Exercise module 6

Bump mapping

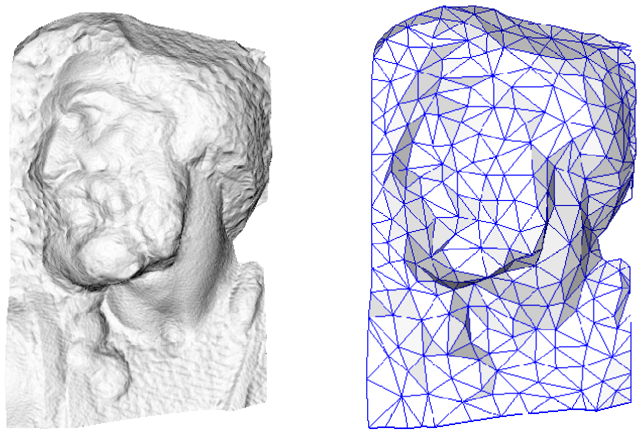
Denis Steinemann
Computer Graphics Laboratory
ETH Zürich

Overview

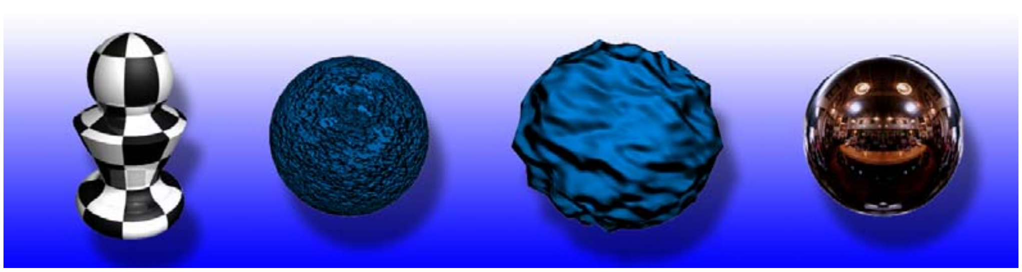
- Bump–mapping principle
- How to Bump–map?
- What the exercise is about: How to approximately Bump–map using Textures …

Bump–mapping principle

- Add more realism to synthetic images without adding a lot of geometry



Bump–mapping principle



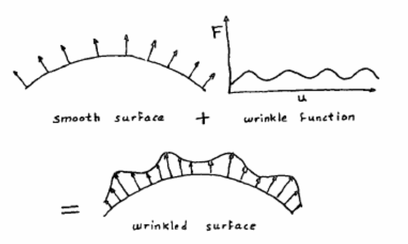
- Image texture / Bump–map / Displacement–map / Environment–map

How to Bump–map
Definitions

- Flat object surface: $P(u,v)$
- Bump–map (2D height field): $F(u,v)$

$$P'(u,v) = P(u,v) + \frac{F(u,v)N}{|N|}$$

- Bumpy surface:



- Normal of bumped surface? $N' = P'_u \times P'_v = ?$

How to Bump–map
Perturbed normal

- Normal of bumped surface, so-called *perturbed* normal:

$$N' = N + F_u \frac{N \times P_v}{|N|} + F_v \frac{P_u \times N}{|N|}$$

- Derivation can be found in “Simulation of Wrinkled Surfaces”
  James F. Blinn
  SIGGRAPH ’78 Proceedings, pp. 286-292, 1978
  (Pioneering paper...)
- Partial derivatives thru forward differencing / finite differences in bump–map & surface parameterization

How to Bump–map
Implementation

- Needs Phong–shading, i.e. evaluation of the lighting equation @ every pixel position
- Doable using:
  - Software renderer
  - Today's graphix hardware (pixel-/vertex-shaders)
  - Approximative solution, using textures & accumulation buffering …

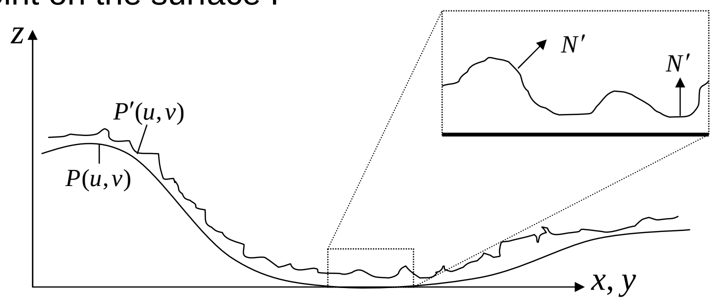
Bump–maps with textures
History

- This is what the exercise is about
- Original idea:
  "*Efficient bump mapping hardware*"
  Mark Peercy et al. (sgi)
  SIGGRAPH '97 Proceedings, pp. 303-306, 1997
- (Mis-)use texture to store either:
  - perturbed normal map
  - bump–map itself

Bump–maps with textures

Assumption

- We need: $N' = P'_u \times P'_v$
- Assume a tangent surface coincident with the xy–plane @ some point on the surface P



- Then: $P'(u,v) \equiv F(u,v)$

$$N' = \left(\frac{\partial}{\partial u} F, \frac{\partial}{\partial v} F, 1 \right)^T$$

