pointshop

An Interactive System for Point-based Surface Editing

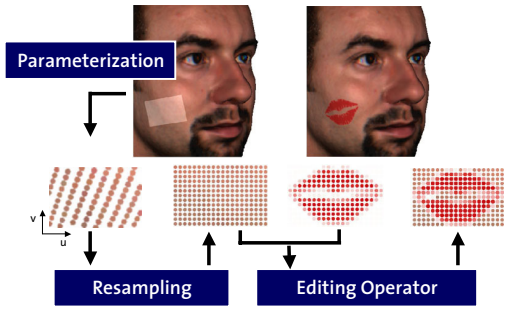
Overview

- Introduction
- Pointshop3D System Components
  - Point Cloud Parameterization
  - Resampling Scheme
  - Editing Operators
- Summary

PointShop3D

- Interactive system for point-based surface editing
- Generalizes 2D photo editing concepts and functionality to 3D point-sampled surfaces
- Uses 3D surface pixels (*surfels*) as versatile display and modeling primitive

Concept



Key Components

- Point cloud parameterization Φ
  - brings surface and brush into common reference frame
- Dynamic resampling Ψ
  - creates one-to-one correspondence of surface and brush samples
- Editing operator Ω
  - combines surface and brush samples

$$S' = \Omega(\Psi(\Phi(S)), \Psi(B))$$

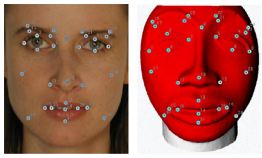
modified surface | original surface | brush

Parameterization

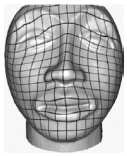
- Constrained minimum distortion parameterization of point clouds

$$\mathbf{u} \in [0,1]^2 \Rightarrow X(\mathbf{u}) = \begin{bmatrix} x(\mathbf{u}) \\ y(\mathbf{u}) \\ z(\mathbf{u}) \end{bmatrix} = \mathbf{x} \in P \subset R^3$$

Parameterization



contraints = matching of feature points



minimum distortion = maximum smoothness

Parameterization

- Find mapping X that minimizes objective function:

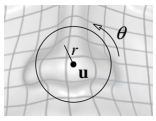
brush points surface points

$$C(X) = \sum_{j \in M} \underbrace{(X(\mathbf{p}_j) - \mathbf{x}_j)^2}_{\text{fitting constraints}} + \varepsilon \underbrace{\int_P \gamma(\mathbf{u}) d\mathbf{u}}_{\text{distortion}}$$

Parameterization

- Measuring distortion

$$\gamma(\mathbf{u}) = \int_\theta \left(\frac{\partial^2}{\partial r^2} X_{\mathbf{u}}(\theta, r) \right)^2 d\theta$$



- Integrates squared curvature using local polar re-parameterization

$$X_{\mathbf{u}}(\theta, r) = X\left(\mathbf{u} + r \begin{bmatrix} \cos(\theta) \\ \sin(\theta) \end{bmatrix} \right)$$

Parameterization

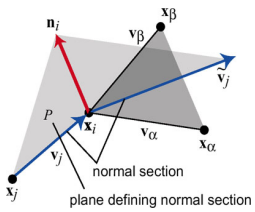
- Discrete formulation:

$$\tilde{C}(U) = \sum_{j \in M} (\mathbf{p}_j - \mathbf{u}_j)^2 + \varepsilon \sum_{i=1}^{n} \sum_{j \in N_i} \left(\frac{\partial U(\mathbf{x}_i)}{\partial \mathbf{v}_j} - \frac{\partial U(\mathbf{x}_i)}{\partial \tilde{\mathbf{v}}_j} \right)^2$$

- Approximation: mapping is piecewise linear

Parameterization

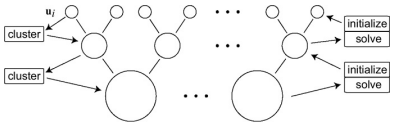
- Directional derivatives as extension of divided differences based on k-nearest neighbors



Parameterization

- Multigrid solver for efficient computation of resulting sparse linear least squares problem

$$\tilde{C}(U) = \sum_j \left(\mathbf{b}_j - \sum_{i=1}^{n} a_{j,i} \mathbf{u}_i \right)^2 = \|\mathbf{b} - A\mathbf{u}\|^2$$



Reconstruction

- Parameterized scattered data approximation

fitting functions

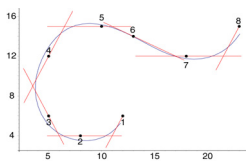
weight functions

$$X(\mathbf{u}) = \frac{\sum_i \Phi_i(\mathbf{u}) r_i(\mathbf{u})}{\sum_i r_i(\mathbf{u})}$$

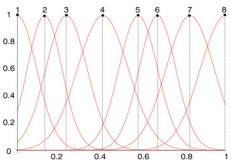
normalization factor

- Fitting functions
  - Compute local fitting functions using local parameterizations
  - Map to global parameterization using global parameter coordinates of neighboring points

Reconstruction



reconstruction with linear fitting functions



weight functions in parameter space

Reconstruction

- Reconstruction with linear fitting functions is equivalent to surface splatting!
  - ⇨ we can use the surface splatting renderer to reconstruct our surface function (see chapter on rendering)
  - This provides:
    - Fast evaluation
    - Anti-aliasing (Band-limit the weight functions before sampling using Gaussian low-pass filter)
  - Distortions of splats due to parameterization can be computed efficiently using local affine mappings

Sampling

- Three sampling strategies:
  - Resample the brush, i.e., sample at the original surface points
  - Resample the surface, i.e., sample at the brush points
  - Adaptive resampling, i.e., sample at surface or brush points depending on the respective sampling density

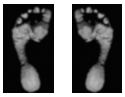
Editing Operators

- Painting
  - Texture, material properties, transparency

Editing Operators

- Sculpting
  - Carving, normal displacement

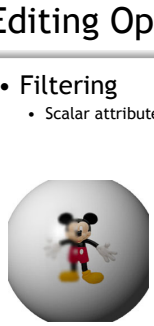
texture map



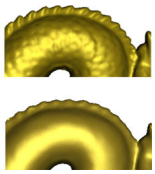
displacement maps

carved and texture mapped point-sampled surface

Editing Operators



- Filtering
  - Scalar attributes, geometry



Summary

- Pointshop3D provides sophisticated editing operations on point-sampled surfaces
  - ⇨points are a versatile and powerful modeling primitive
- Limitation: only works on "clean" models
  - sufficiently high sampling density
  - no outliers
  - little noise
  - ⇨requires model cleaning (integrated or as pre-process)

Reference

- Zwicker, Pauly, Knoll, Gross: *Pointshop3D: An interactive system for Point-based Surface Editing*, SIGGRAPH 2002

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- check out:

www.pointshop3D.com