Texture Mapping, Bump Mapping

Outline

- Buffers and Digital Images
- Sampling and Aliasing
- Mapping Methods
  - Texture mapping
  - Environment mapping
  - Bump mapping

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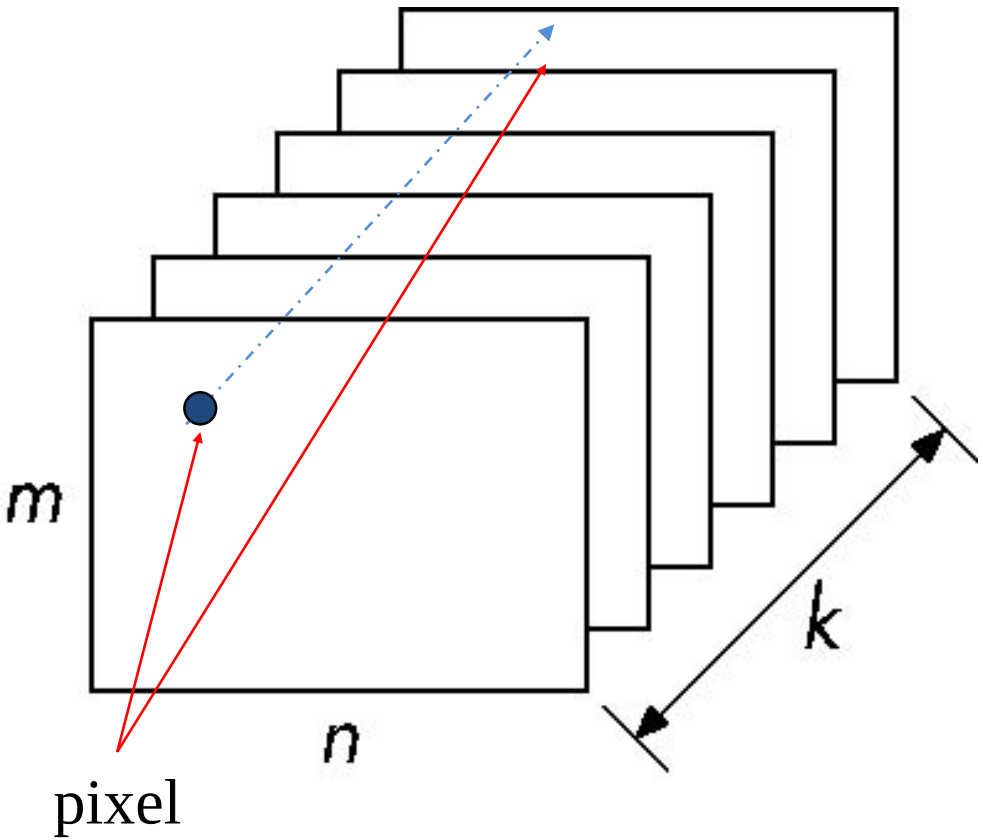
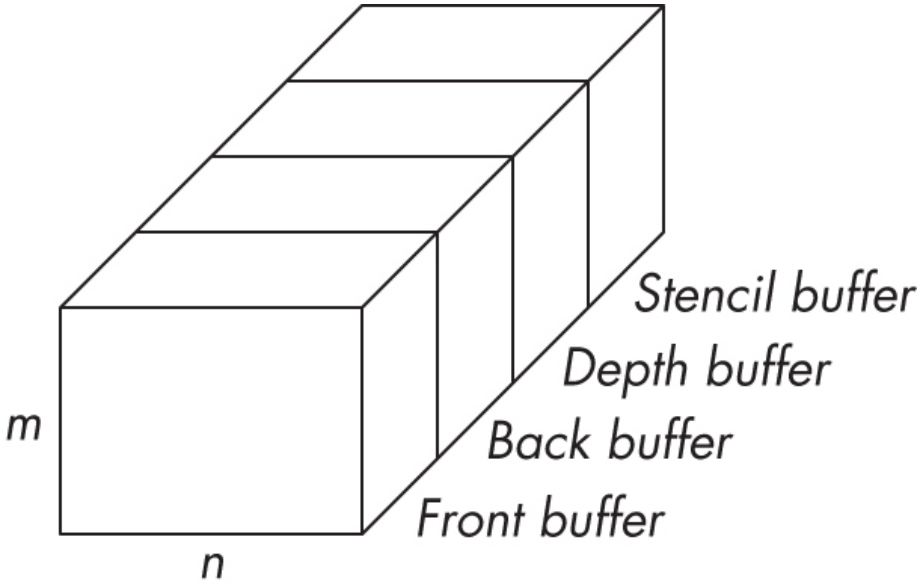
Buffer

