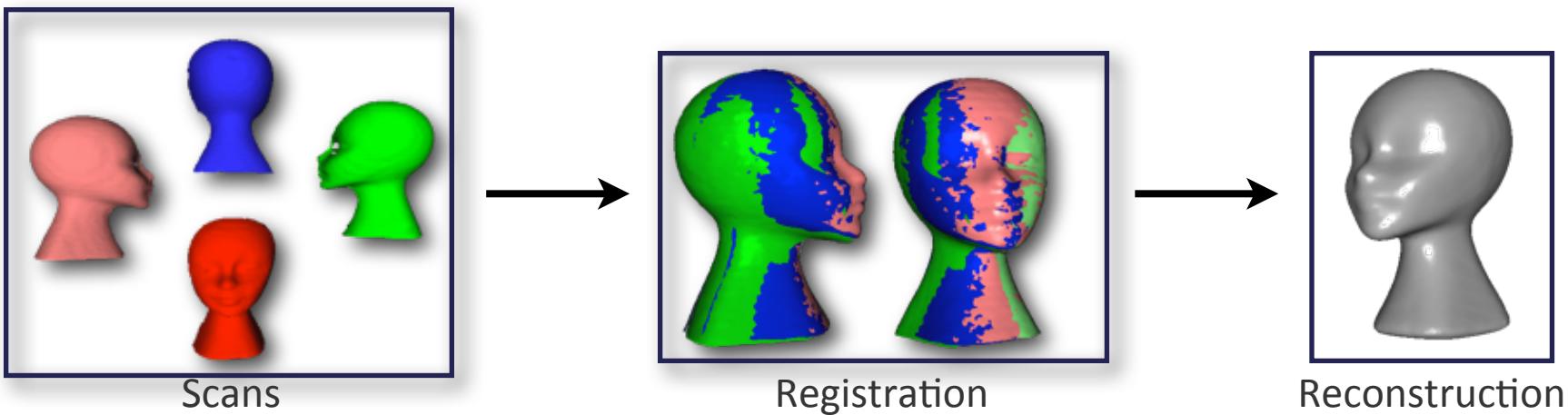
# High-Resolution 3D Model Acquisition Problem



...

