

Computer Graphics

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ICL/ITRI



Introduction to Computer Graphics

Basic concept of computer graphics



What is Computer Graphics

*Differences between IP, CV/PR, and CG
CG Applications
Graphics System*



Categorization

- ◆ What are the difference between Computer Graphics, Computer Vision (Pattern Recognition) and Image Processing

<i>Input</i>	<i>Output</i>	<i>Category</i>
Image	Image	Image Processing
Description Images	Description	Computer Vision Pattern Recognition
Description	Image	Computer Graphics



Image Processing

- ◆ The *analysis* of scenes, or the *reconstruction* of models of 2D or 3D objects from their pictures

Example: Image Compression



Example: Image Compression



Example: Image Compression



Original: 1.1MB

JPEG-Compressed: 81KB



Example: Edge Detection

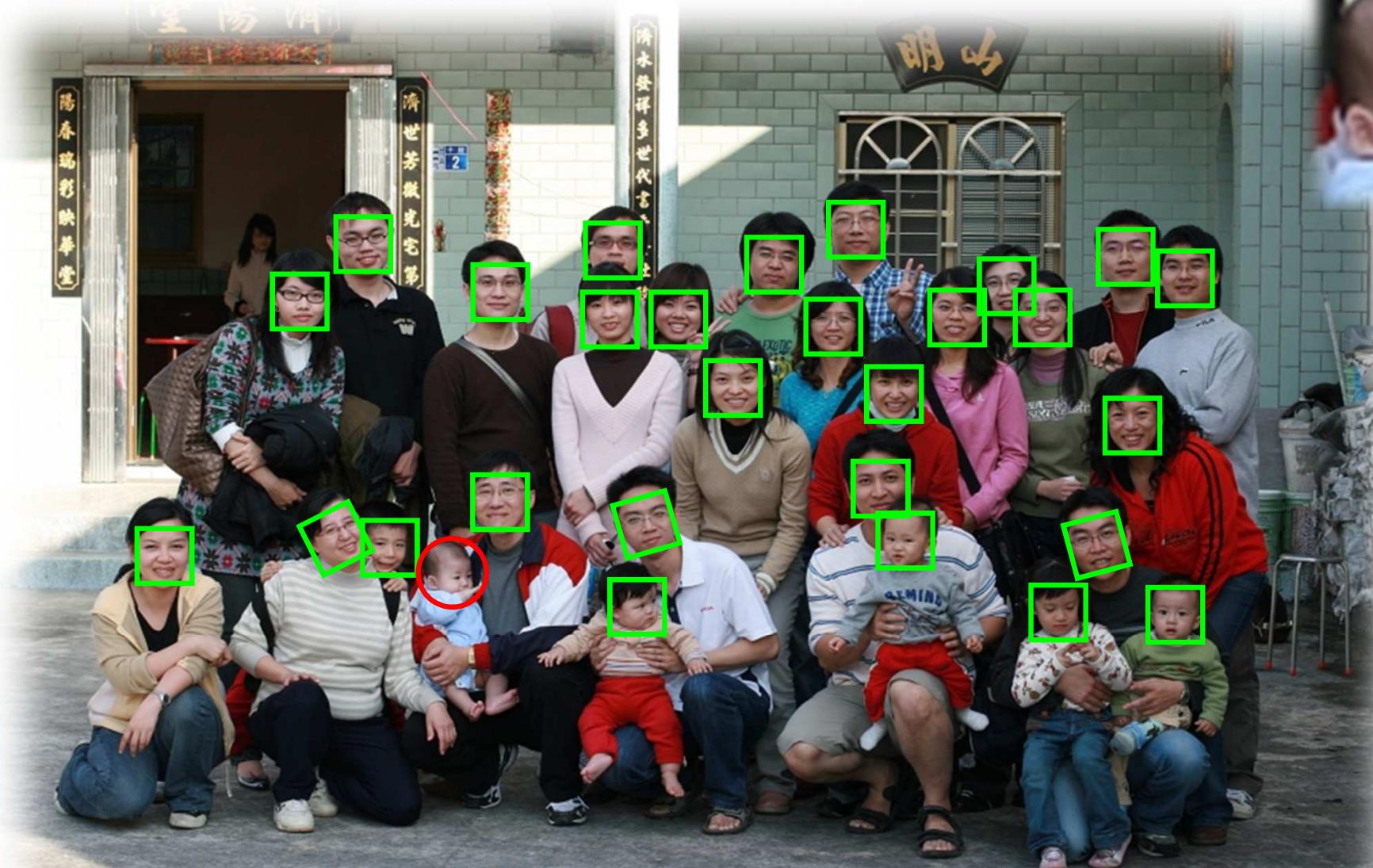


Computer Vision / Pattern Recognition

- ◆ Computer Vision is concerned with the theory for building artificial system that obtain information from images
 - It tries to perform the similar tasks the a human visual system can do
- ◆ Pattern Recognition aims to classify data (patterns) based on either prior knowledge or on statistical information extracted from the patterns
 - DNN is trying to solve the similar problems



Application of Computer Vision



Computer Graphics

- ◆ Computer graphics concerns the pictorial *synthesis* of real or imaginary objects from their computer-based models.



Columbia Pictures
Stuart Little



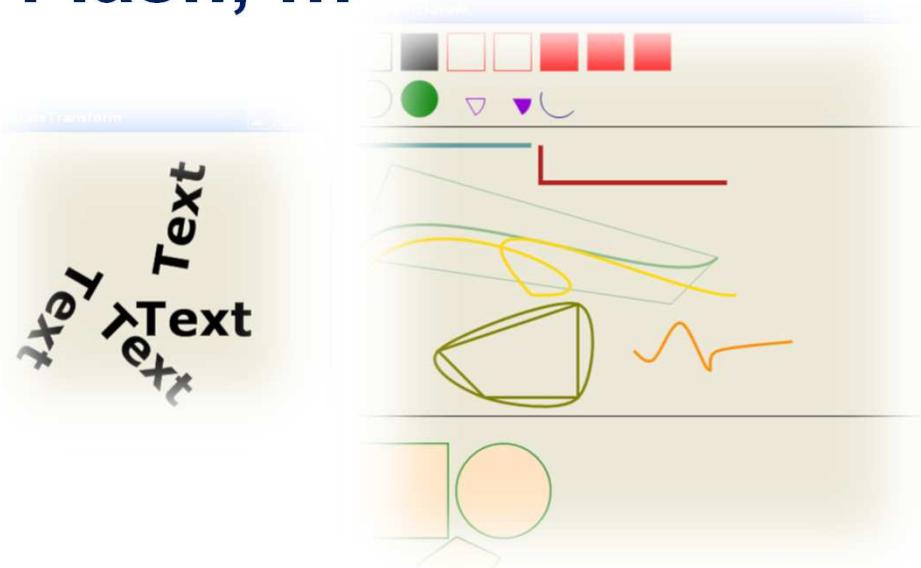
DreamWorks Pictures
Transformers



Types of Computer Graphics

◆ 2D Graphics

- The object being drawn is defined in 2D (x, y) coordinate system
- Eg. Texts, 2D lines / arcs / polygons, images, ...
- Vector graphics, 2D drawing tools, Adobe Flash, ...