- Buffers *(make up the FB):*
  - Color buffers (front and back)
  - Depth buffer
  - Others
- A (2D) buffer is a block of memory (portion of GPU mem.) with:
  - Spatial resolution (n x m)
  - Depth (k)



WebGL Framebuffer

- **Framebuffer** is a collection of buffers
- **Front:** what you see on the screen
- **Back:** following images those will be on the screen later
- **Depth (z-buffer):** depth information of objects in 3D space. For non-transparent objects and surfaces, it is not possible to see the parts behind the closer parts (hidden surfaces). They must be removed.
- **Stencil:** used to mask areas of a scene
- Even in a simple case, total depth goes over 100 bits/pixel
  - Front and back buffers (one at least): (RGBA and 8 bits per component) 32 + 32 = 64 bits
  - A: alpha, transparency
  - Depth buffer (24 or 32 bits)
  - Stencil buffer (24 or 32 bits)



(Digital) Images

- 2D array of pixels (an array of values)
- GIF, JPEG, PNG keep data differently mainly to reduce size
- WebGL doesn’t have functions to directly read these formats or to convert, web browsers and HTML have

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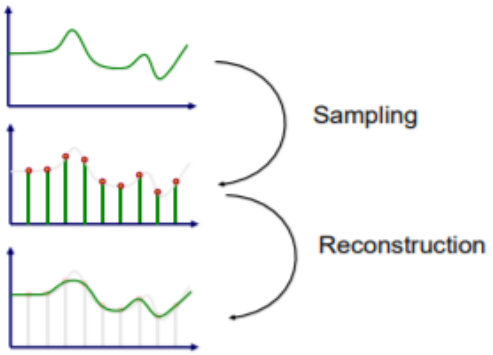
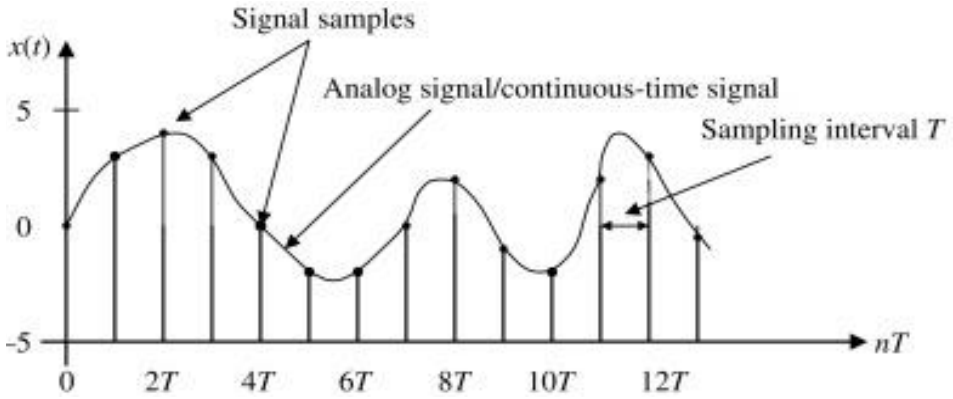
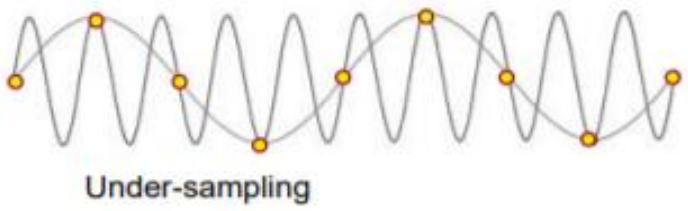
Shannon's Theorem

- a discrete-time signal can be obtained by sampling a continuous-time signal at equally spaced time instants
- the fixed time interval between samples is inversely proportional to the sampling rate
- how frequently do we need to sample? the sampling rate must be at least twice the frequency of the signal (twice the frequency of the highest frequency component) otherwise *aliasing* occurs, Nyquist rate (min. sampling rate).





