Example-Based 3D Scan Completion

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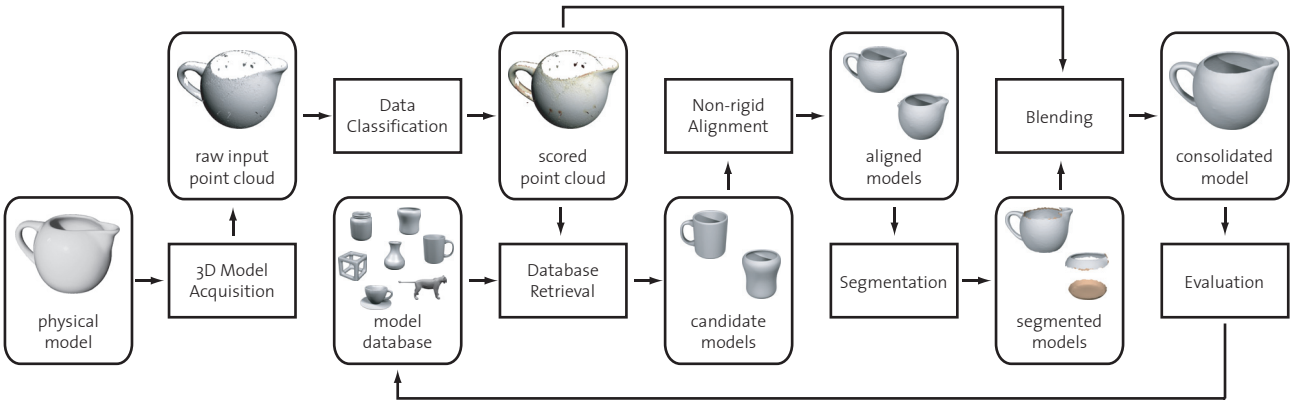


Goal: Simplify the creation of 3D models from acquired data using context information retrieved from a 3D model database

3D Model Acquisition

- 3D acquisition devices produce discrete samples of the surface of a given physical object (e.g. laser range or structured light scanning)
- Acquired sample set is often noisy and incomplete due to occlusion and physical limitations of the scanner
- Current systems require significant manual intervention to extract a clean, complete, and consistent model

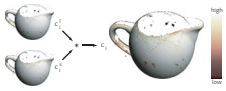
Data Classification

- Classify data according to geometric fidelity to improve robustness in the presence of noise and outliers
- Confidence estimate based on eigenvalues of covariance matrix of local neighborhood

$$\mathbf{C}_i = \sum_j (\mathbf{p}_j - \mathbf{p}_i)(\mathbf{p}_j - \mathbf{p}_i)^T \phi_i(\|\mathbf{p}_j - \mathbf{p}_i\|),$$

$$c_i^\lambda = 1 - \frac{3\lambda_i^1}{\lambda_i^1 + \lambda_i^2 + \lambda_i^3}$$

$$c_i^\sigma = \lambda_i^2 / \lambda_i^3$$



Database Retrieval

- Combination of textual search and shape-based signatures to retrieve suitable context models from the database
  - Keywords to confine search space
  - PCA to factor out global scaling and initial pose
  - Rigid alignment using minimization of squared distances

$$E(M,P) = \sum_{i \in P} c_i \|R\mathbf{p}_i - \mathbf{q}_i\|^2$$

Non-rigid Alignment

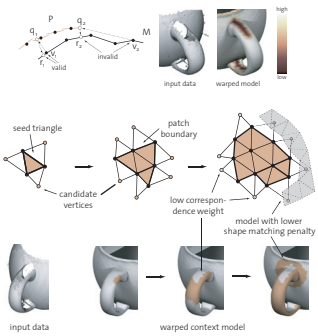
- Compute 3D warping function using optimization to align context models with input point cloud
- Define consistent shape matching penalty function:

$$\Psi(P,M,T) = \alpha \cdot \Phi(M,T) + (1-\alpha) \cdot \Omega(P,M,T)$$

- Distortion of warp: $\Phi(M,T) = \sum_{j \in M} \sum_{k \in N_1(j)} A_{jk} \left(\frac{\mathbf{t}_j - \mathbf{t}_k}{|\mathbf{e}_{jk}|} \right)^2$
- Geometric error: $\Omega(P,M,T) = \sum_{j \in M} \omega_j A_j \|\mathbf{v}_j + \mathbf{t}_j - \mathbf{q}_j\|^2$

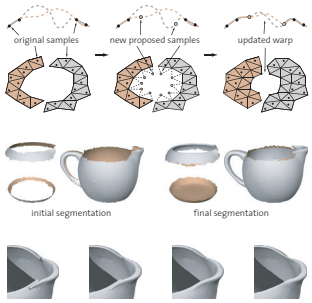
Segmentation

- Segment context model according to best local fit with input data
  - Incremental region growing process that respects local shape matching penalty and input data correspondence weights

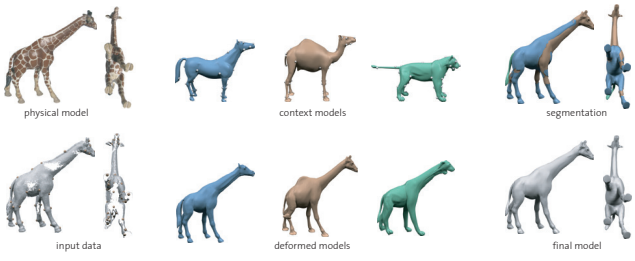


Blending

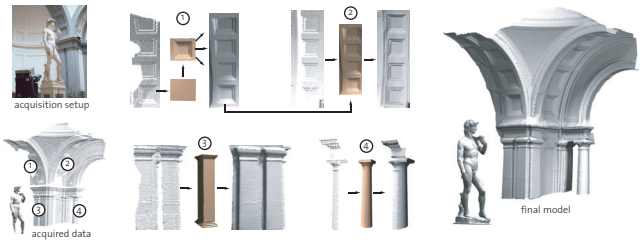
- Extrapolate geometric information to fill in regions of missing data
  - Incrementally add triangles at current patch boundary
  - Continuously update warping function to create smooth transition
  - Combine context models using geometric stitching



Results



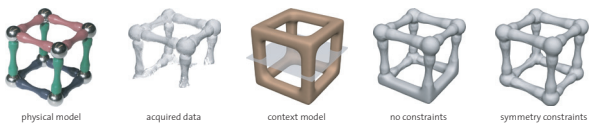
Shape completion zoo



Completing the Galleria dell' Accademia

Model re-use

Evaluation of completed model



Incorporating high-level semantics