Types of Computer Graphics

◆ 3D Graphics

- The object being drawn is defined in 3D (x, y, z) coordinate system
- Project the objects onto 2D projection plane and render
- Model the human visual system with one eye only
- Similar to the process in using camera to take a photo on the 3D world

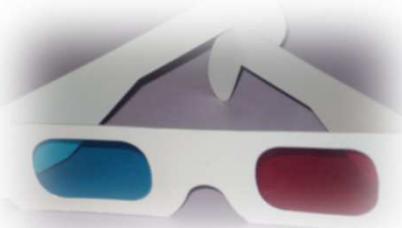
2D and 3D Graphics:
What's the Difference?
goodlearning.com



Types of Computer Graphics

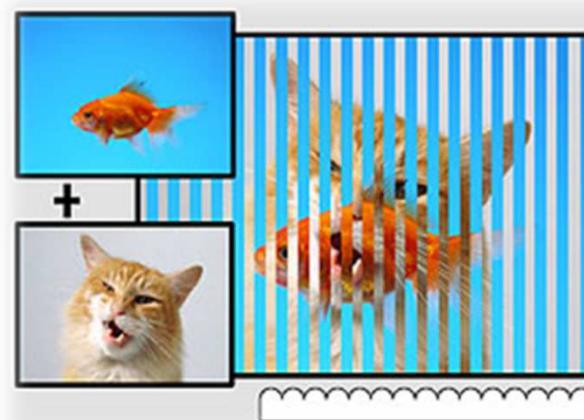
◆ Stereo 3D Graphics

- Modeling human visual system with left and right eyes
- Render left and right images with respect to the images seen by the left and right eyes, respectively
- Need special devices, such as glasses or display, to present the stereo 3D effect



Types of Computer Graphics

◆ Example Stereo 3D Image



Computer Graphics Applications

*Computer Games / Mobile Games
Modeling and Animations
Photo-Realistic Rendering
Visualization and Simulation
Visual Effects and Composition
Artwork Creation
Graphics User Interface
Virtual Reality / Augmented Reality
E-Commerce / E-Book*



Computer Games / Mobile Games

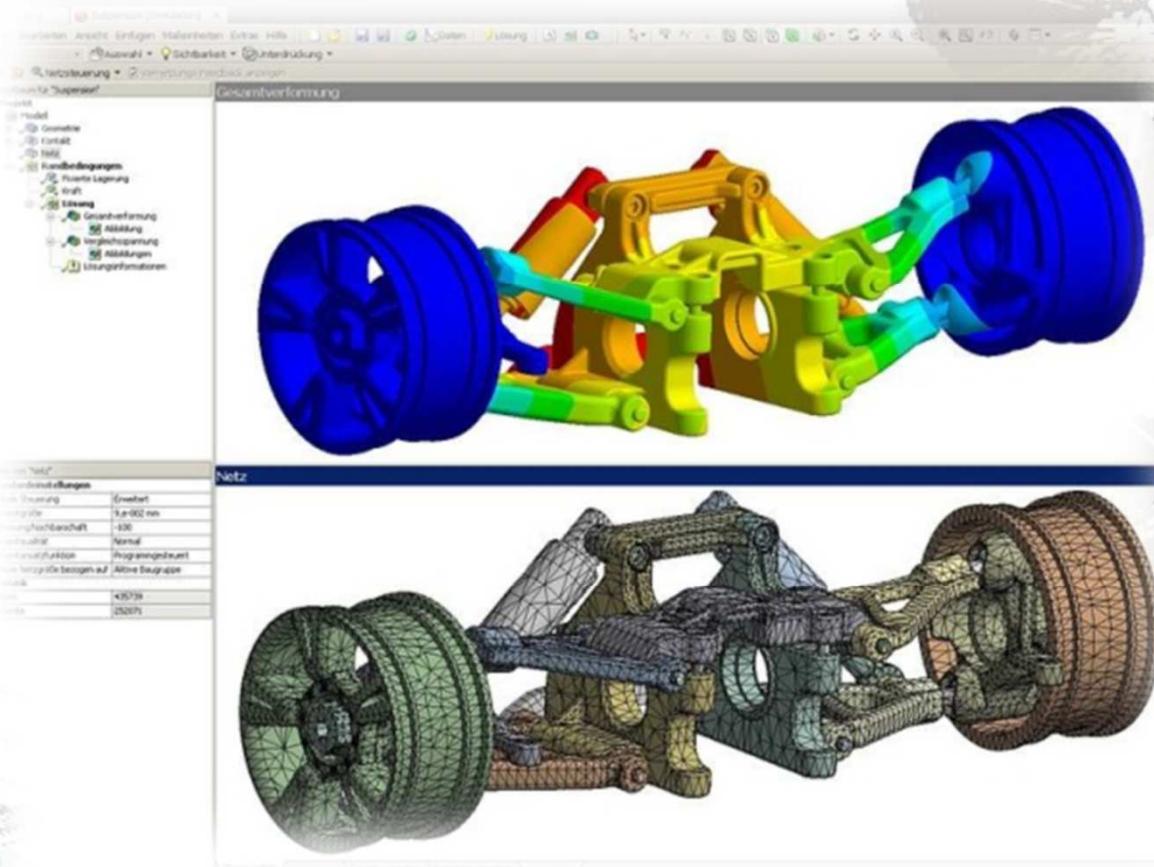
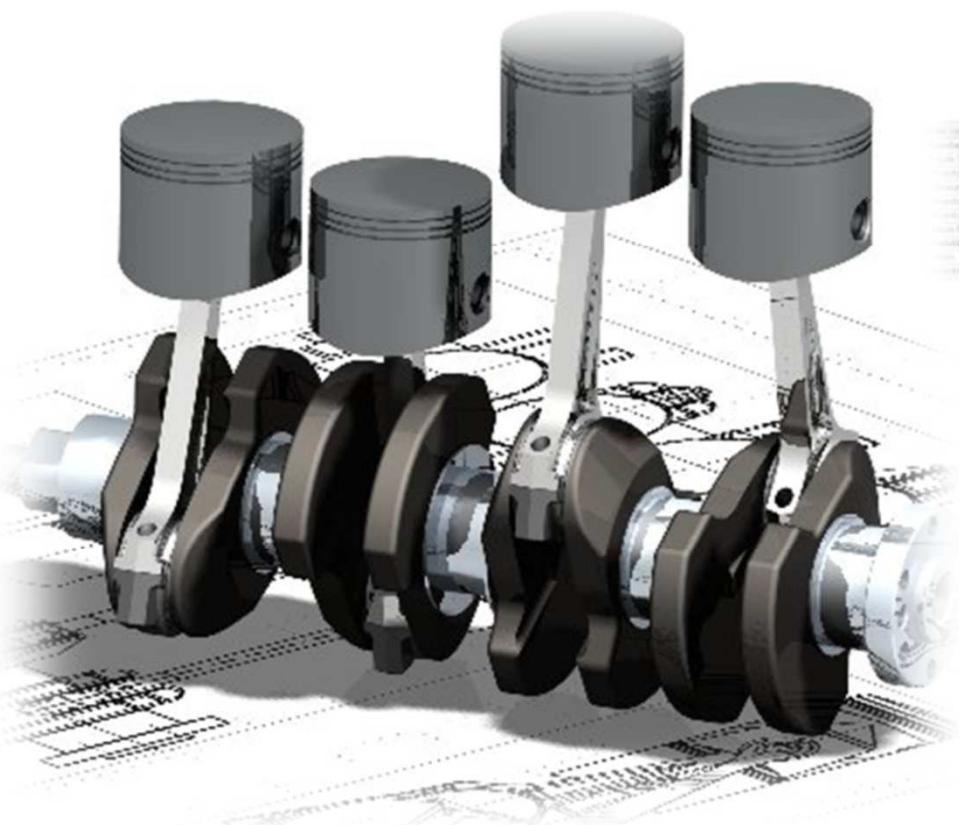


