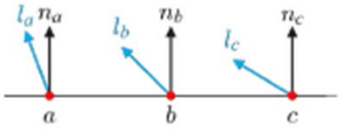
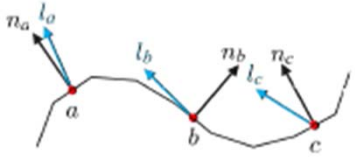
Chapter XIV
Normal Mapping

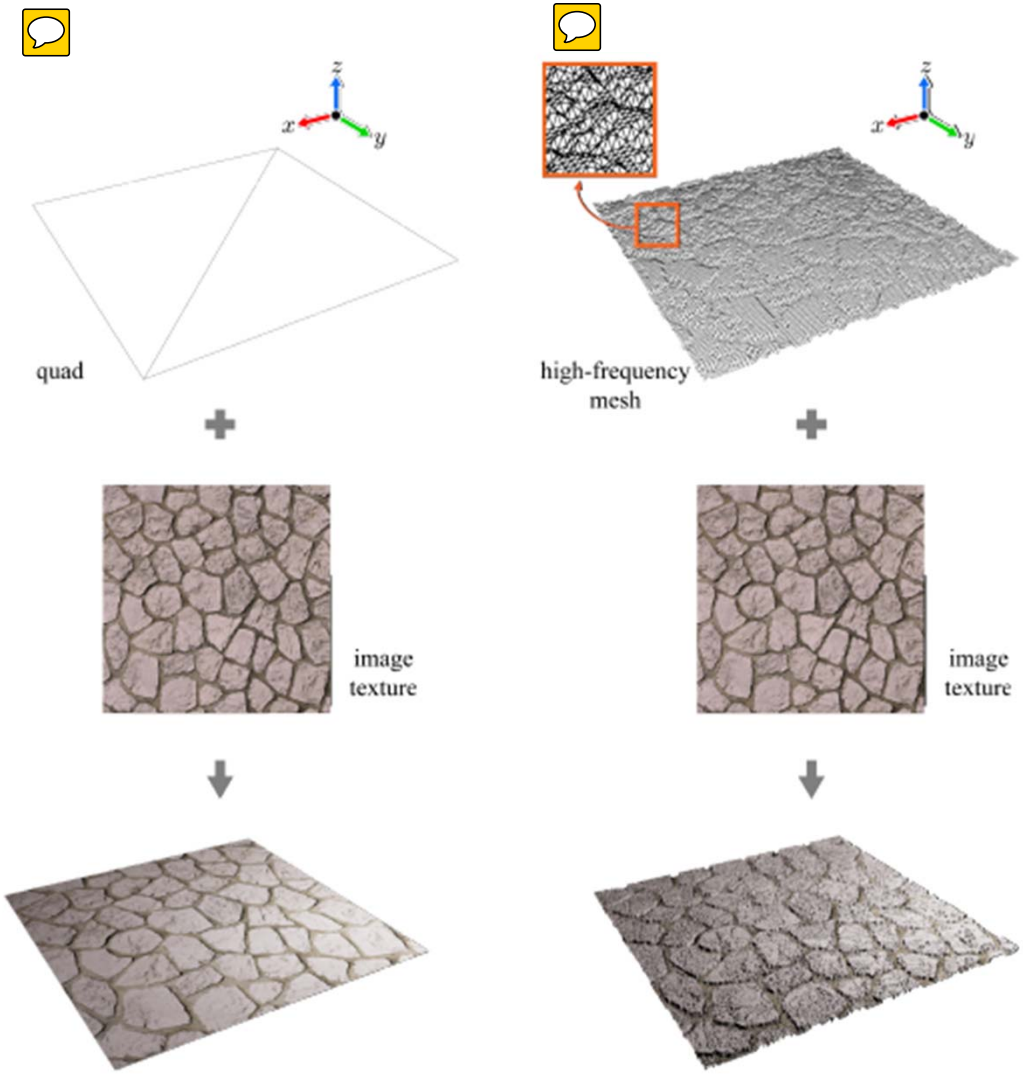
Bumpy Surfaces

- Image texturing only
  - Fast
  - Not realistic



- Highly tessellated mesh
  - Realistic
  - Slow

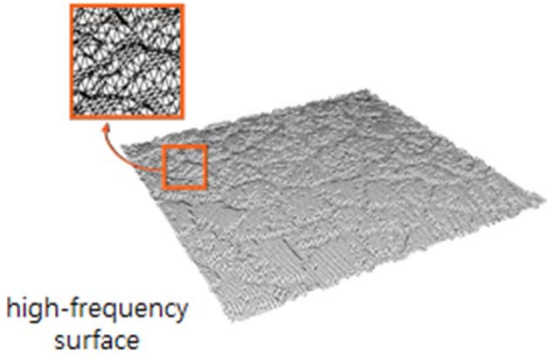


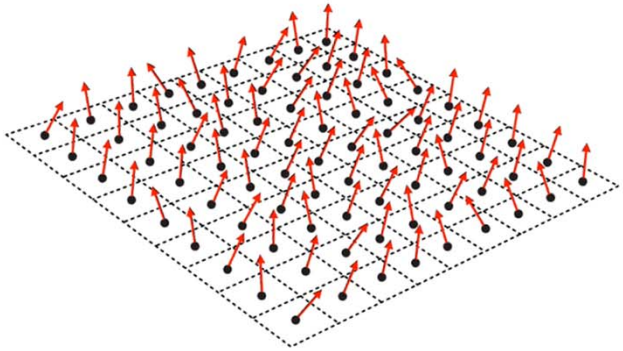


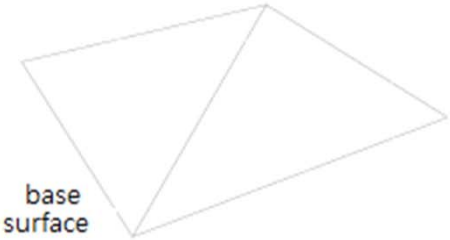
- Surface normals play key roles in lighting.

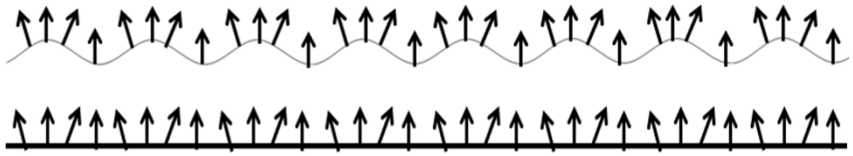
Normal Mapping

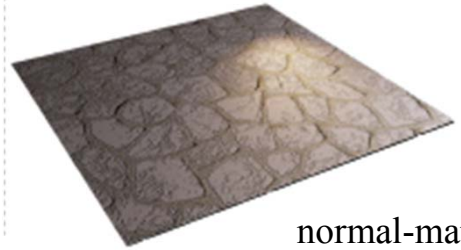
- A way out of this dilemma is
  - to pre-compute and store the normals of the high-frequency surface into a special texture named *normal map*, and
  - to use a lower-resolution mesh at run time which we call *base surface* and fetch the normals from the normal map for lighting.