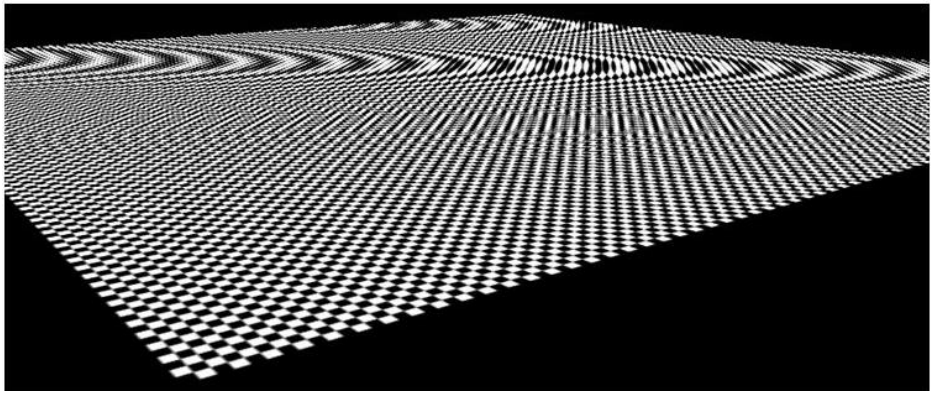


If sampling rate is lower than Nyquist rate, aliasing occurs (original analog signal cannot be reconstructed)

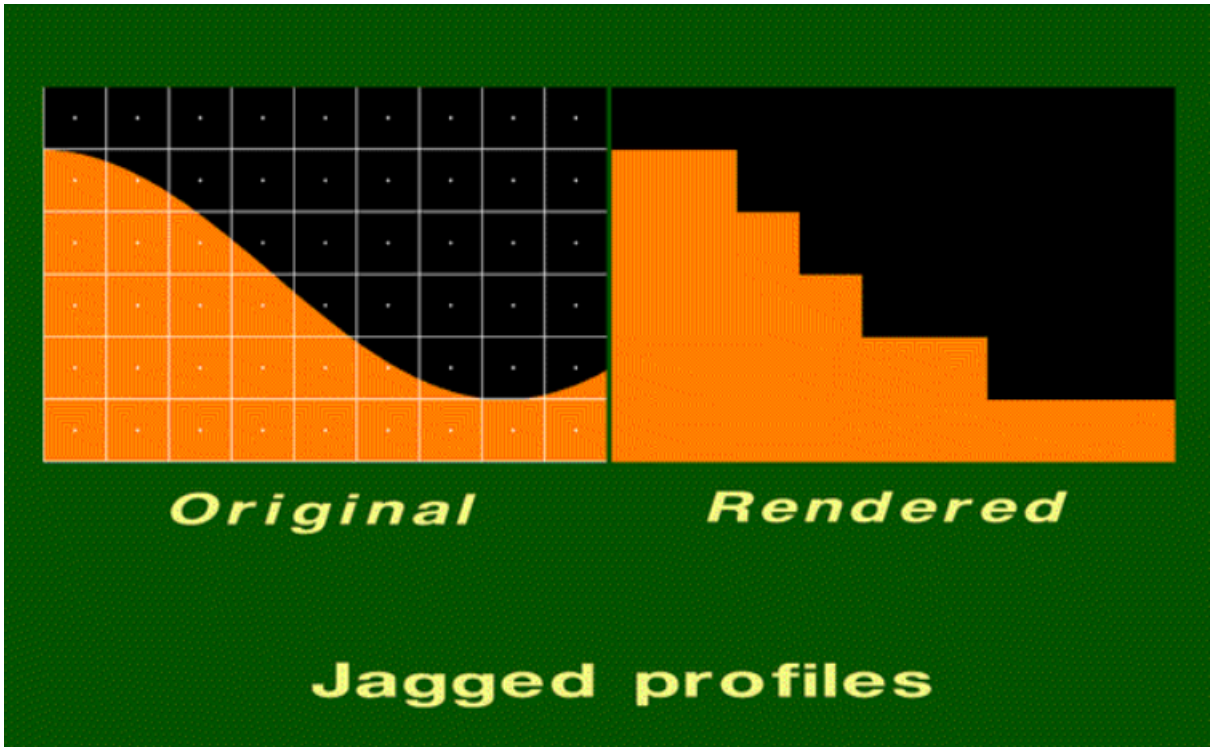
Sampling and Aliasing

- **aliasing** is an effect that causes different signals to become indistinguishable (or aliases of one another) when **sampled**
- the distortion or artifact that results when a signal reconstructed from samples is different from the original signal

The wagon-wheel effect: The wheel can appear to rotate more slowly than the true rotation, it can appear stationary, or it can appear to rotate in the opposite direction from the true rotation.