2D Game
Angry Birds, Rovio



3D Game
Dead or Alive 4, TECMO

Modeling



Modeling



Animations



Big Hero 6 (Disney)



Hotel Transylvania 2 (Sony Pictures Animation)



Minions (Illumination)



Inside Out (Pixar)



The Good Dinosaur (Pixar)

Animation

◆ Facial Expression Transfer

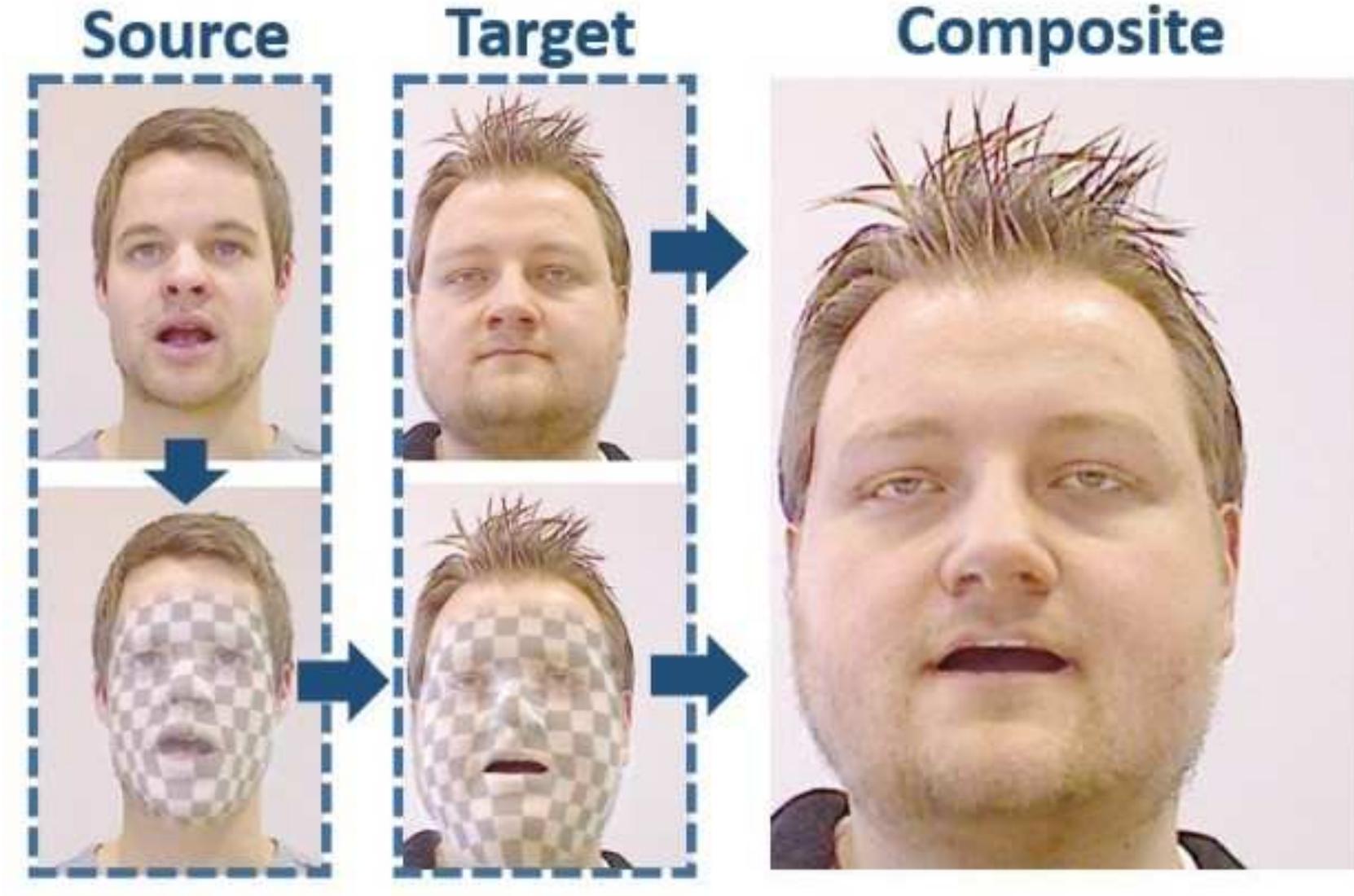