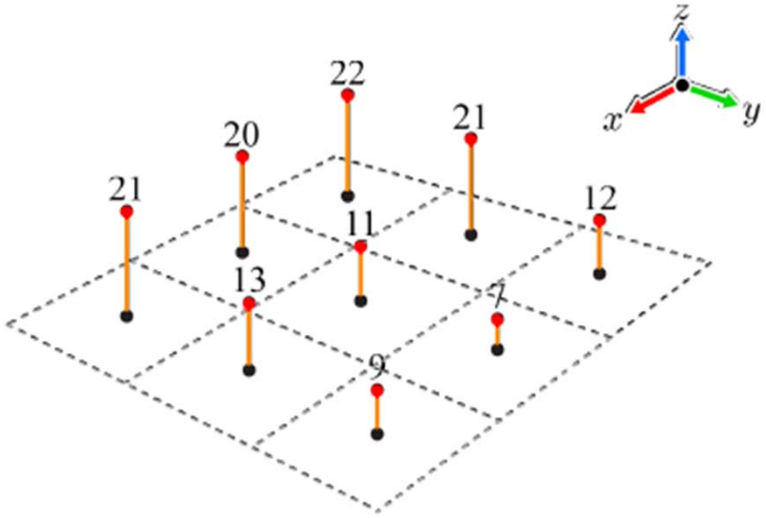




normal-mapped
base surface

Height Field

- A popular method to represent a high-frequency surface is to use a *height field*. It is a function $h(x,y)$ that returns a height or z value given (x,y) coordinates.
- The height field is sampled with a 2D array of regularly spaced (x,y) coordinates, and the height values are stored in a texture named *height map*.
- The height map can be drawn in gray scales. If the height is in the range of [0,255], the lowest height 0 is colored in black, and the highest 255 is colored in white.



Normal Map

- Simple image-editing operations can create a gray-scale image (height map) from an image texture (from (a) to (b)).