Sampling and Aliasing



The picture on the left shows the sampling grid superimposed on the original scene.
The picture on the right is the rendered image.
a jagged profile in the rendered image

Antialiasing

- Two major categories of antialiasing:
  - prefiltering
  - postfiltering

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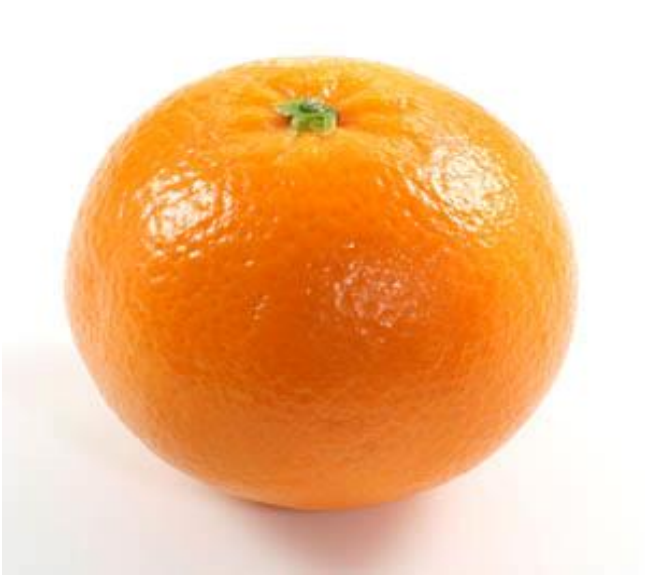
Mapping Methods



How a realistic object like an orange can be produced by only modeling geometry and coloring primitives?

What about a tree with leaves like this?

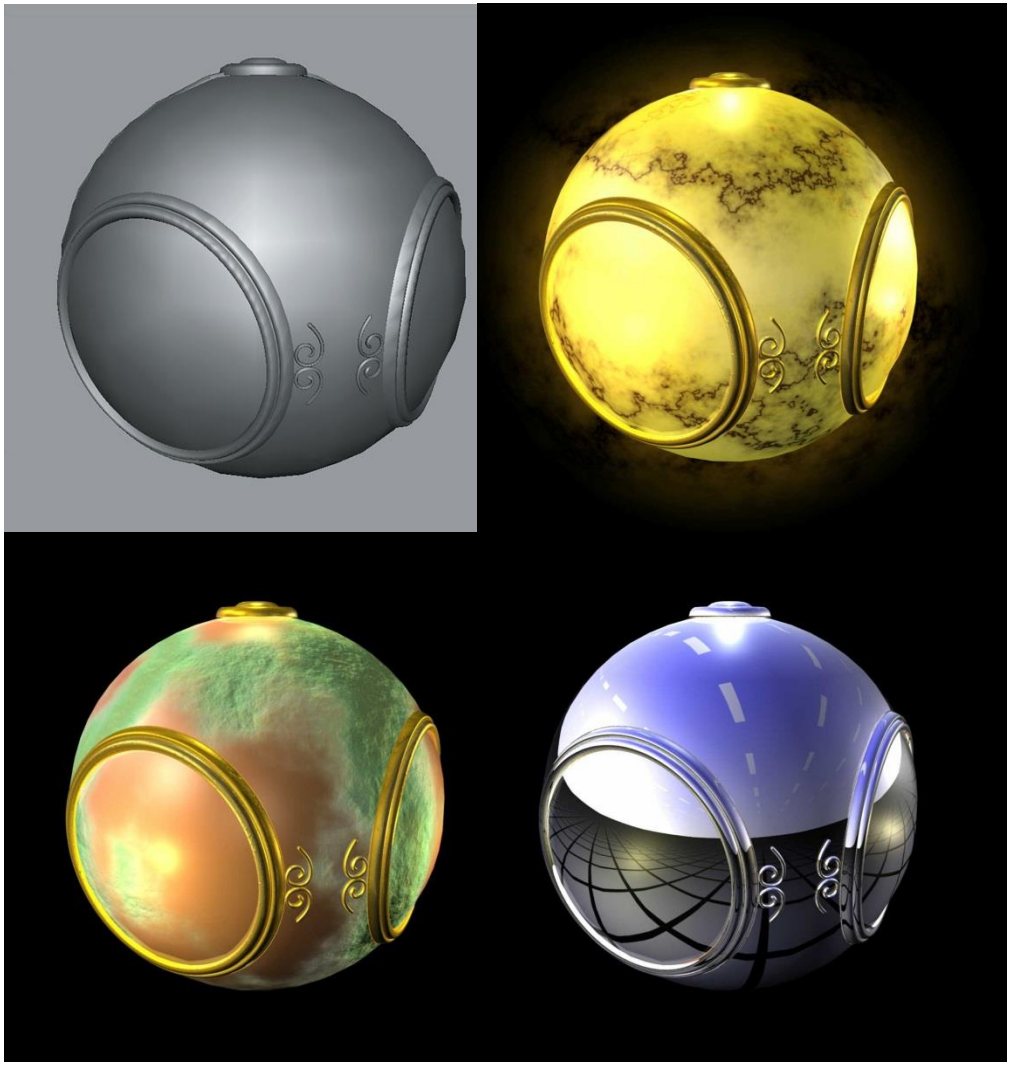
A solution is to keep using simple geometric models but add detail.