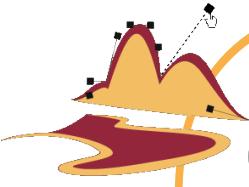


# Usual Pairwise Surface Registration

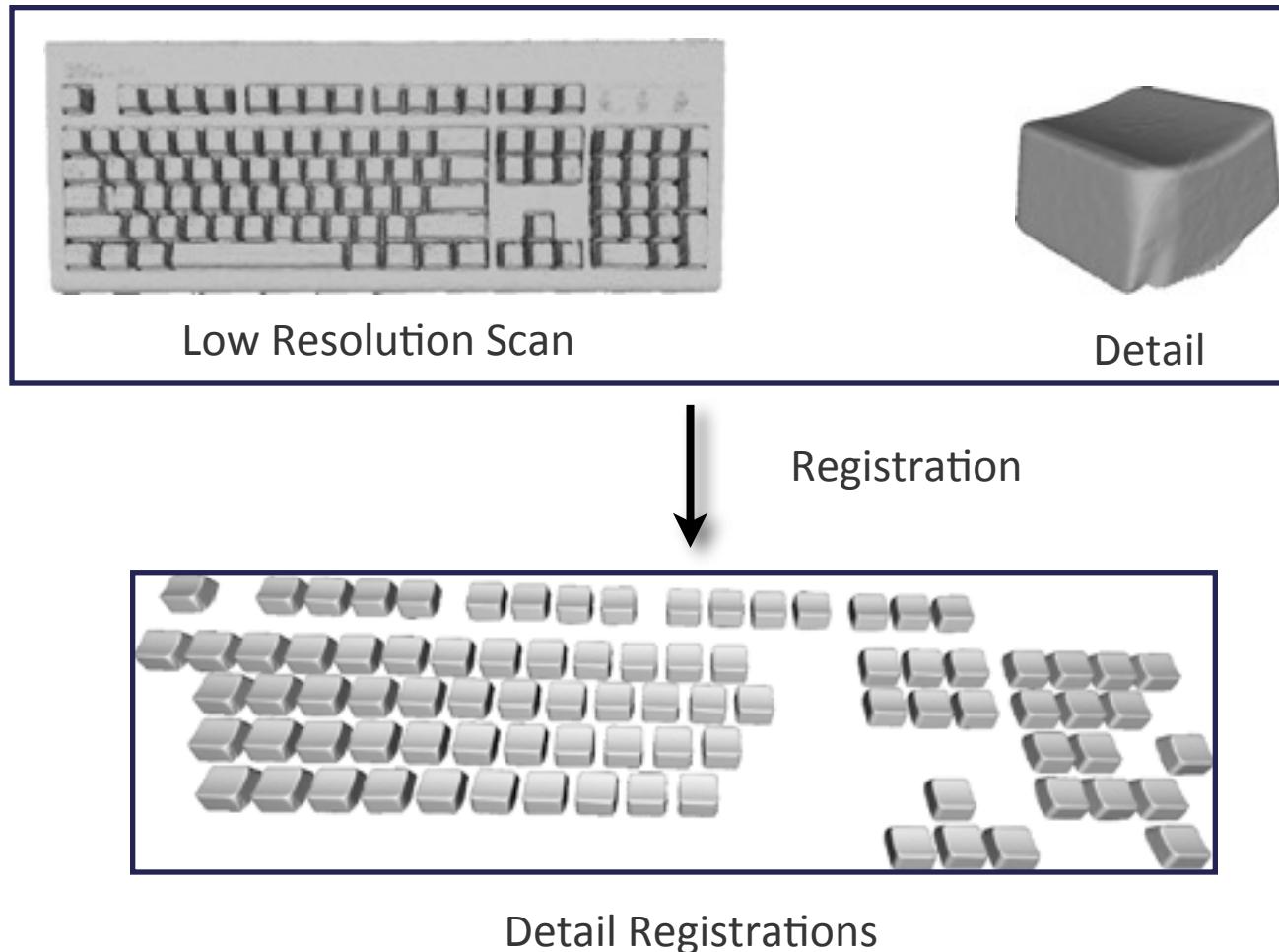


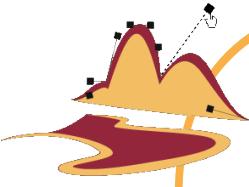
Single occurrences registration

Common resolution

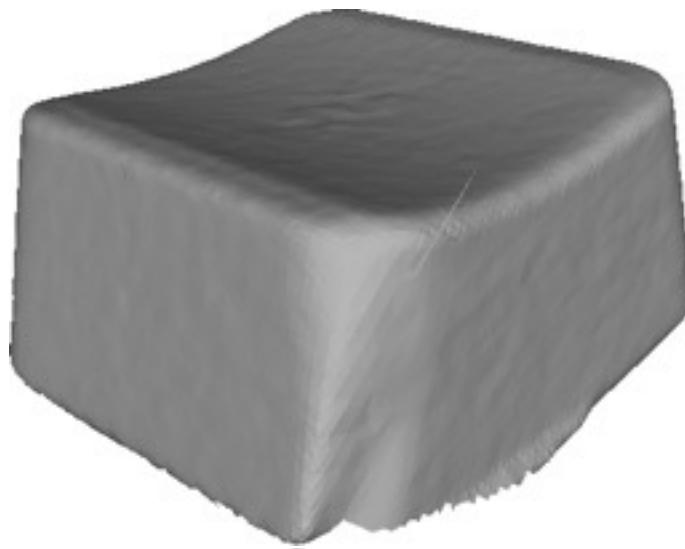


# Challenges: Multiple Occurrences



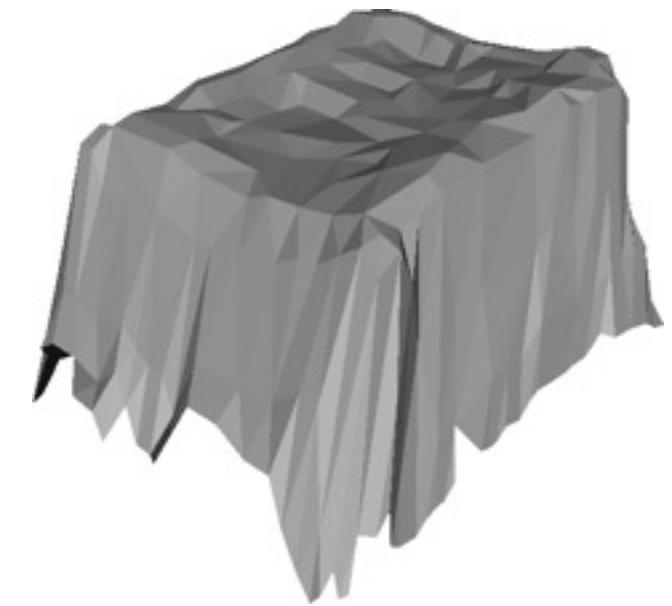


# Challenges: Mixed-Resolution Registration

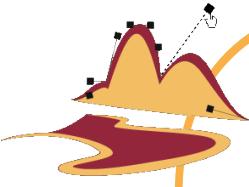


High Resolution Detail

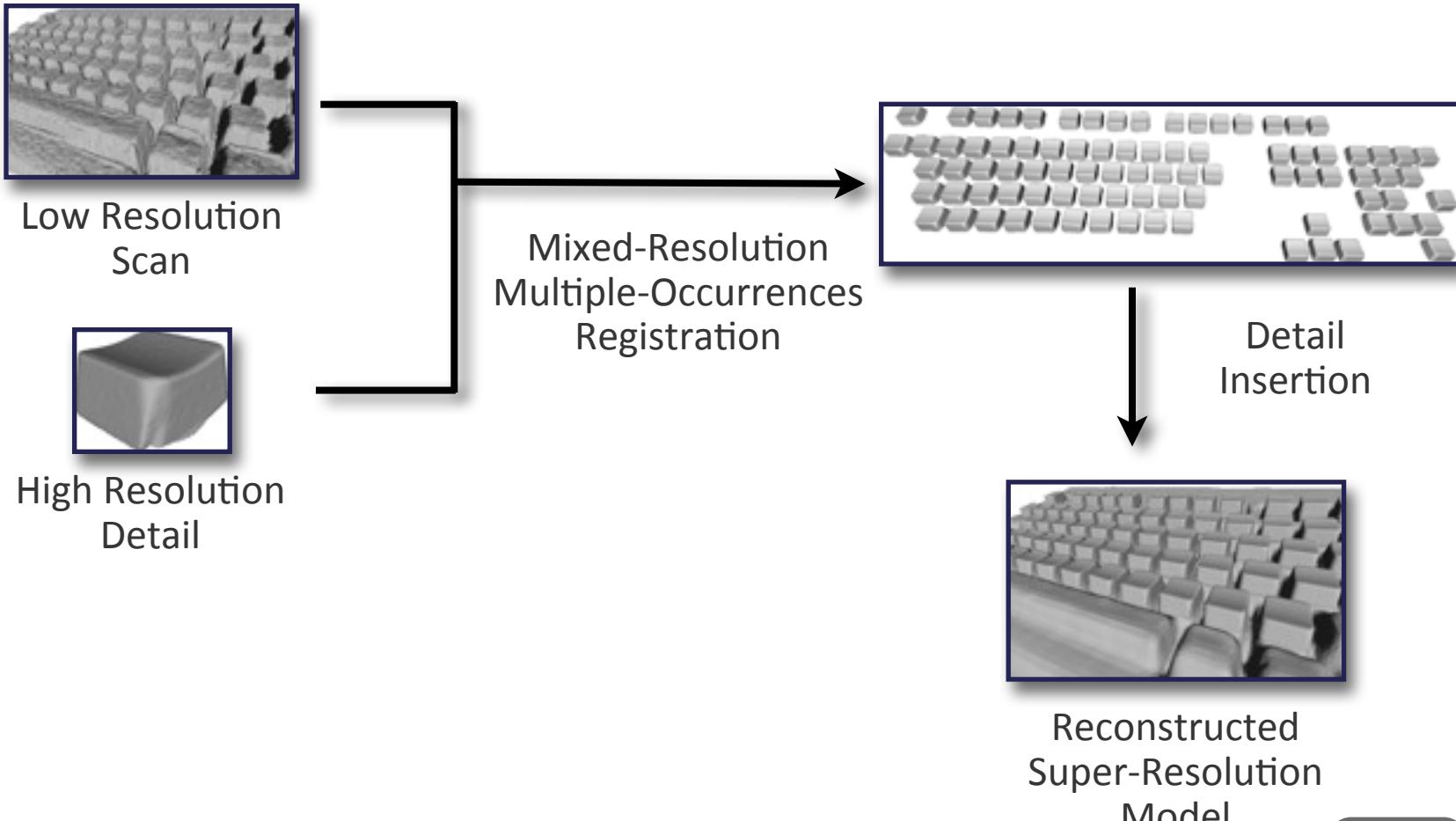
→  
T ?