Photo-Realistic Rendering



Photo-Realistic Rendering

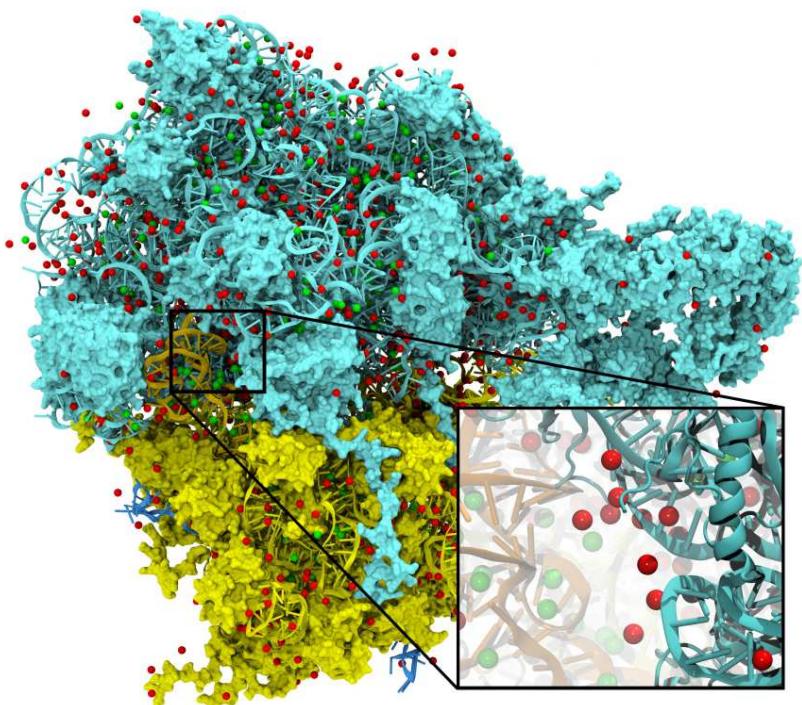


Photo-Realistic Rendering

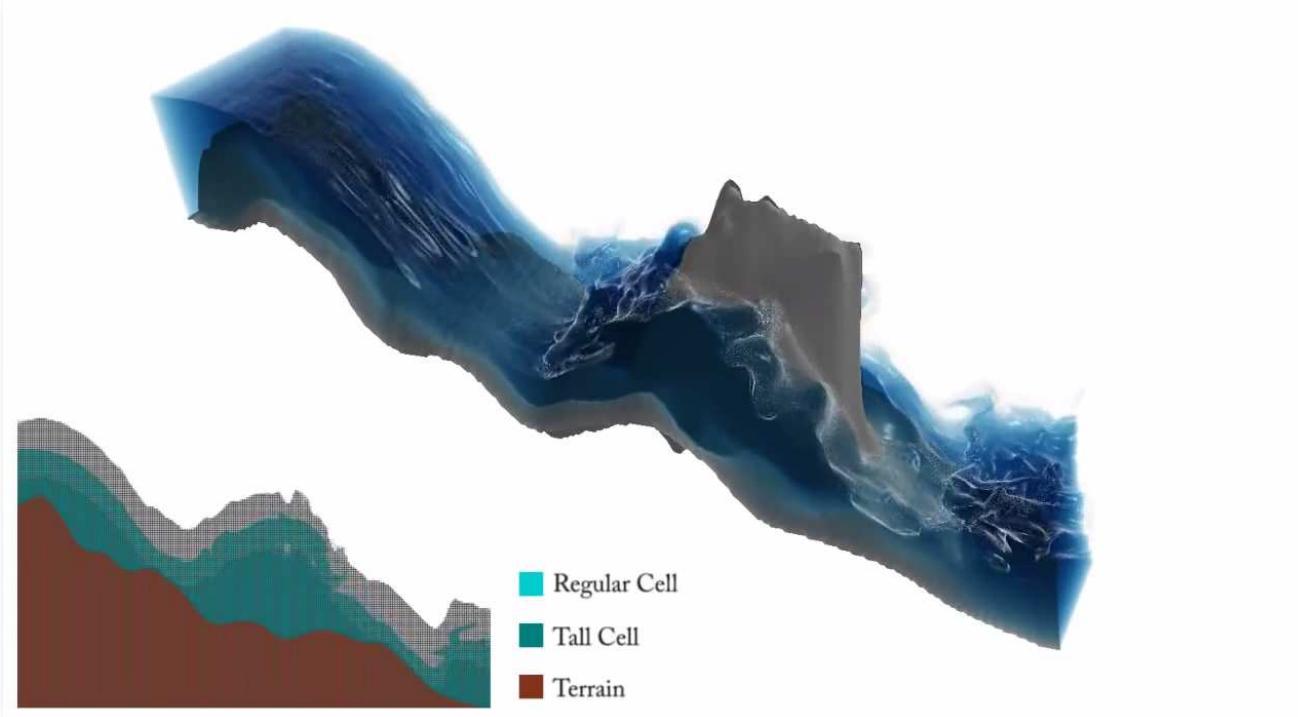


Visualization and Simulation

◆ Scientific Visualization and Physic Simulation



Molecular Modeling

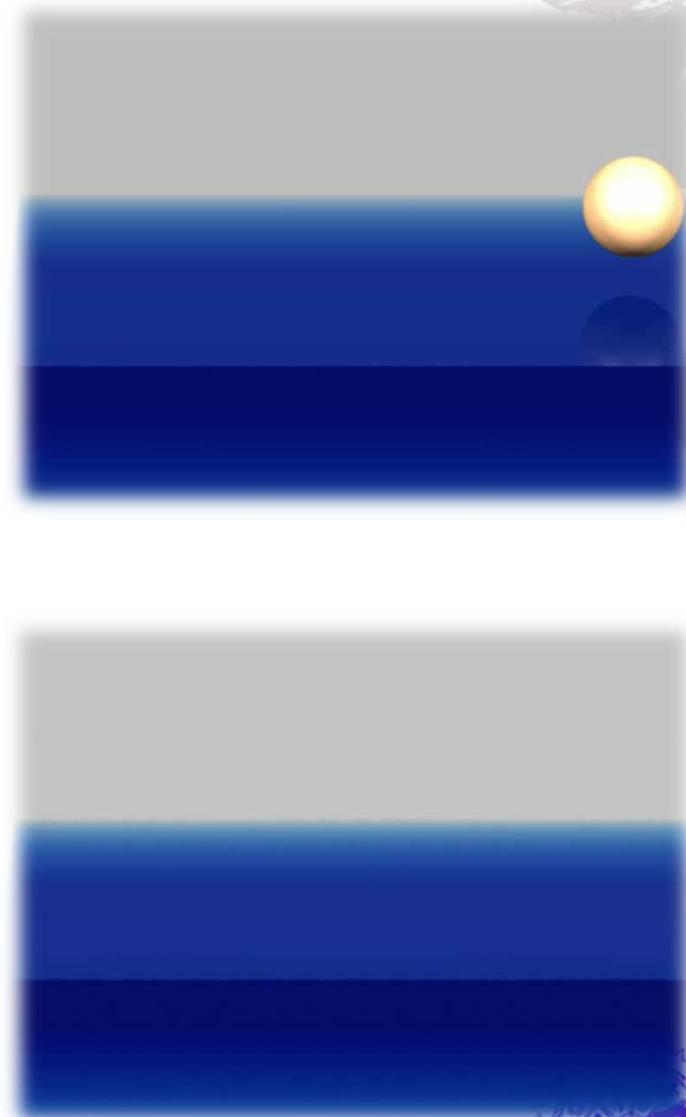
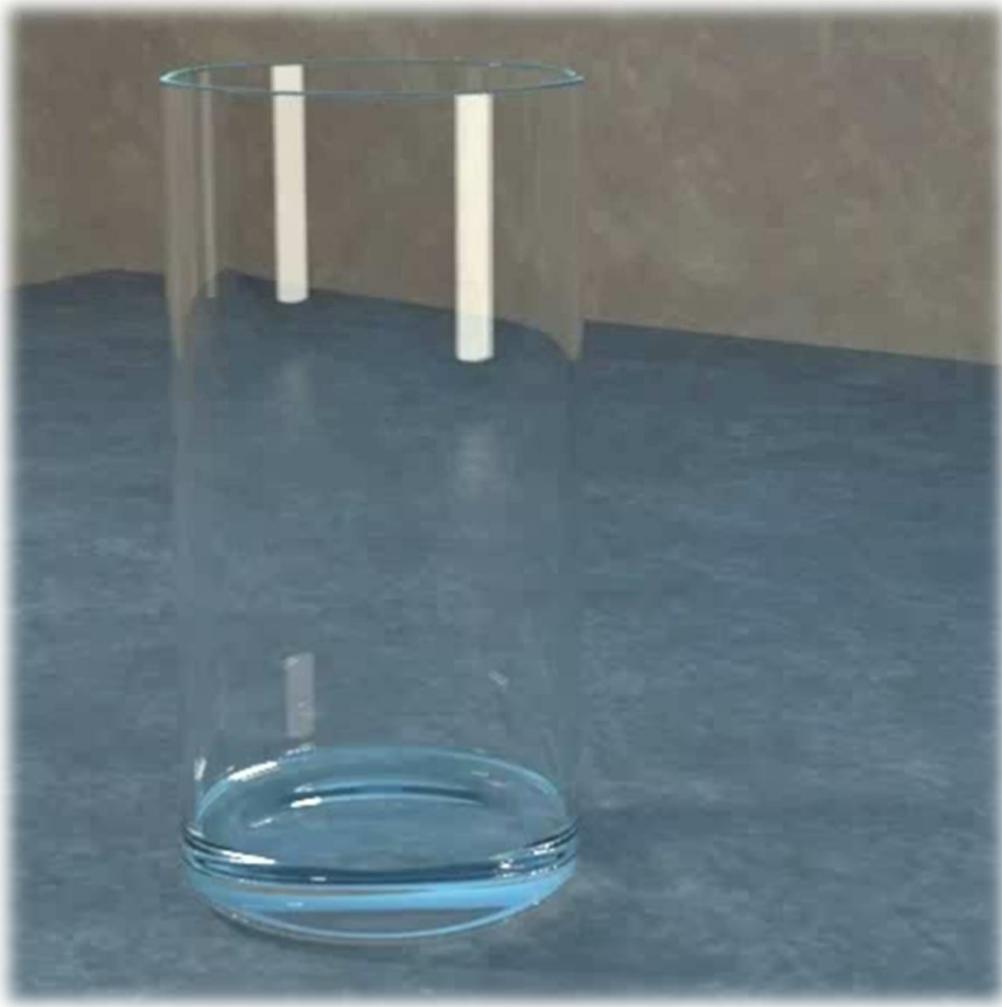