Bump–maps with textures

Evaluation (1)

- Diffuse lighting component: $N' \cdot L$

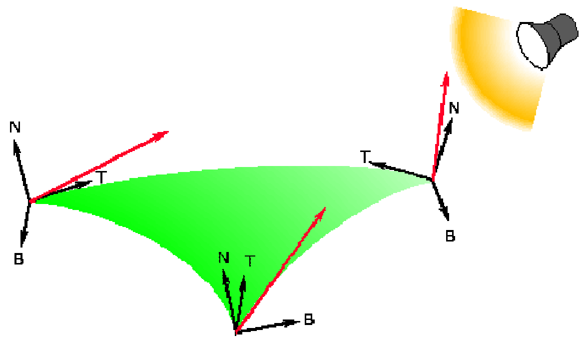
$$N' \cdot L = \frac{\partial}{\partial u} F \cdot L_x + \frac{\partial}{\partial v} F \cdot L_y + L_z$$

- This requires the surface to lie in the xy–plane!
- Instead of transforming surface, transform light source direction vector to local *tangent space* (local coordinate system)

Bump–maps with textures

Tangent Space

- Tangent space defined @ polygon vertices



- Basis vectors: $T, N, B = (T \times N)$

Bump–maps with textures

Tangent Space Transformation

- Coordinate system transform:

$$x = M \cdot x_{new} \qquad x_{new} = M^{-1} \cdot x$$

- Transformation matrix (homogeneous, *orthonormal*):

$$M = \begin{bmatrix} T & B & N & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} T_x & B_x & N_x & 0 \\ T_y & B_y & N_y & 0 \\ T_z & B_z & N_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad M^{-1} = M^T = \begin{bmatrix} T_x & T_y & T_z & 0 \\ B_x & B_y & B_z & 0 \\ N_x & N_y & N_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- Transform light vector, using transformation matrix

Bump–maps with textures
Evaluation (2)

- How do we evaluate

$$N' \cdot L = \frac{\partial}{\partial u} F \cdot L_x + \frac{\partial}{\partial v} F \cdot L_y + L_z$$

→ Separation: use parallel and perpendicular components of transformed light vector

Bump–maps with textures
Evaluation (3)

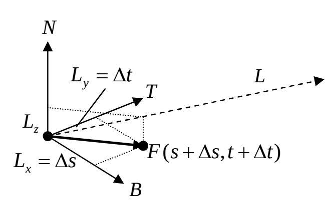
- Multipass method with accumulation buffer:

$$N' \cdot L = \underbrace{\boxed{\frac{\partial}{\partial u} F \cdot L_x + \frac{\partial}{\partial v} F \cdot L_y}}_{\text{Directional derivatives in 1-D thru forward differencing}} + \underbrace{\boxed{L_z}}_{\text{Diffuse lighting term}}$$

Directional derivatives in 1-D thru forward differencing:

$$F'(s) \cdot \Delta s \cong F(s) - F(s + \Delta s)$$
$$F'(t) \cdot \Delta t \cong F(t) - F(t + \Delta t)$$

Diffuse lighting term

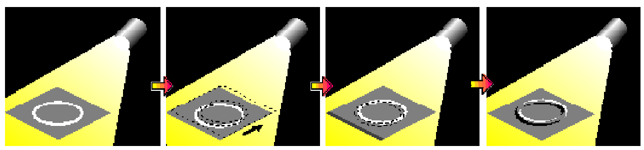


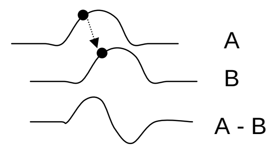
- „Render – Shift – Subtract“ (1st part, 2 passes)
- Add diffuse lighting term (2nd part, 1 pass)

Bump–maps with textures

Render – Shift – Subtract

- Render the bump–map texture (1st pass)
- Shift the texture coordinates (s,t) (towards light!)
- Re-render, *subtracting* from 1st image (2nd pass)
- this corresponds to evaluating the directional derivatives using forward differencing!





Bump–maps with textures

Recipe

1. Render polygon with bump–map on it (1st pass)
2. Find vectors T,N,B @ each vertex
3. Transform light vector L into tangent space
4. Shift texture coordinates s,t @ each vertex in direction of the light (using x,y coords of transformed light vector)
5. Re-render polygon with shifted map (2nd pass)
6. Subtract 2nd image from 1st
7. Render polygon, smooth shaded, with lighting enabled, texturing disabled, add it! (3rd pass)

Steps 1–6: Render-Shift-Subtract

Step 7: Diffuse Lighting

Bump–maps with textures

What do you have to do ?

- Implement the following 2 functions:
  - shiftcoords(…)
    - Determine light vector L
    - Transform into tangent space
    - Shift texture coordinates s,t
  - redrawbump(void)
    - Render cylinder using accumulation buffering

- Read paper by Peercy ...
- http://www.opengl.org/resources/tutorials/advanced/advanced98/notes/node107.html ...
- Submit to deniss@inf.ethz.ch until January 28th