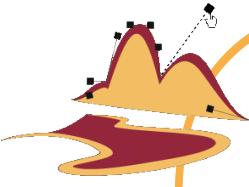


Low Resolution Detail



# Geometry Super-Resolution by Example





# Related Work

## Symmetry Detection

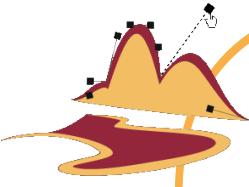


Bokeloh et al., 2009

## Super-resolution from multiple samples

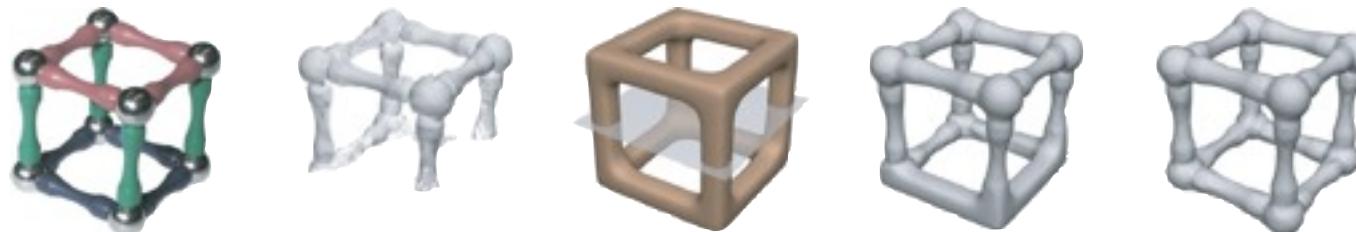


Kil et al., 2006

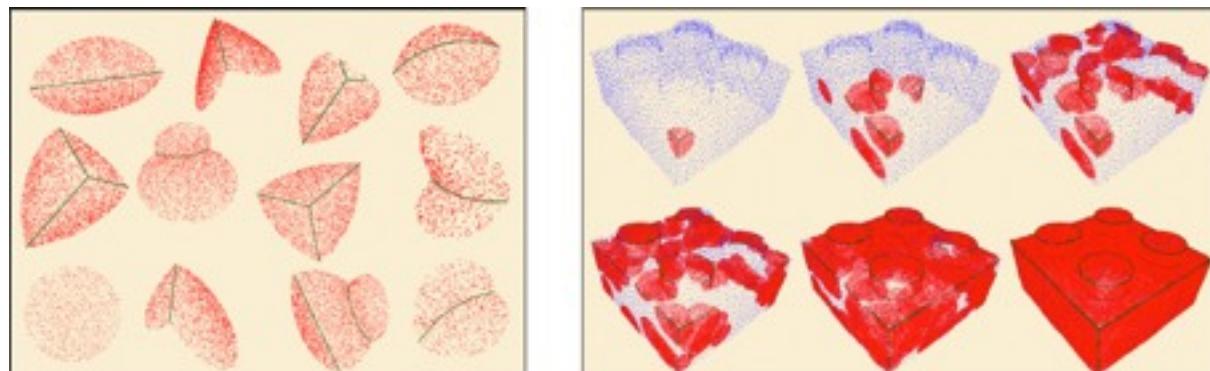


# Related Work

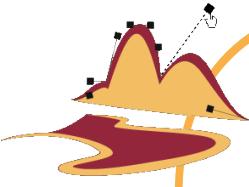
Completion and Super-resolution by example



Pauly et al., 2005

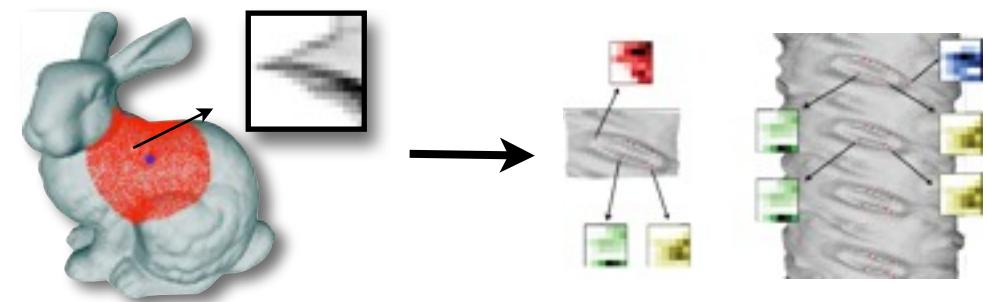
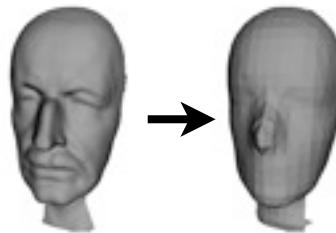


Gal et al., 2007

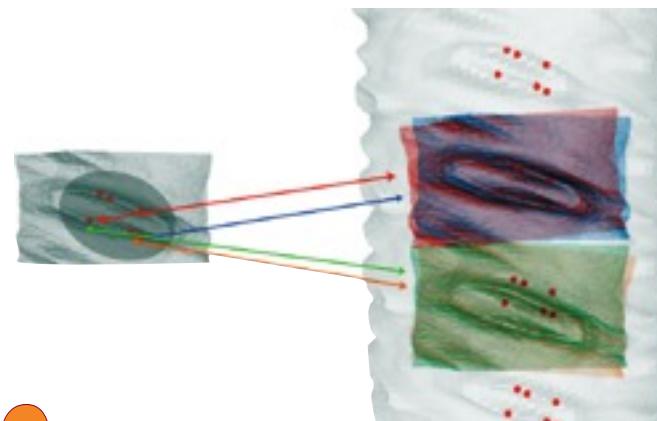


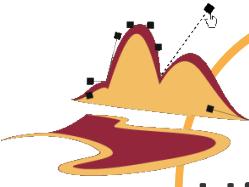
# Contributions

## Mixed-Resolution Detail Registration



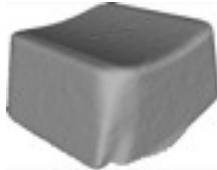
## Multiple Occurrences Detection





# Scenarios

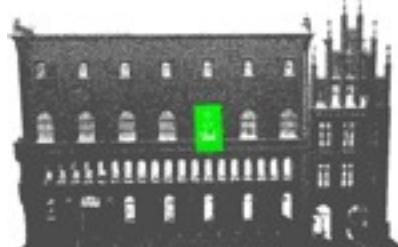
High Resolution Scan Insertion

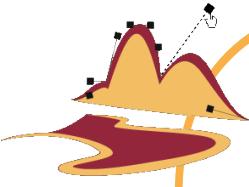


Intelligent Geometry Texture Editing



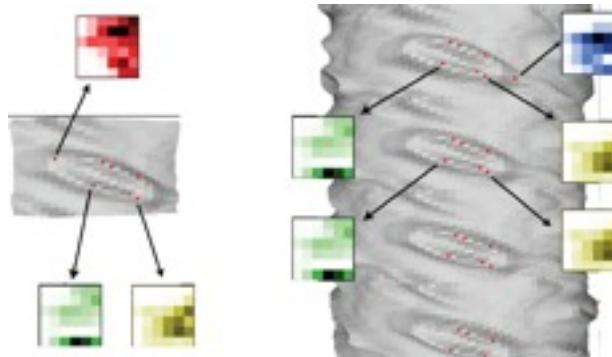
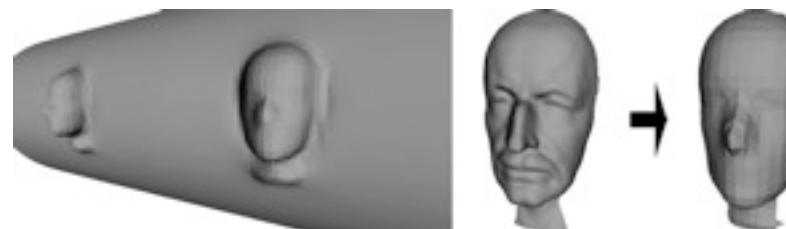
Details' Geometry Accumulation





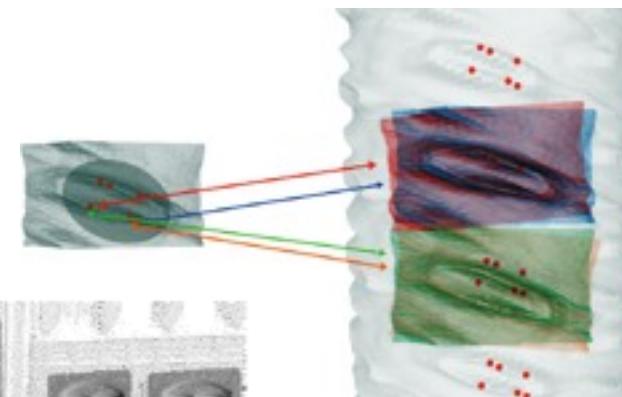
# Steps

I. Scaling

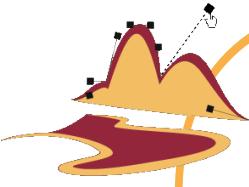


II. Local Feature Matching:  
Spin Image Adaptation

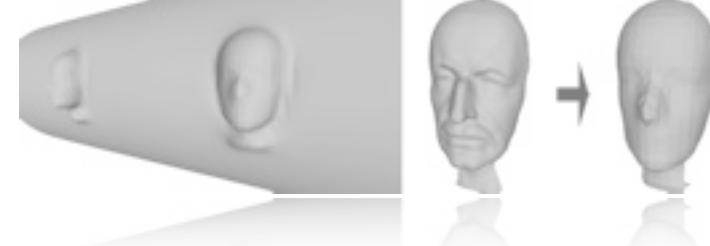
III. Detail Occurrences  
Identification



