Stereological techniques for Solid Textures

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Goal

- Automatic Texture mapping for arbitrary shapes
- Textures with particle distribution like asphalt, rocks and also sponges (particles are void space)
- Should require 2D image input of material only
- Show Video
Why

- It is a difficult and tedious task to get multiple 2D textures to form a consistent visual appearance on a model without it looking bad
- 2D texture synthesis works bad for objects cut out of 3D spatially varying materials
- For use in computer graphics applications
Stereology

- Used in biology and material science
- Try to guess the 3D shapes of a cross section
Solid Textures

- Make an object you want to texture
- To render this object each pixel gives its 3D position to the algorithm which tells it the color it should have
- It is difficult and tedious to get multiple 2D textures to form a consistent visual appearance on a model without looking bad.

(a)  
(b)
Estimating 3D Distribution

- As in stereology, but we try to estimate the distribution of different particles in a medium from a 2D slice.
- Our objective is to establish a relationship between the size distribution of 2D circles in circles per unit area and 3D spheres in spheres per unit volume.
- For any distribution of identical convex particles the particle density is expressed as

\[ N_A = \tilde{H} N_V \]
Spheres

For most volumes it is unlikely that the particles will all be of the same size, so we use a histogram approach.
Other Particles

- We cannot easily classify the profile size according to its diameter.
- $K_{ij}$ represents the relative probability that a particle in column $j$ exhibits a profile in row $i$. 

$$\sqrt{A/A_{\text{max}}}$$
Other Particles

- To compute the K matrix they use the Monte Carlo routine to take advantage of the GPU
- Randomly orient the polygon mesh
- Render such that the near clipping plane of an orthographic camera cuts through the particle at random depth
- Read of the stencil buffer to find the area
- Keep track of the biggest area
- Record all these and create probabilities
- Run around 100,000 times
- Can also be used to find the mean caliper diameter
Other Particles

Before this data can be used we need a scale factor $s$ to relate the size of particle $P$ to the size of the particles seen in our input image $A_{\text{img}}$ is the maximum area in the image and $A_{\text{max}}$ is the Maximum area in our calculations

$$s = \sqrt{\frac{A_{\text{img}}}{A_{\text{max}}}}$$

Aimg is the maximum area in the image and Amax is the Maximum area in our calculations

Calculate the $H$ by multiplying $s$ with the mean caliper diameter then solve as usual

$$N_V = \frac{1}{H} K^{-1} N_A$$
Managing Multiple Particle Types

If there are multiple types of particles of different shape each particle type \( i \) will have its own mean caliper diameter, matrix \( K_i \) and distribution \( N_{vi} \)

\[
N_A = \sum_i (\bar{H}_i K_i N_{vi})
\]

We can assume that the distribution of size is independent of type, so we can express this as

\[
N_A = \sum_i (\bar{H}_i K_i P(i) N_v)
\]

\[
= \sum_i (\bar{H}_i K_i P(i)) N_v
\]

where \( N_v \) is the sum of all \( N_{vi} \)'s and \( P(i) \) is the probability that particle \( p \) is of type \( i \)
Reconstructing the Volume

- Once we have the particle densities $N_v$, a volume can be constructed, the process establishes particle positions and colors.
- Create particles according to the distribution.
- Place all the particles inside a volume.
- Run simulated annealing to resolve collisions.
- This repeatedly searches for all collisions and then relaxes particle positions to reduce collisions.
Reconstructing the Volume

- If size and color are uncorrelated then assign colors to the particles randomly.
- If this is not the case use a k-means clustering algorithm to set the mean profile colors. Then run the stereology algorithms on each color and then combine the results.
- To add fine details the mean is subtracted from the original picture and an existing similar method is used to add these details.
Results

- Recreation of synthetic volumes, very successful
- Work with physical data was hard because the algorithm depends on you creating the particles you think will be in the volume
- Test volume, they carved a shape out of real material and challenged the algorithm to do the same
- Physical inputs, they tried to replicate simple 2D pictures of materials
Conclusions

- The methods expand on the class of 3D solid textures that can be synthesized from 2D photographs
- Building on stereology and existing literature the methods manage to perform accurate predictive rendering with a sound statistical approach
- Future work includes automated estimation of 3D particle shapes and support for greater variety of input textures