All mapping methods are based on modifying the shading of a fragment by using a 2D array (a map).

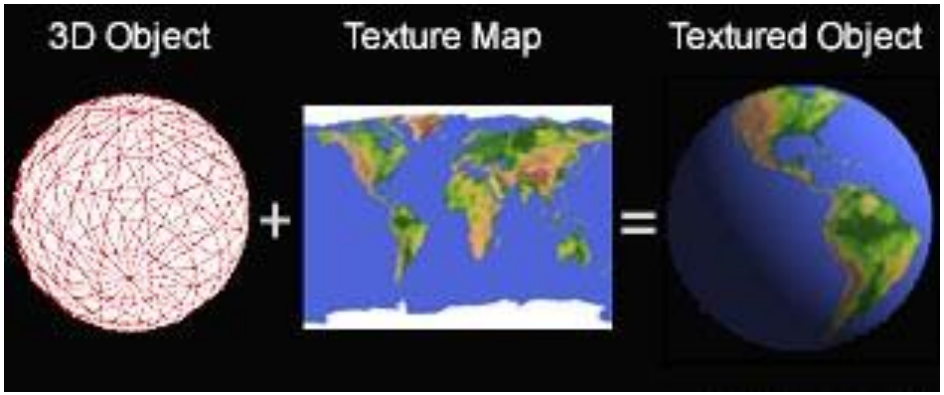
Mapping techniques are not solutions to the same problem, they are doing different things (but how they work is a bit similar).

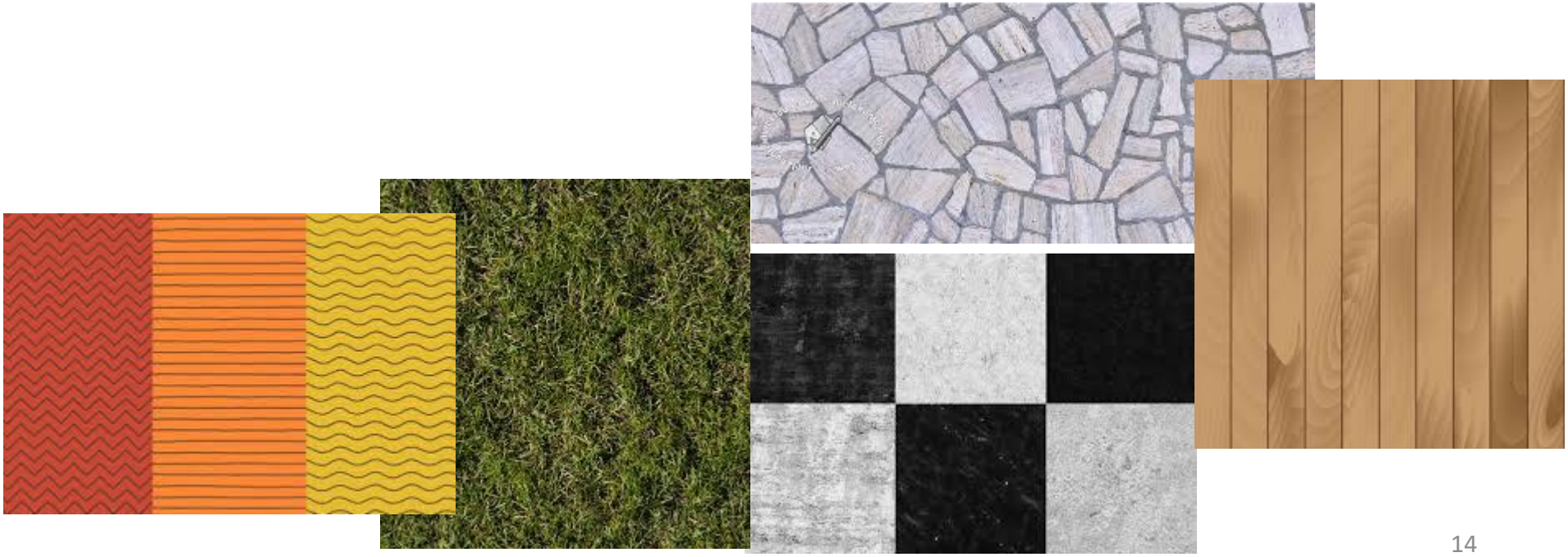
Mapping Methods

- **Texture Mapping**
  - Basic one, uses images to fill inside of polygons
- **Bump mapping**
  - Emulates altering normal vectors during the rendering process
  - Creates the illusion of small variations (bumps, dents) on surface
- **Environment (Reflection) Mapping**
  - Uses a picture of the environment for texture maps
  - Allows simulation of highly reflective surfaces