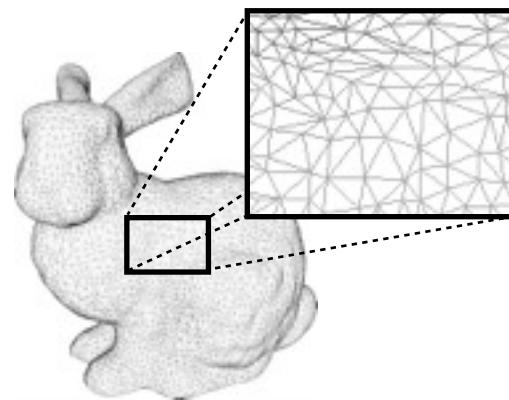
IV. Insertion



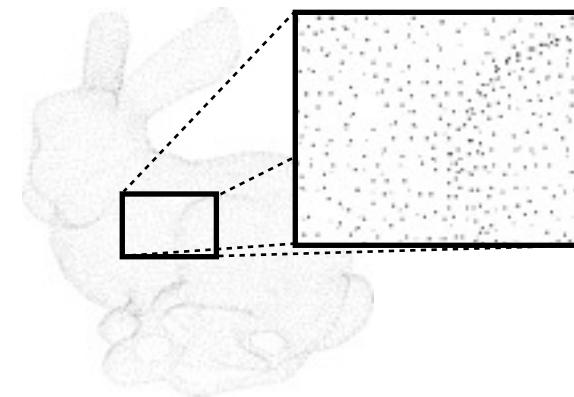
# Scaling



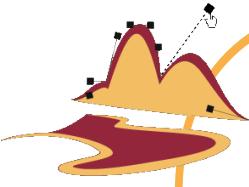
Model Resolution estimation



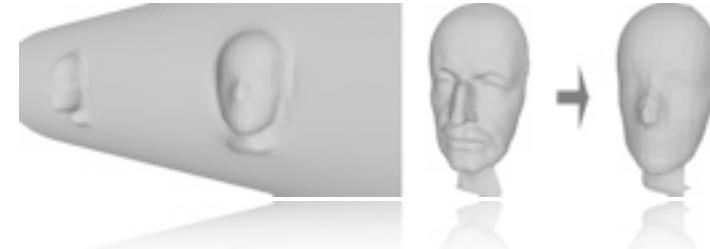
Edges length median



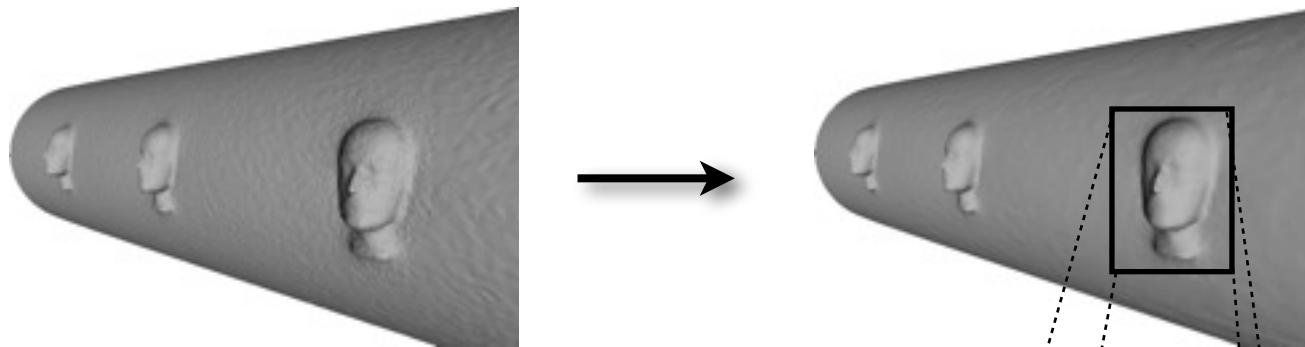
Volume / # Points



# Scaling

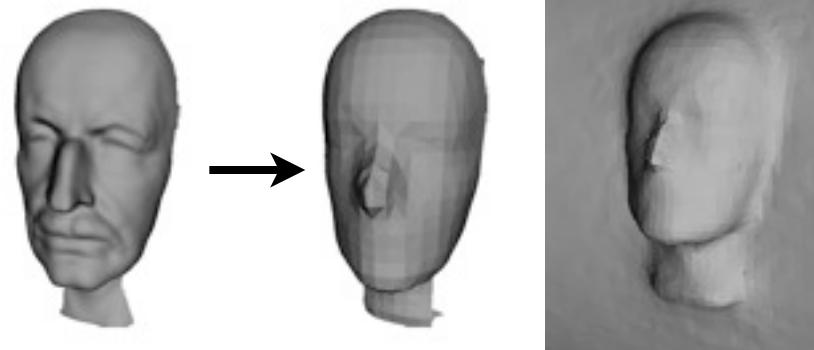


## Model scaling

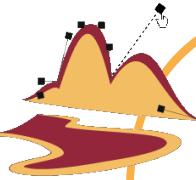


Two-step normal smoothing / vertex fitting

## Detail scaling



Poisson Reconstruction  
(Kazhdan et al., 2006)



# Local Feature Matching

Spin-image Descriptor

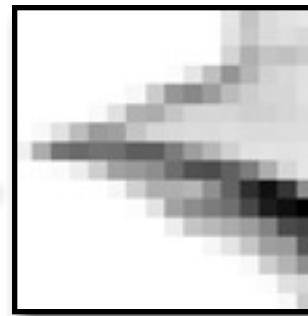
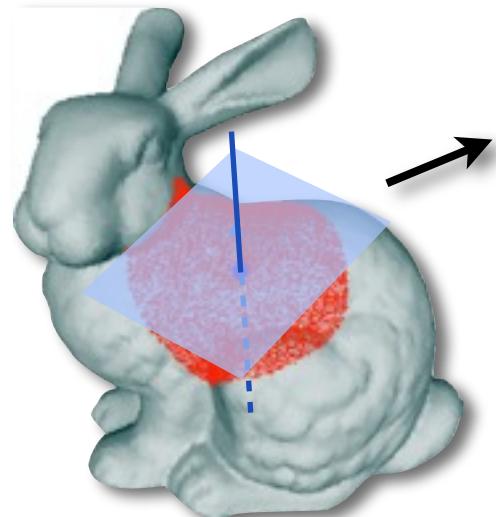


image width: 10 to 20  
bin size: 2 x resolution  
neighborhood size: iw x bs

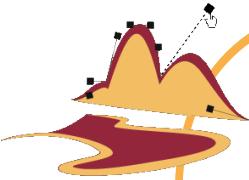
Large neighborhoods!