Real-Time Fluid Simulation



Visualization and Simulation

◆ Water Simulation



Visualization and Simulation

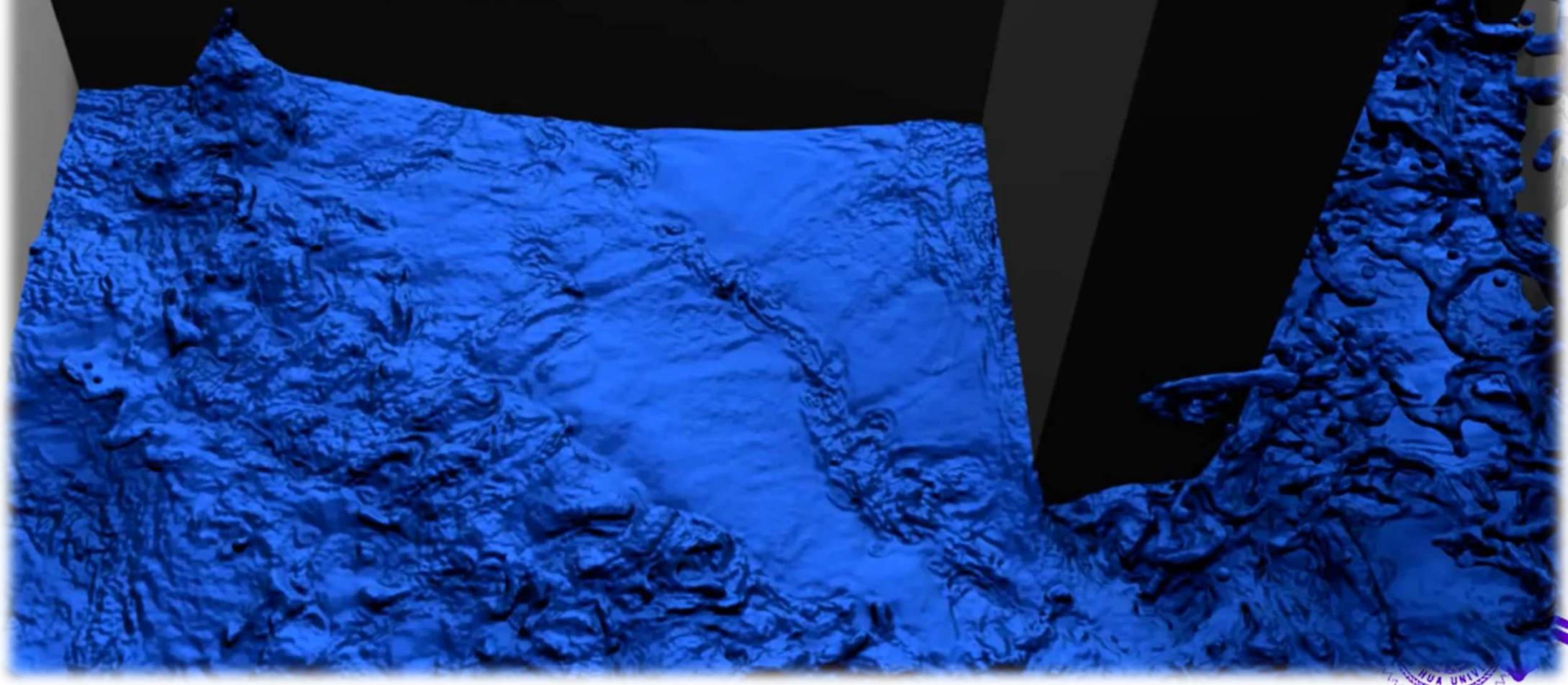
- ◆ Fire Simulation



Visualization and Simulation

Surface Turbulence for Particle-Based Liquid Simulations

Olivier Mercier¹ Cynthia Beauchemin¹ Nils Thuerey² Theodore Kim³ Derek Nowrouzezahrai¹
Université de Montréal¹ TU München² University of California, Santa Barbara³



