California State University
Northridge

Math 396F
Math for 3D Graphics

Fall 08 - week one

course overview

www.csun.edu/~jb715473/math396.html

math for 3D graphics

- main idea: describe a scene in 3D space and render it to a 2D surface still looking 3D
- graphics hardware computes pixel data from vertex data ... of course doing this is not trivial
- why math?
    - geometry: project 3D object onto a plane
    - but there is more: how can the scene be described efficiently? how is the information about the color, the light, and the texture of an object stored?
    - and how does the hardware manipulate and display it?

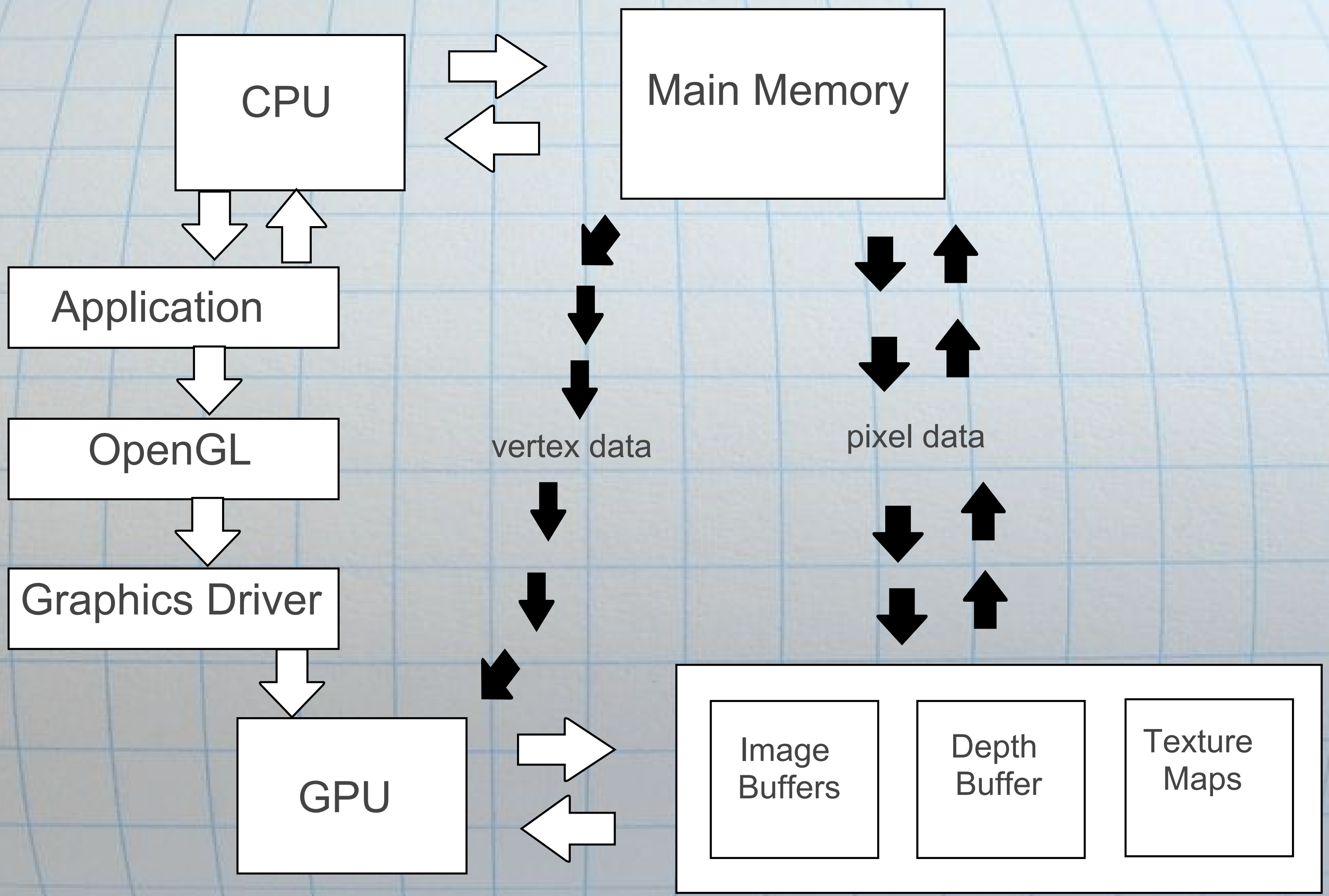
the rendering pipeline - overview

- a 3D scene consists of separate objects, each defined by a set of vertices and a graphics primitive
- information about the object and its properties is stored at each vertex
- how that information is manipulated and displayed requires several transformations and a number of mathematical operations
- the sequence of transformations from vertices (input) to display (output) is known as the rendering pipeline
- in chapter 0, the book provides a detailed description of this process, which we'll summarize here

the rendering pipeline - hardware

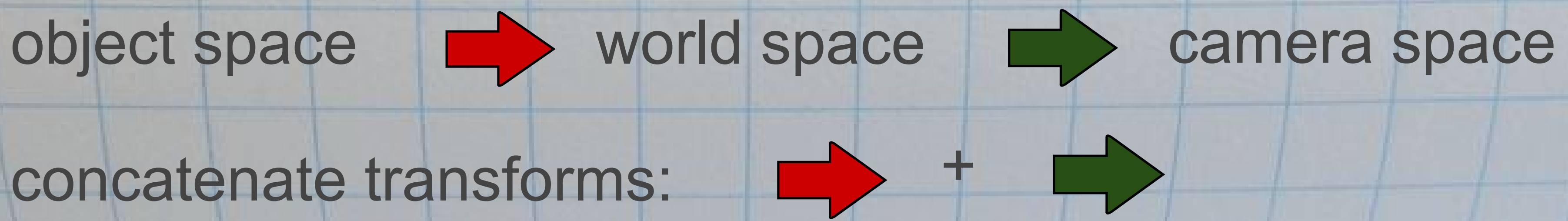
- on modern computers graphics are handled by Graphical Processing Unit (GPU), separate from CPU
- CPU communicates with graphics application
- application sends rendering commands to graphics library (e.g., OpenGL)
- OpenGL sends commands to GPU (through a graphics driver)
- GPU processes vertex data to produce pixel data
- pixel data is displayed in image buffers

the rendering pipeline - hardware



the rendering pipeline - transforms

- several 3D coordinate systems some local, some global,
  - vertex data is stored in 3D object space - local
  - position of each object is given in world space - global
  - also camera/eye space: x and y align with display, and z in viewing direction
- model-view transformation



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object space → camera space

the rendering pipeline - transforms

more transforms:

- projection: apply perspective
- performed in four-dimensional homogeneous clip space - graphics primitives clipped to visible area
- in clip space x, y, and z are in [-1,1], coordinates represent position vector of vertices
- viewport transformation of vertices from normalized coordinates to pixel coordinates - vertices now in window space

the rendering pipeline - transforms

now some calculations:

- how much light reaches each vertex? how much is reflected?...
- per-vertex lighting - pixel light is interpolated from vertices
- vertices may also carry texture coordinates
- all these information is interpolated to determine the final color for each pixel in the viewport...

rasterization and fragment operations

once in viewport coordinates:

- rasterization - what pixels are covered by what primitive?
- fragment - depth, color, texture, and location of pixel
- fragment/pixel shading - fragment data is used to determine the final color and depth for each pixel
- several test are performed so as to determine what pixels will be visible before calculating fragment shading so as to avoid unnecessary operations
- if a pixel/fragment passes all tests, its color is blended to the buffer