Texture Mapping

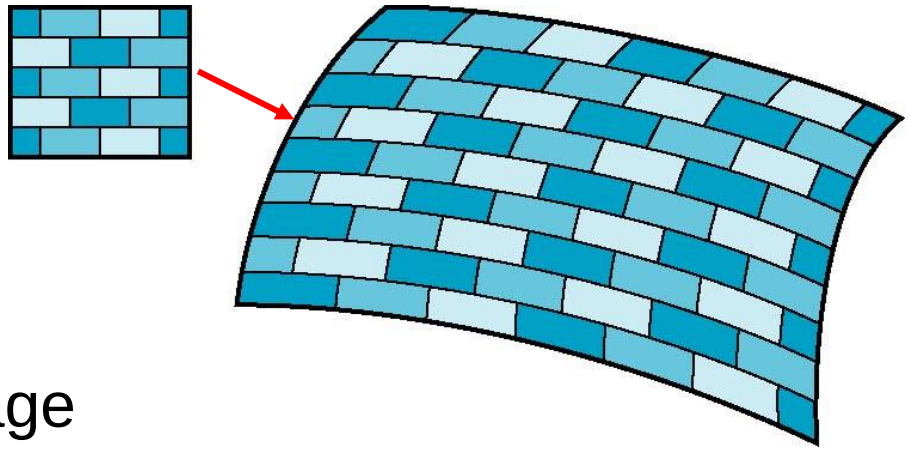




Texture Mapping

- 2D texture is an image
- not pixels but **texels**
- where and what are **texture coordinates**
- A **texture map** associates a texel with a point on a geometric object surface

Is it simple?