Digital Painting Tools

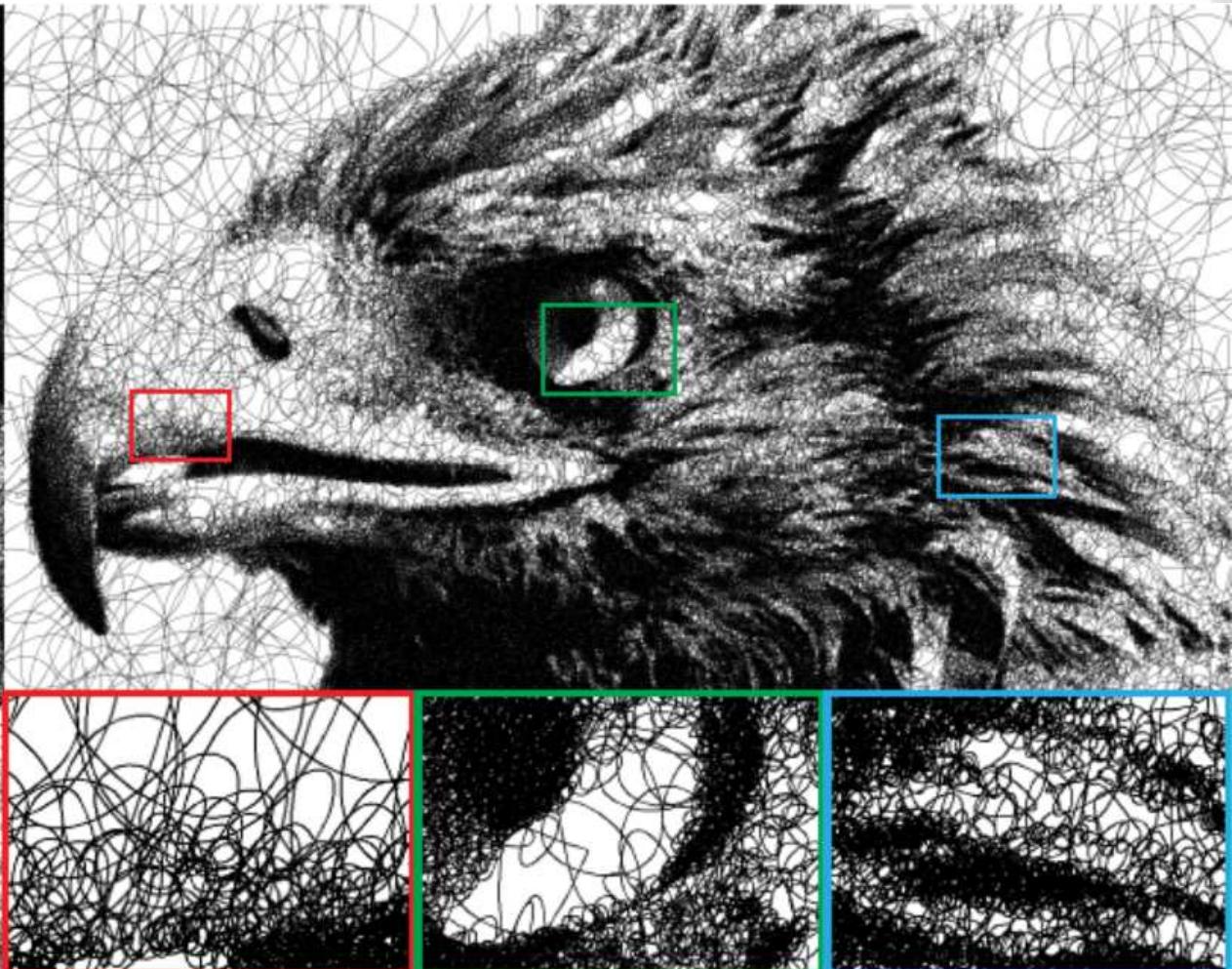


Grid-based liquid and particles visualized



Only particles visualized

Simulate Artwork Creation

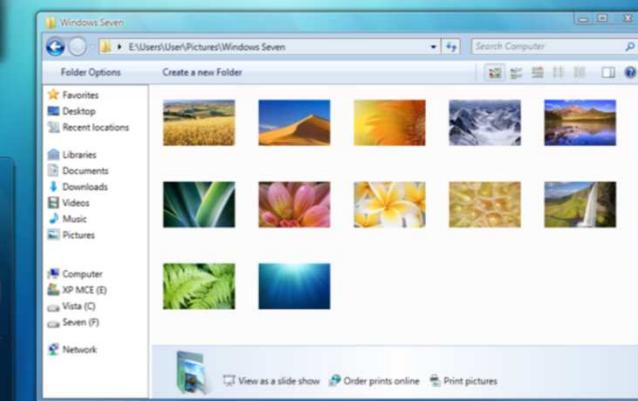


Graphics User Interface

◆ Windows UI



Microsoft
Windows 7



Microsoft Windows 8



Ubuntu Linux

Graphics User Interface

◆ Not just Windows



Graphics User Interface

◆ GUI and Information Display



Photo
Browser



Car
Dashboard



Cockpit Display



Photo
Browser



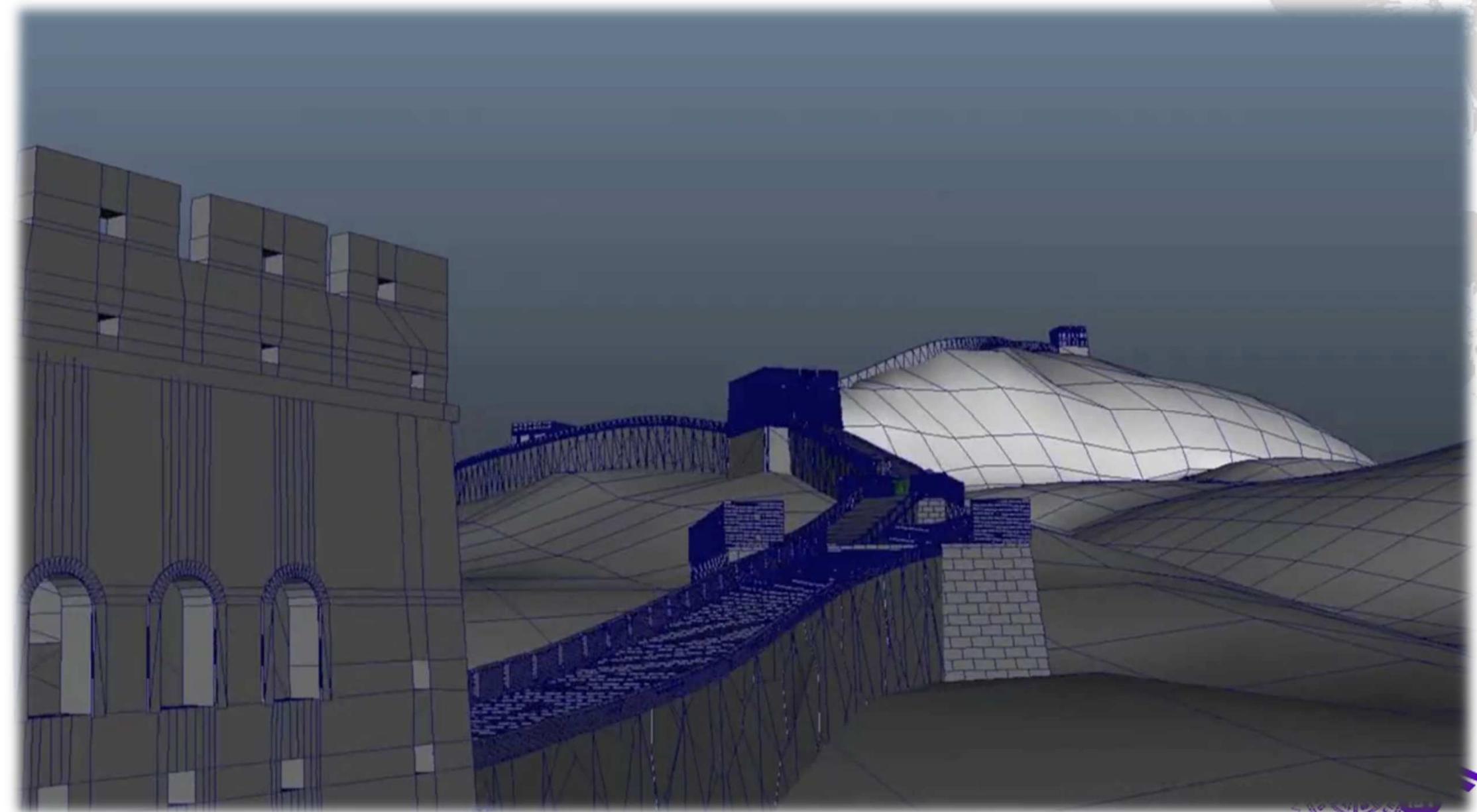
GPS Navigation



Visual Effect and Composition



Visual Effect and Composition



Virtual Reality



Augmented Reality



E-Commerce

EDDIEBAUER.COM HOME PAGE CLOTHING & GEAR HOME STORE OUTLET B2B

Eddie Bauer

MEN'S WOMEN'S DRESS CASUAL LUGGAGE & GEAR WEEKLY SPECIALS

VIEW CART CATALOG ORDER LOGIN MY ACCOUNT HELP

Search GO

Once you get a 3-D view,
you'll never look at our
gadgets the same.