Usual Matching

$$R_{PQ} = \frac{1}{\sigma_P \sigma_Q} \left( N \sum_i p_i q_i - \sum_i p_i \sum_i q_i \right)$$

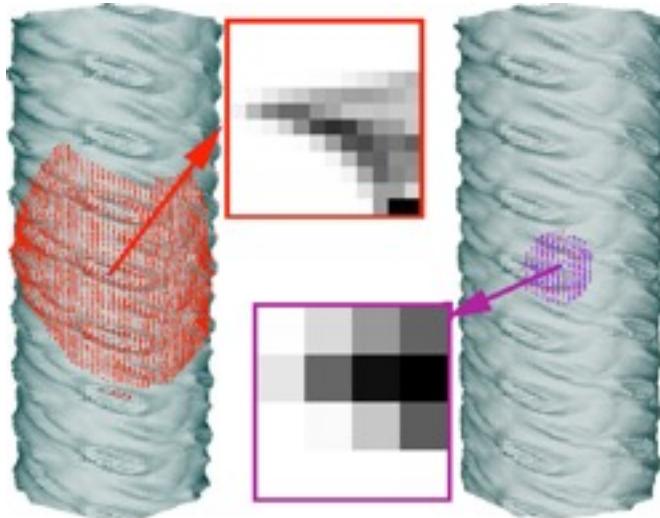
Partial overlap! ←

$$C_{PQ} = \operatorname{atanh}^2(R_{PQ}) - \frac{\lambda}{N-3}$$



# Local Feature Matching

## Spin-image Adaptation



## Adapted Matching

$$R_{PQ} = \frac{1}{\sigma_P \sigma_Q} \left( N \sum_i p_i q_i - \sum_i p_i \sum_i q_i \right)$$

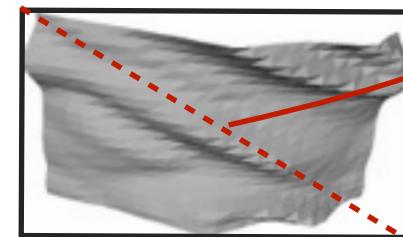


Usual

image width: 10 to 20  
bin size: 2 x resolution  
neighborhood size: iw x bs

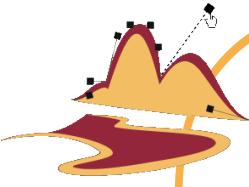
Adaptation

neighborhood size: ~ diag/4  
bin size: 2 x resolution  
image width: ns / bs

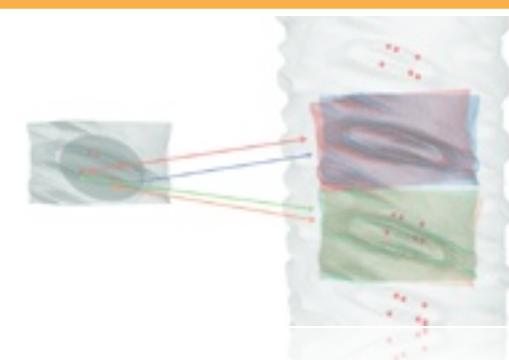


## Feature Selection

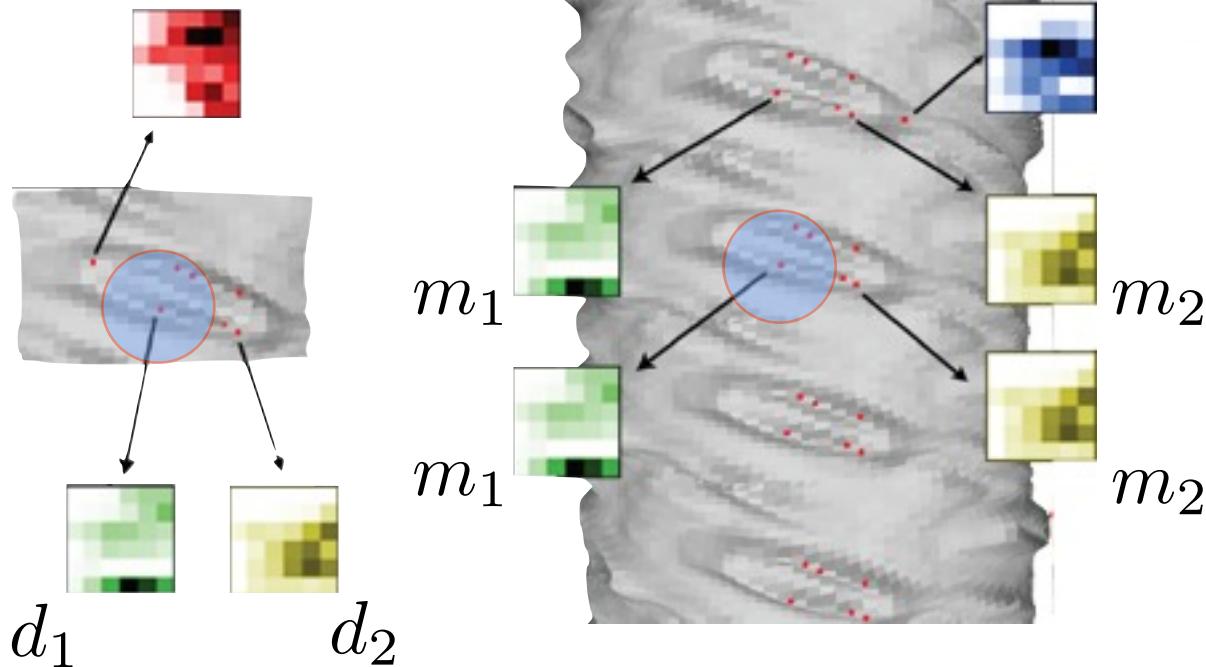
Detail: 10% highest curvature points  
Model: According to detail features interval