2D
image

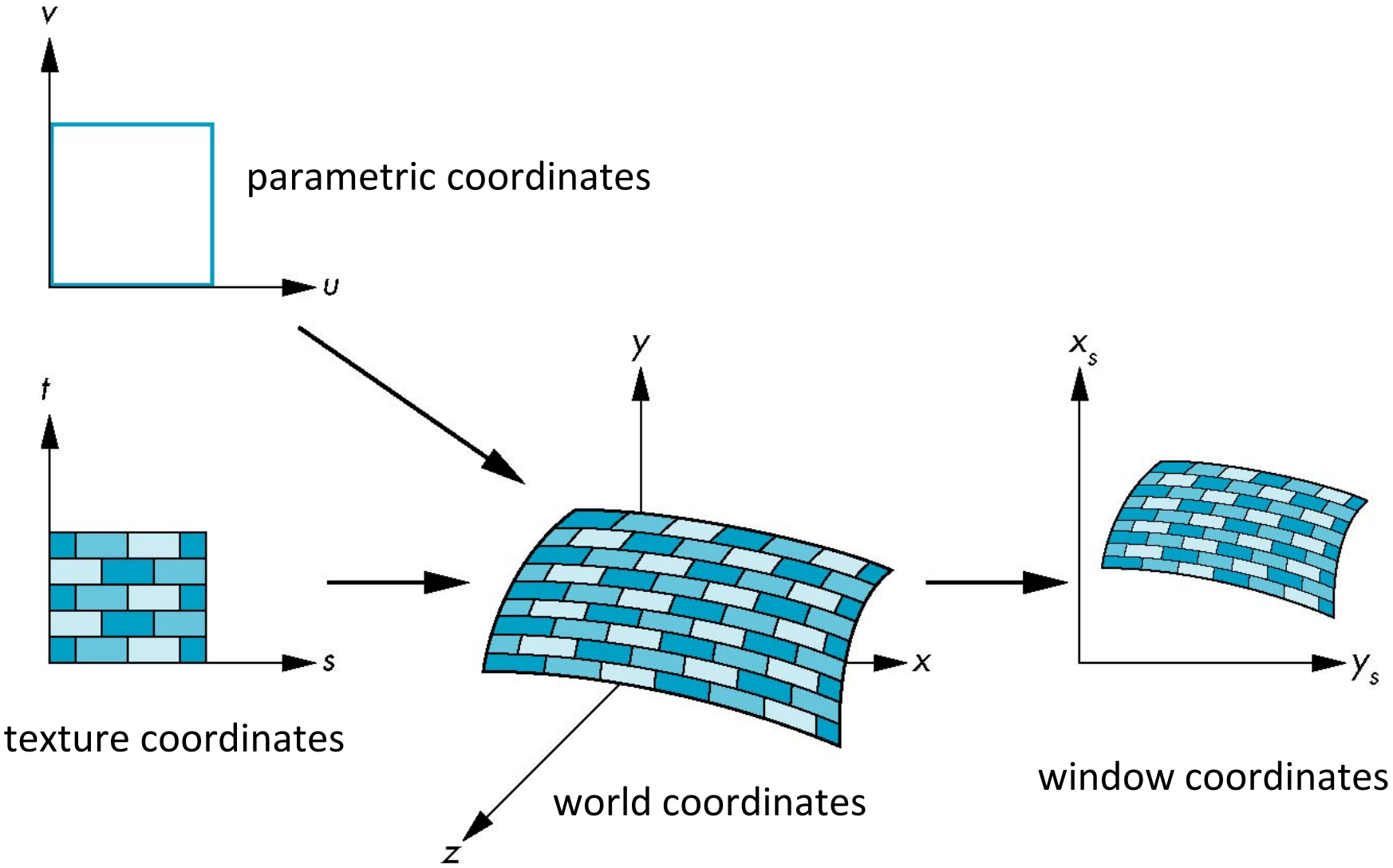
3D surface

mapping an image to a surface involves 3 or 4 coordinate systems

Coordinate Systems

- Parametric Coordinates
  - May be used to model curves and surfaces
- Texture Coordinates
  - Used to identify points in the image to be mapped
- Object or World Coordinates
  - Where the mapping takes place
- Window Coordinates
  - Where the final image is really produced

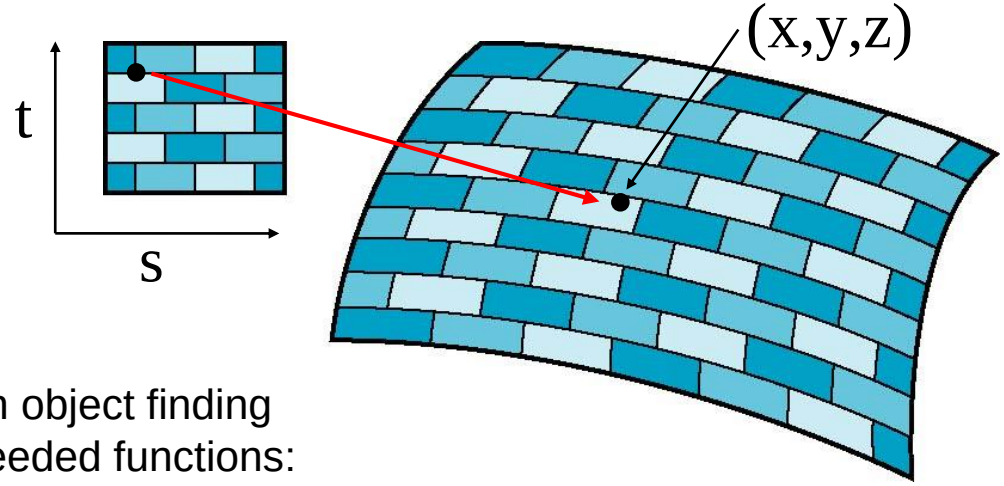
Texture Mapping



Mapping Functions

- How to find the maps?
- Mapping from texture coordinates to a point on a surface needs three functions (given a texel finding the corresponding point on the surface):

$$x = x(s,t)$$
$$y = y(s,t)$$
$$z = z(s,t)$$



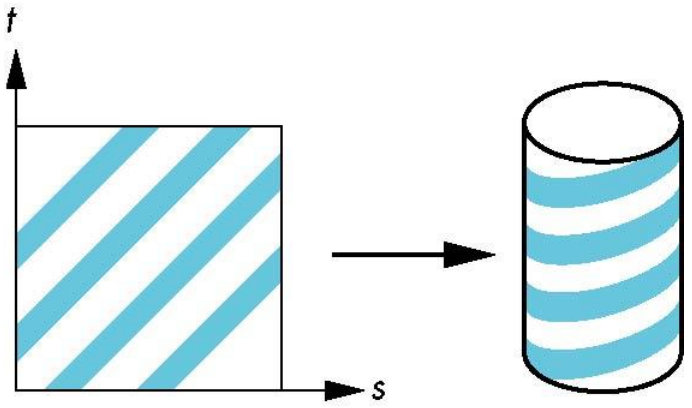
backwards given a point on an object finding the corresponding texel the needed functions:

s = s(x,y,z)
t = t(x,y,z)

sometimes complex functions and distortions may occur (e.g. mapping a rectangle to a sphere)