Powered By:
 Viewpoint



GENERAL
INSTRUCTIONS

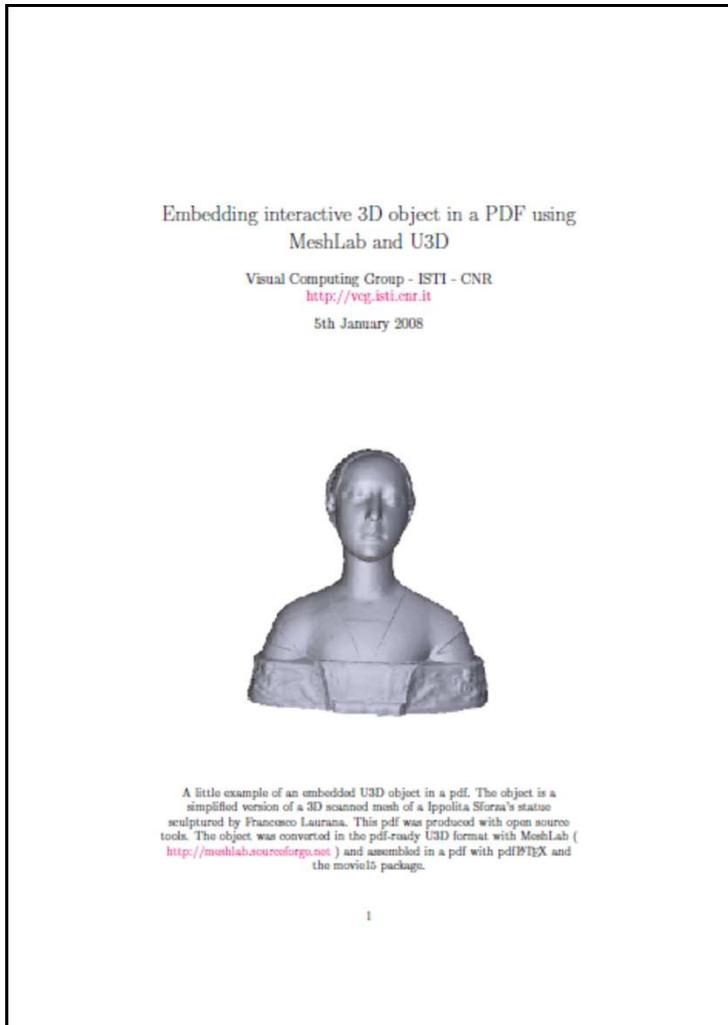
Welcome to the Eddie Bauer GADGETS COLLECTION

Using the newest technology, we bring you EB3-D, a different way to look at some of our featured products. Flip 'em, spin 'em, zoom in, zoom out — that's what EB3-D is all about.

[See our Gadgets in 3-D](#)

E-Book Document

◆ U3D format: pdf with 3D for better illustration



Saint Peter Chanel Catholic Church

The model is displayed below as a **shaded illustration**, but could also be displayed **shaded**, as an **illustration** or **transparent**, which can be useful for viewing objects that might otherwise be obscured. You may also wish to view one of the pre-defined views, [exterior](#) (default), [interior plan](#), [south elevation](#), or from the altar looking down the nave [transept left](#) [transept right](#).

I believe this project illustrates and exemplifies the concept of a truly integrated Building Design System/Solution. In my mind such a system should encompass CAD + CAM + Document Management + Legacy Data + Analysis Tools+ Design Tools + BIM + ...). I have been a firm believer and endorse for quite some time in the concept of a single building model and a truly integrated Building Design System. This is a very evolutionary concept and dependent on current technologies. There is still much work to be done to fully achieve this, however, Bentley's approaches to adopting BIM, as evidenced in their new versions of MicroStation and the various vertical applications, seem sound and targeted to realizing this vision. I firmly believe that BIM is not an end in itself, but rather the latest evolution of the simpler more generic Building Design System. With an emphasis on 'information', BIM does not encompass all aspects, primarily that of Design. I want to derive more from my models than just a conglomeration of data. I want my models to be able to convey design intent. I believe this project does just that. With the single building model I am able to leverage several technologies to aid in the capturing and conveyance of design intent.

You can interactively view shaded, three-dimensional models and animations. To view the interactive 3D content of this file, it must be opened with Adobe Acrobat or Reader™. If it is viewed in a browser at right, you do not have the latest version available. [Download Acrobat Reader™](#)

Clicking on a 3D object will activate a toolbar with a set of tools for navigating within the scene. The standard Acrobat tools (rotate, navigate, zoom, pan) are documented in the Acrobat Help. When clicking on the links and bookmarks, it may be necessary to click on the graphics to see the desired effect.