# Detail Occurrences Identification

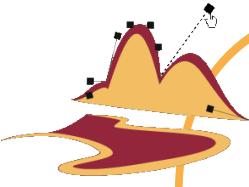


## Grouping



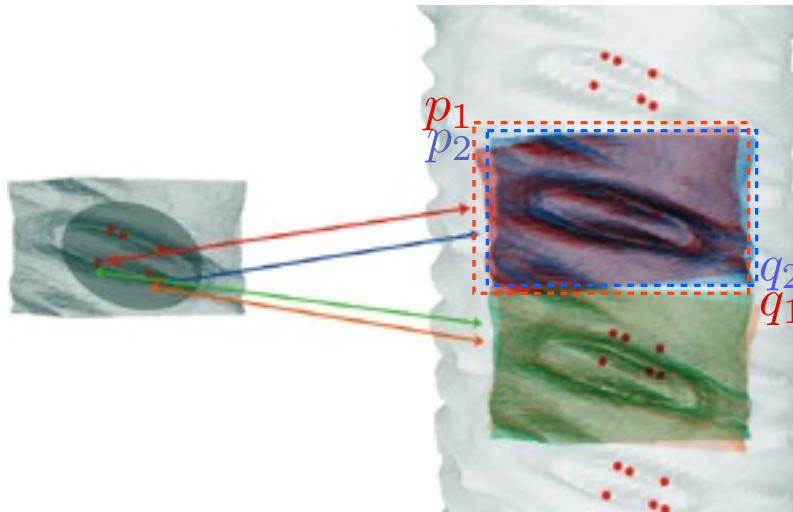
$$\|m_1 - m_2\| < 0.5 \cdot diag$$

$$\|d_1 - d_2\| - \|m_1 - m_2\| < \epsilon$$



# Detail Occurrences Identification

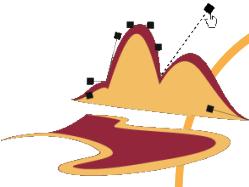
## Validation



- ✓ Full Overlap Test
- ✓ Duplicate Filtering

$$M(T_1, T_2) = \frac{1}{2} \|p_1 - p_2\| + \frac{1}{2} \|q_1 - q_2\|$$

$$M(T_1, T_2) \leq \frac{1}{2} \|p_1 - q_1\|$$

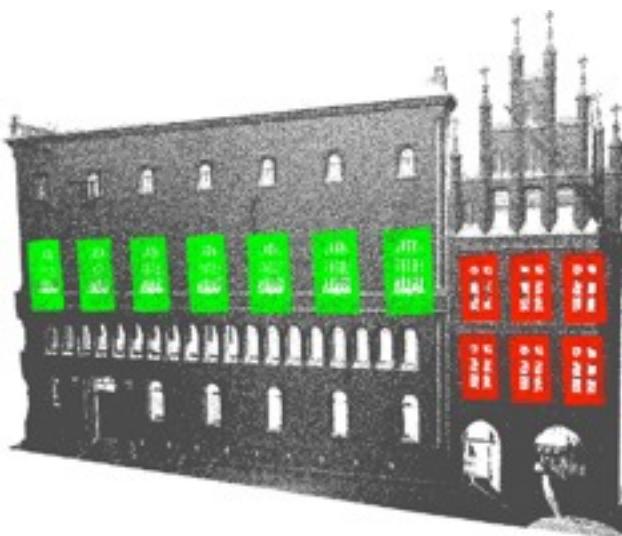


# Insertion



Precise Alignment & Overlap Detection

ICP Algorithm Variation (Besl and McKay, 1992)

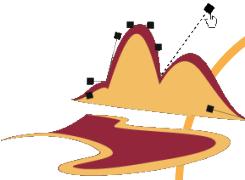


Overlap Regions

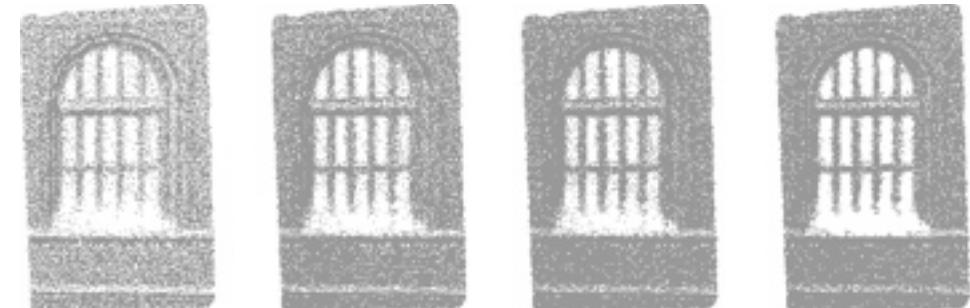
Overlap Removal  
→  
Details Insertion



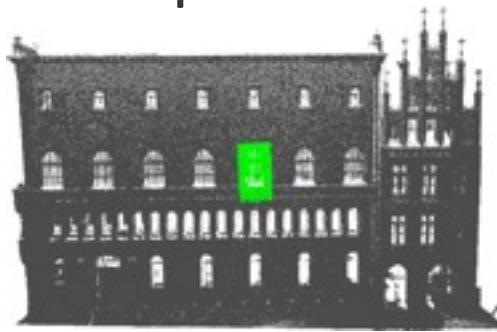
Inserted Super-Resolution Details



# Geometry Accumulation

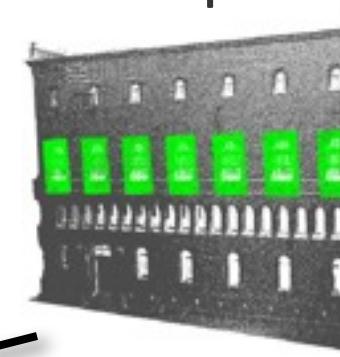


“Super-Resolution by Multiple Samples Example”