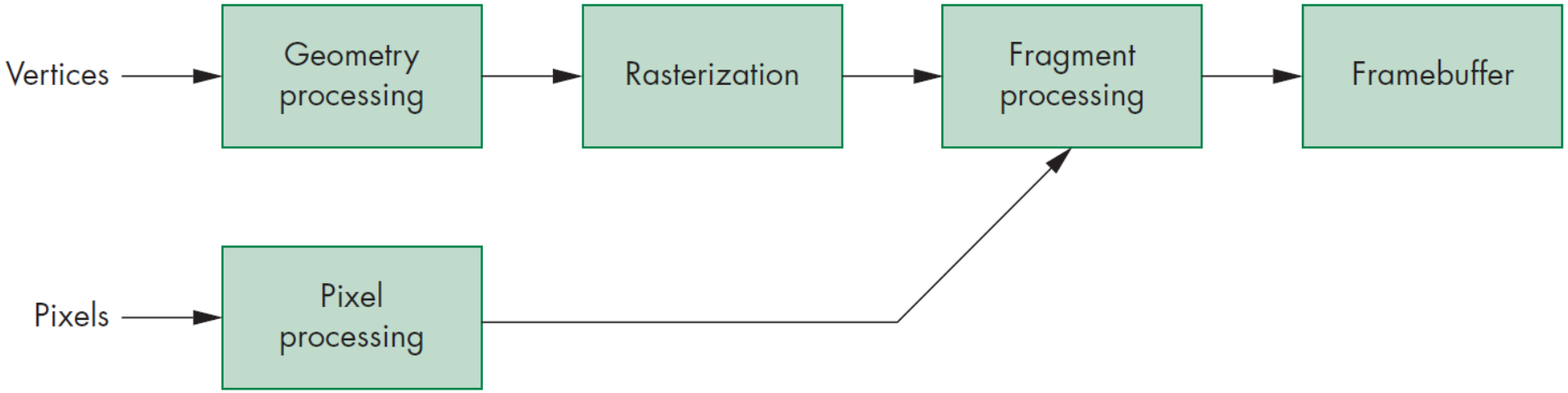
Two-Step Mapping

* Map the texture to a simple intermediate surface (map to cylinder, sphere, or box)
* Map this surface to the actual surface



Texture Mapping in WebGL

two parallel pipelines: geometric and pixel processing

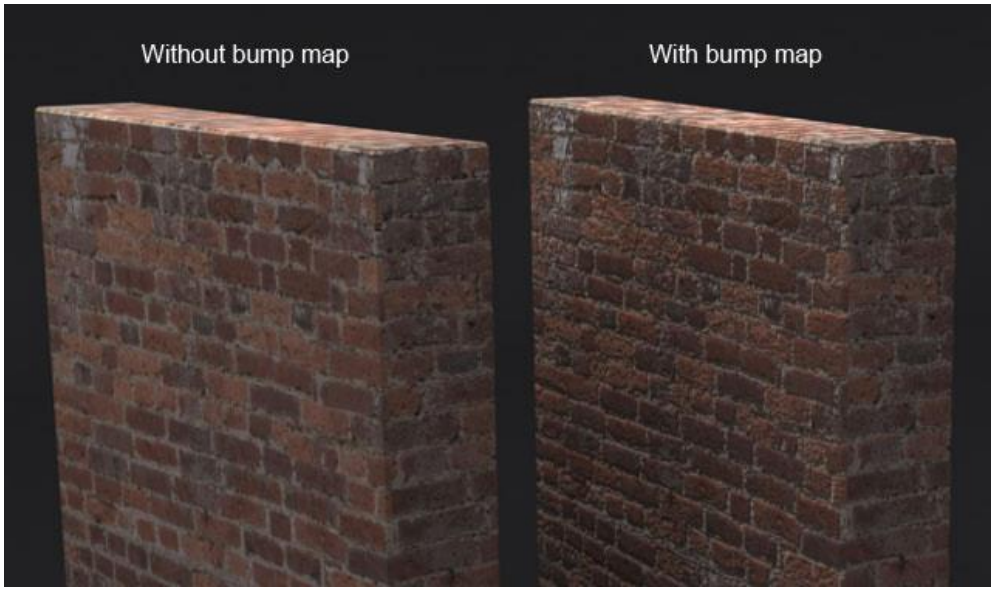


The color of fragments are manipulated using techniques such as texture mapping, bump mapping, environmental mapping.

Environment (reflection) Mapping

- Creates the appearance of highly reflective surfaces without global calculations

Bump Mapping



Bump mapping is used to alter the surface normal to change the illumination (to prevent the flat view of texture mapping) and it uses a texture also.