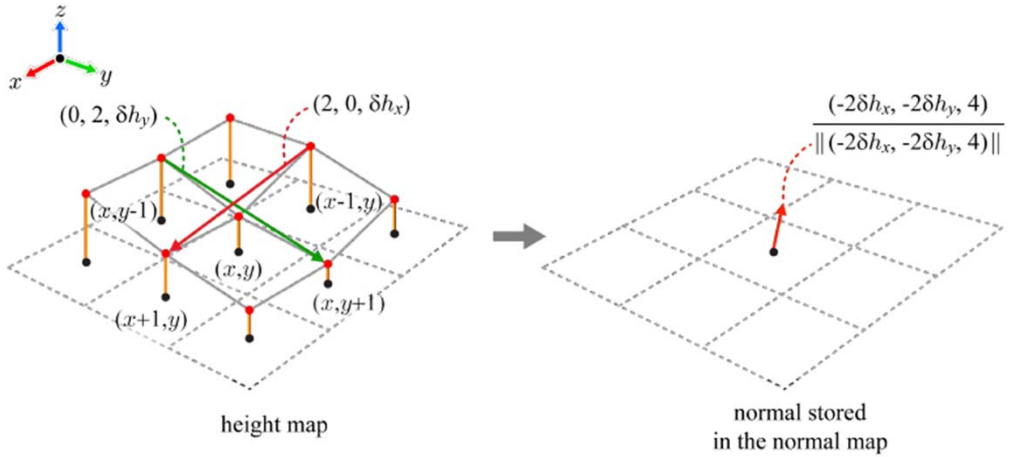
(a) (b) (c)

- The next step from (b) to (c) is done automatically.

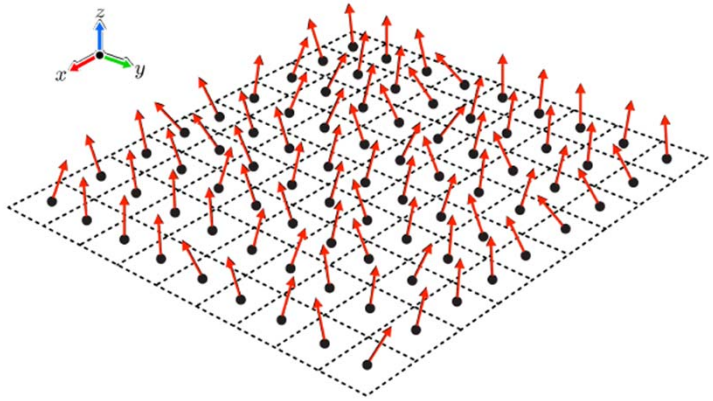
Normal Map (cont'd)

- Creation of a normal map from a height map

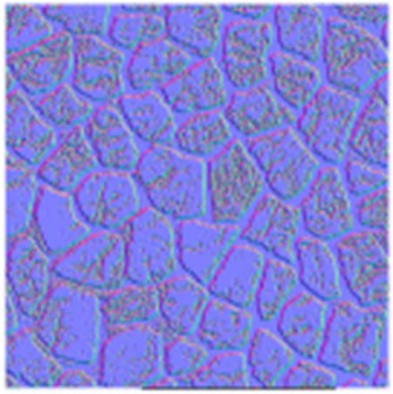
$$\delta h_x = h(x+1, y) - h(x-1, y)$$
$$\delta h_y = h(x, y+1) - h(x, y-1)$$



- Visualization of a normal map

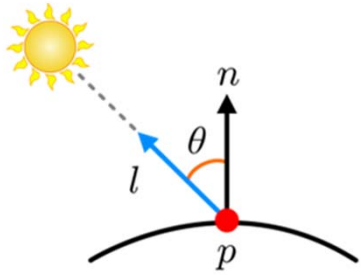


$$R = 255(0.5x + 0.5)$$
$$G = 255(0.5y + 0.5)$$
$$B = 255(0.5z + 0.5)$$



Normal Mapping (cont'd)

- The polygon mesh is rasterized and texture coordinates (s,t) are used to access the normal map.
- The normal at (s,t) is obtained by filtering the normal map.
- Recall the diffuse reflection term, $max(n \bullet l,0)s_d \otimes m_d$.
  - The normal n is fetched from the normal map.
  - m_d is fetched from the image texture.



$$max(n \cdot l, 0)s_d \otimes m_d + (max(r \cdot v, 0))^{sh} s_s \otimes m_s + s_a \otimes m_a + m_e$$

Normal Mapping (cont'd)