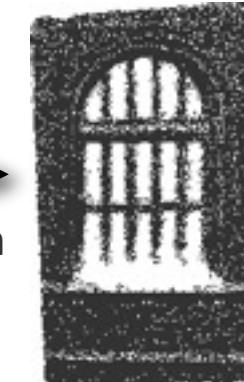
Initial user selection

Occurrences  
Detection



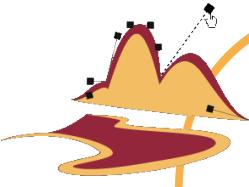
Accumulated  
geometry

MLS Projection  
Weyrich  
et al., 2004



Super-Resolution  
detail

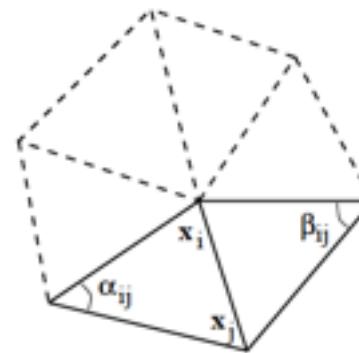
Super-Resolution  
by Example



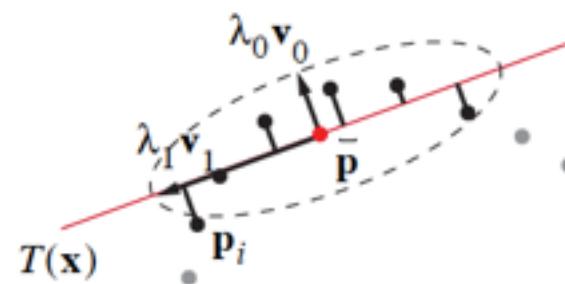
# Implementation details

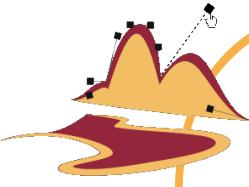
Neighborhood searching: Kd-tree

Mean Curvature for meshes: Meyer et al., 2002



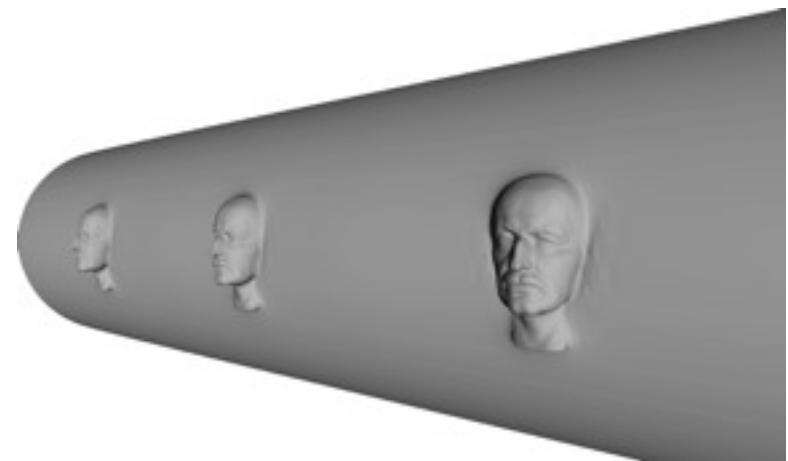
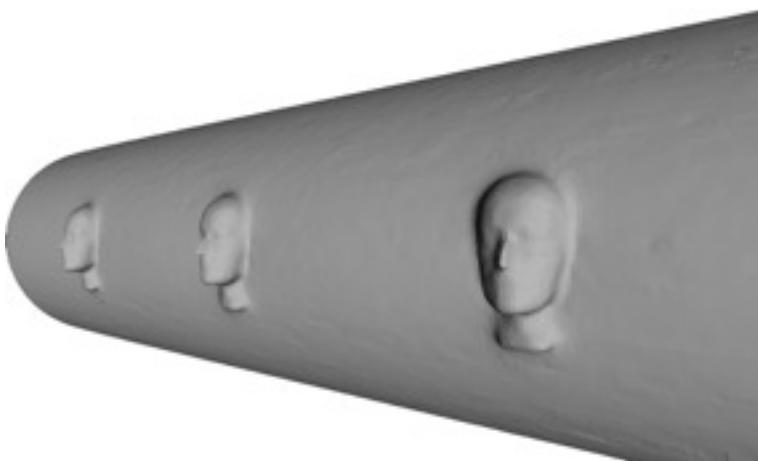
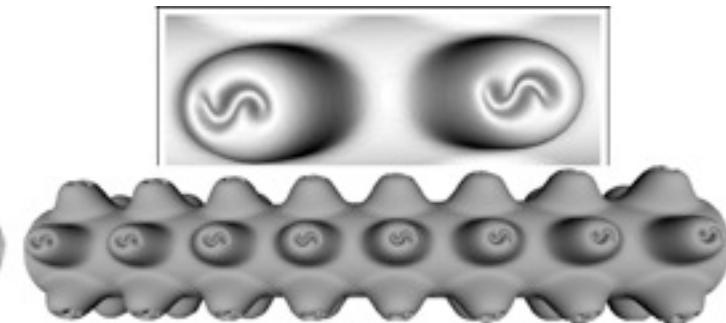
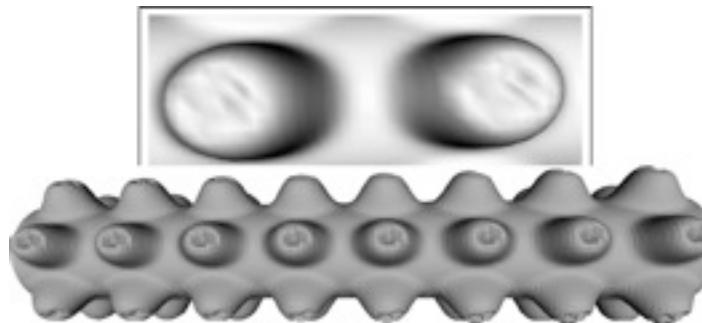
Mean Curvature for point clouds: Pauly et al., 2002

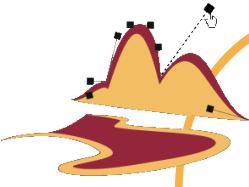




# Results

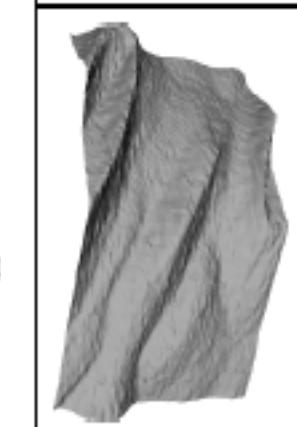
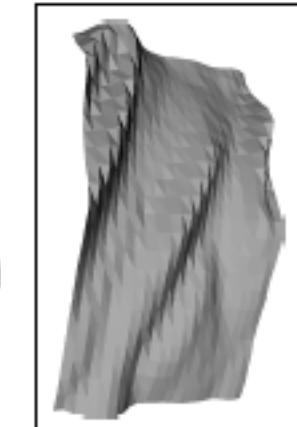
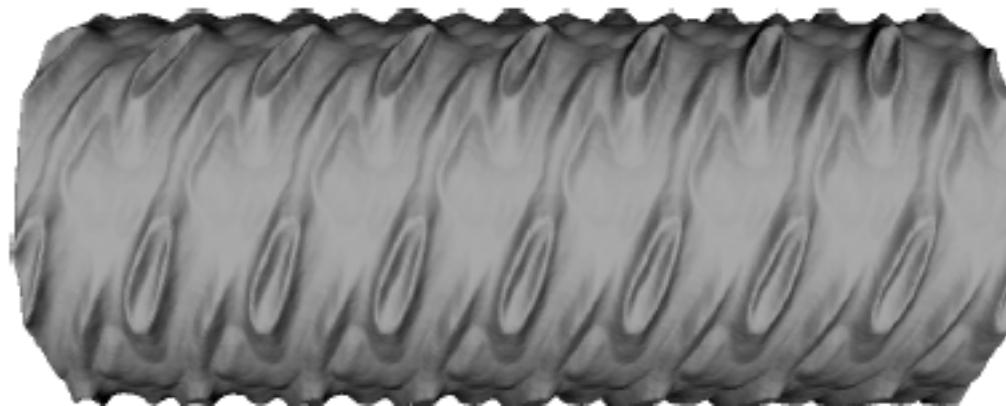
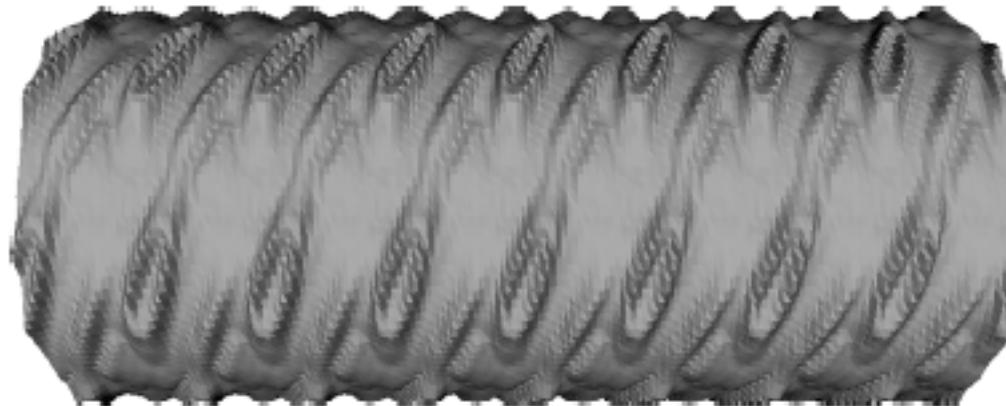
## Synthetic Models

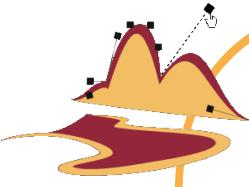




# Results

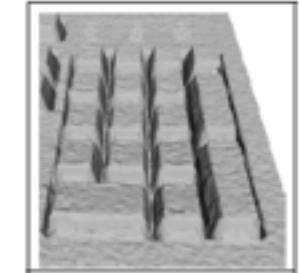
## Synthetic Models





# Results

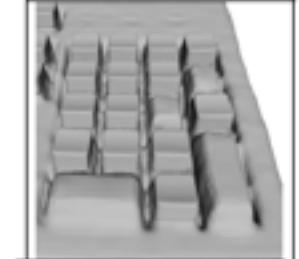
## Real Models



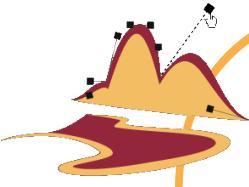
Scanned from a Minolta VIVID 910 scanner



Scanned Example

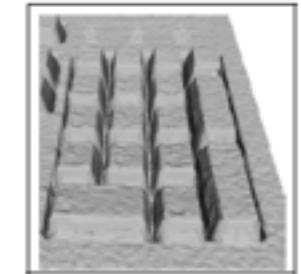


Reconstructed Super-Resolution Model



# Results

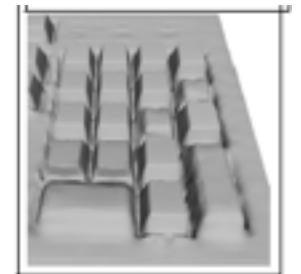
## Real Models



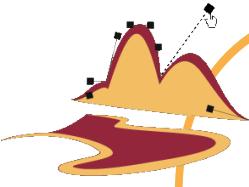
Scanned from a Minolta VIVD 910 scanner



Example from multiple samples



Reconstructed Super-Resolution Model

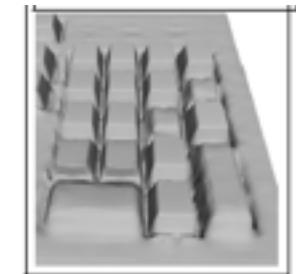


# Results

## Real Models



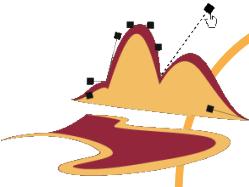
Example from multiple samples



Reconstructed Super-Resolution Model

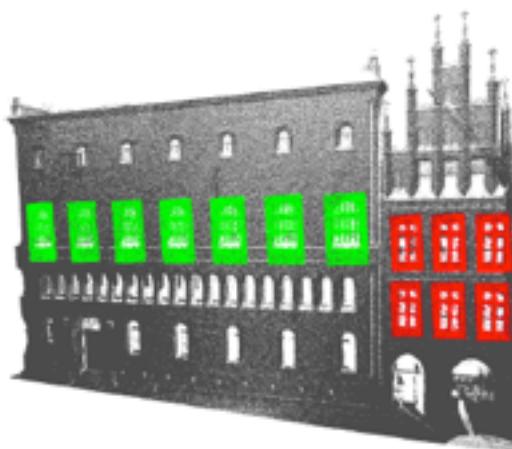
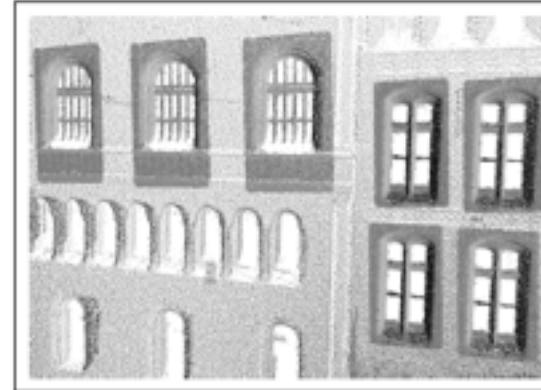


Reconstructed Model with Geometric Textures



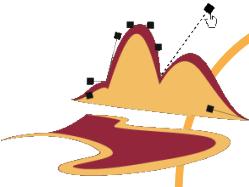
# Results

## Real Models



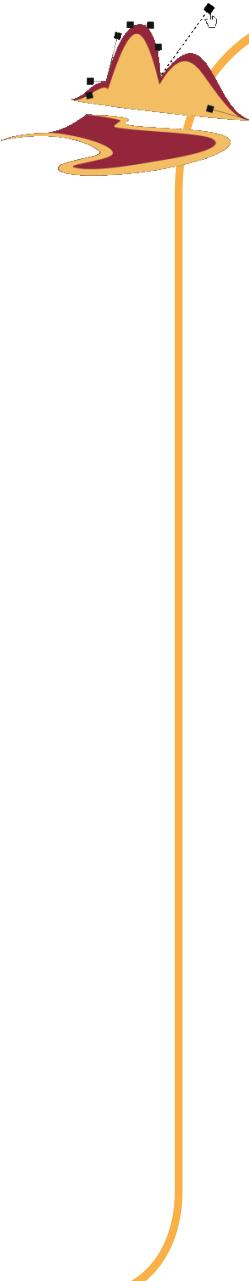
Accumulation

Altes Rathaus Hannover from the Institute of Cartography and  
Geoinformatics of the Leibniz University of Hannover

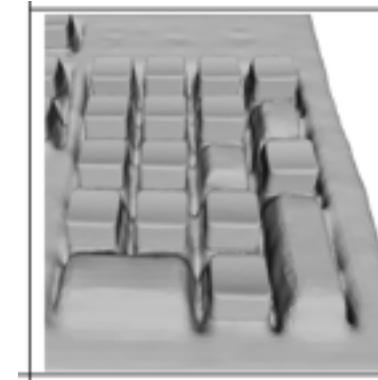
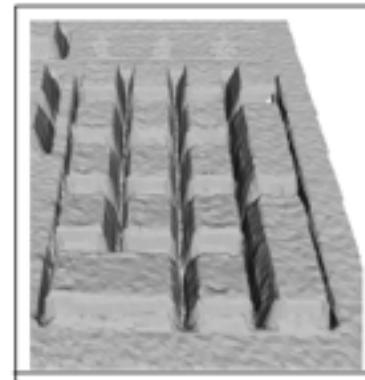


# Timings

Model	detail occur.	low model points $\times 10^3$	detail ref. points $\times 10^3$	total points $\times 10^3$	spin image corresp. secs.	filtering secs.	validation secs.	insertion secs.	total secs.
max planck	3	53.4	19.3	110.4	2.7	1.9	1.7	1.4	6.2
textured cylinder	48	25.3	9.2	442.3	1.5	0.9	0.9	14.0	15.5
s cylinder	48	25.3	9.2	442.3	1.9	1.4	1.4	13.8	18.7
keyboard	86	88.1	11.6	1,237.8	28.9	15.4	84.3	39.2	128.7
+ flower keyboard	86	88.1	23.6	2,087.3	0.0	0.0	0.0	177.2	177.2
rathaus window #1	7	1,063	17	1,460	256.7	25.3	10.4	30.1	322.5
rathaus window #2	6	1,460	14	1,821	190.5	22.1	9.7	32.6	254.9



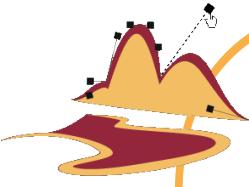
# Limitations



Robustness



Accuracy



# Future Work

- Advanced ICP Algorithms
- Non-Rigid Registration





# Thank you for your attention!

Geometry Super-Resolution by Example

Thales Vieira

Alex Bordignon

Thomas Lewiner

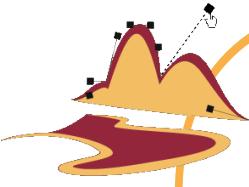
Luiz Velho

Matmídia Lab - Department of  
Mathematics - PUC-Rio

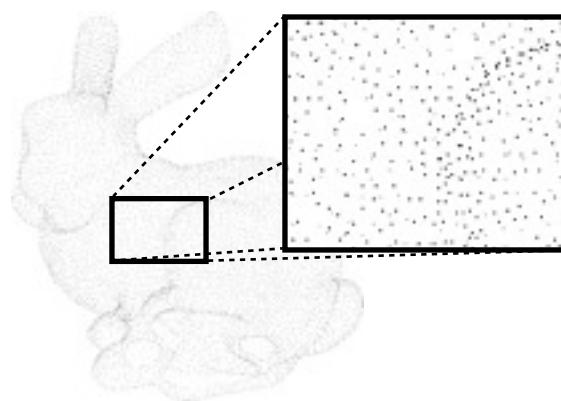
Visgraf Lab - IMPA

**SIBGRAPI 2009**





# Fast Point Cloud Resolution Estimation



$$Area \propto r^2 \propto n \cdot \mu^2$$

$$Volume \propto r^3 \propto (\sqrt{Area})^3 \propto (\sqrt{n} \cdot \mu)^3$$

$$\mu \propto \frac{\sqrt[3]{Volume}}{\sqrt{n}}$$