CDH PARTNERS



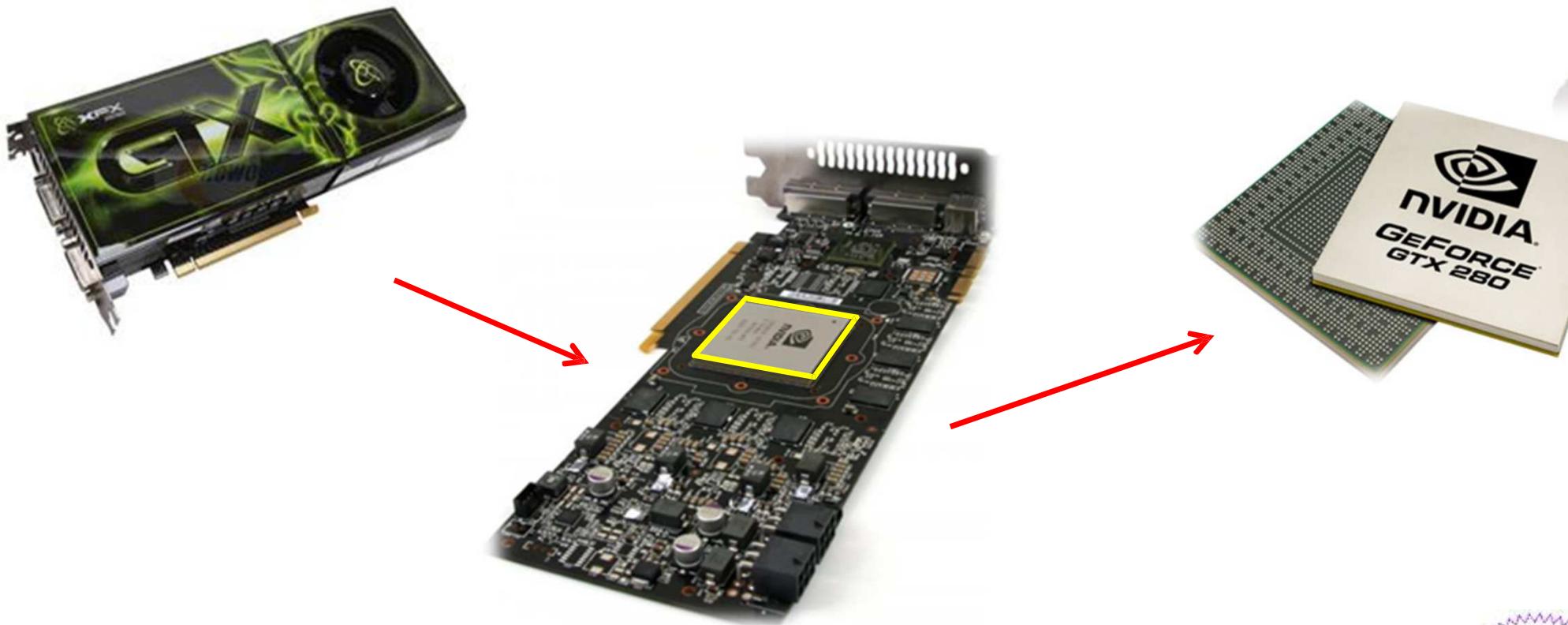
Graphics Hardware System

*Graphics Processing Unit
Graphics System*



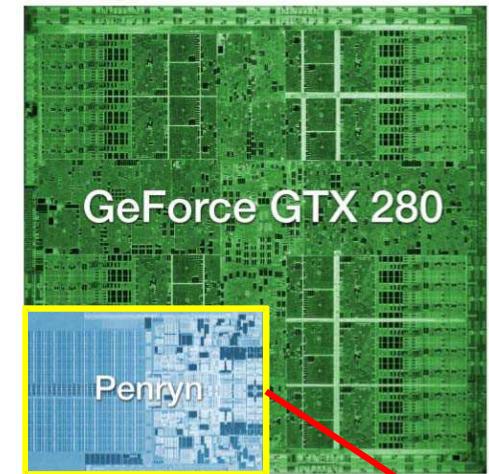
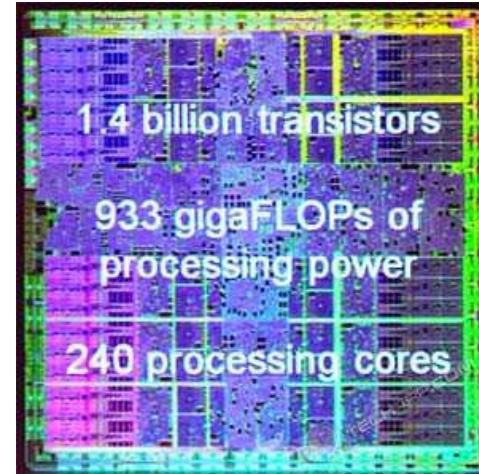
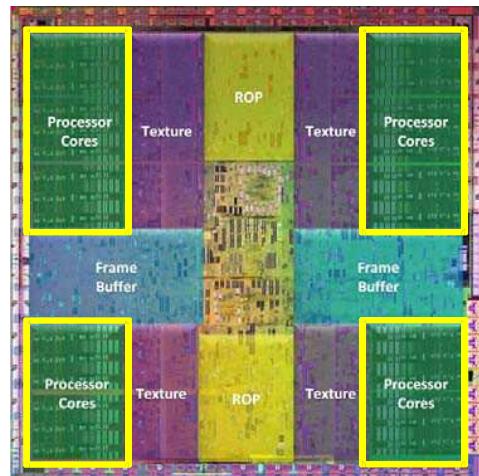
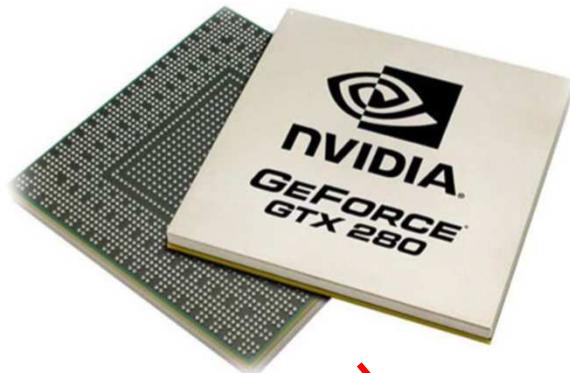
GPU – Graphics Processing Unit

- ◆ Acceleration of Graphics Processing

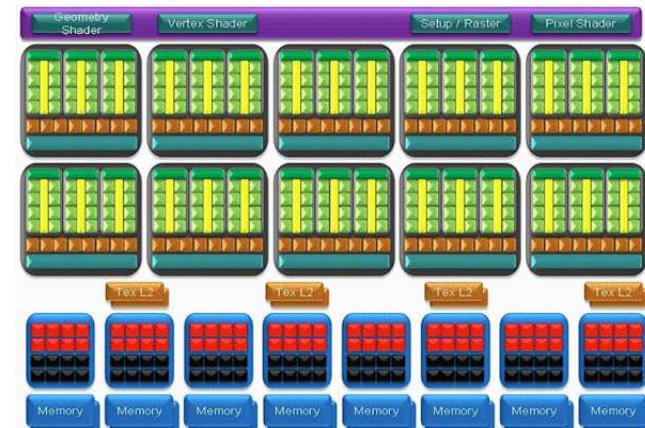


GPU – Graphics Processing Unit

- ◆ Very high complexity with massively parallelism



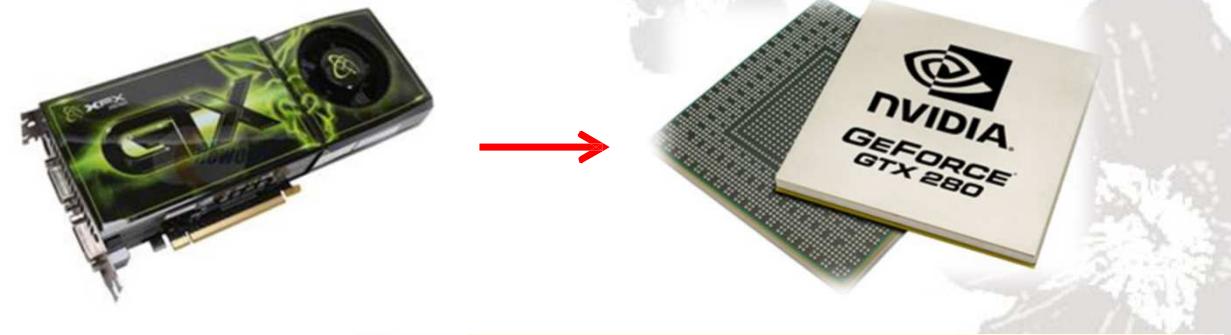
Intel Core 2 Duo



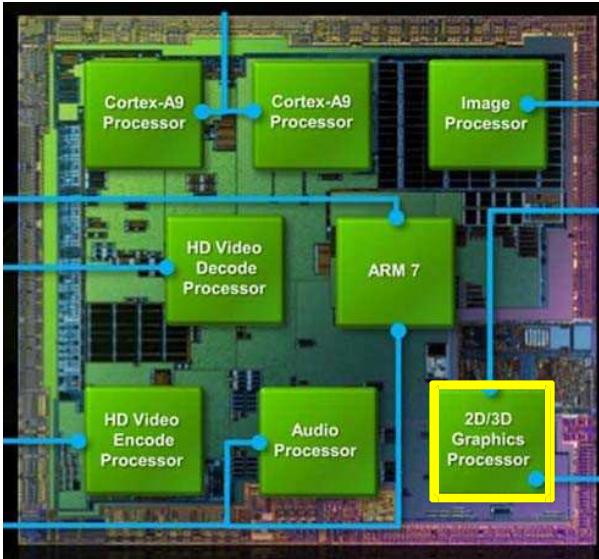
Processor Cores
(Shaders)



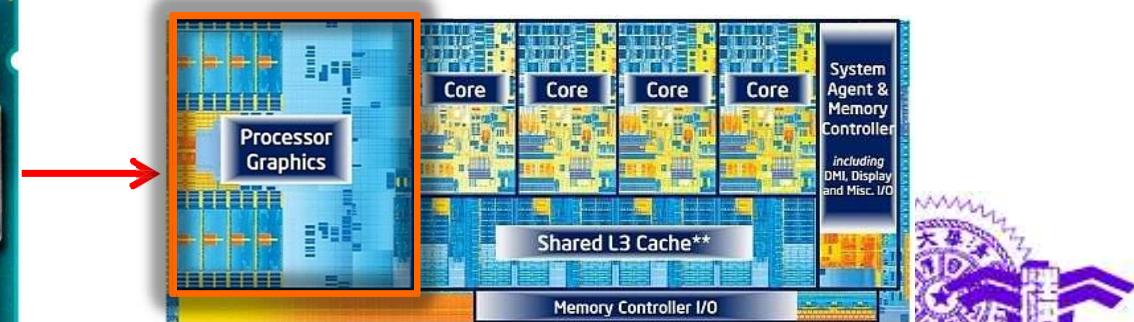
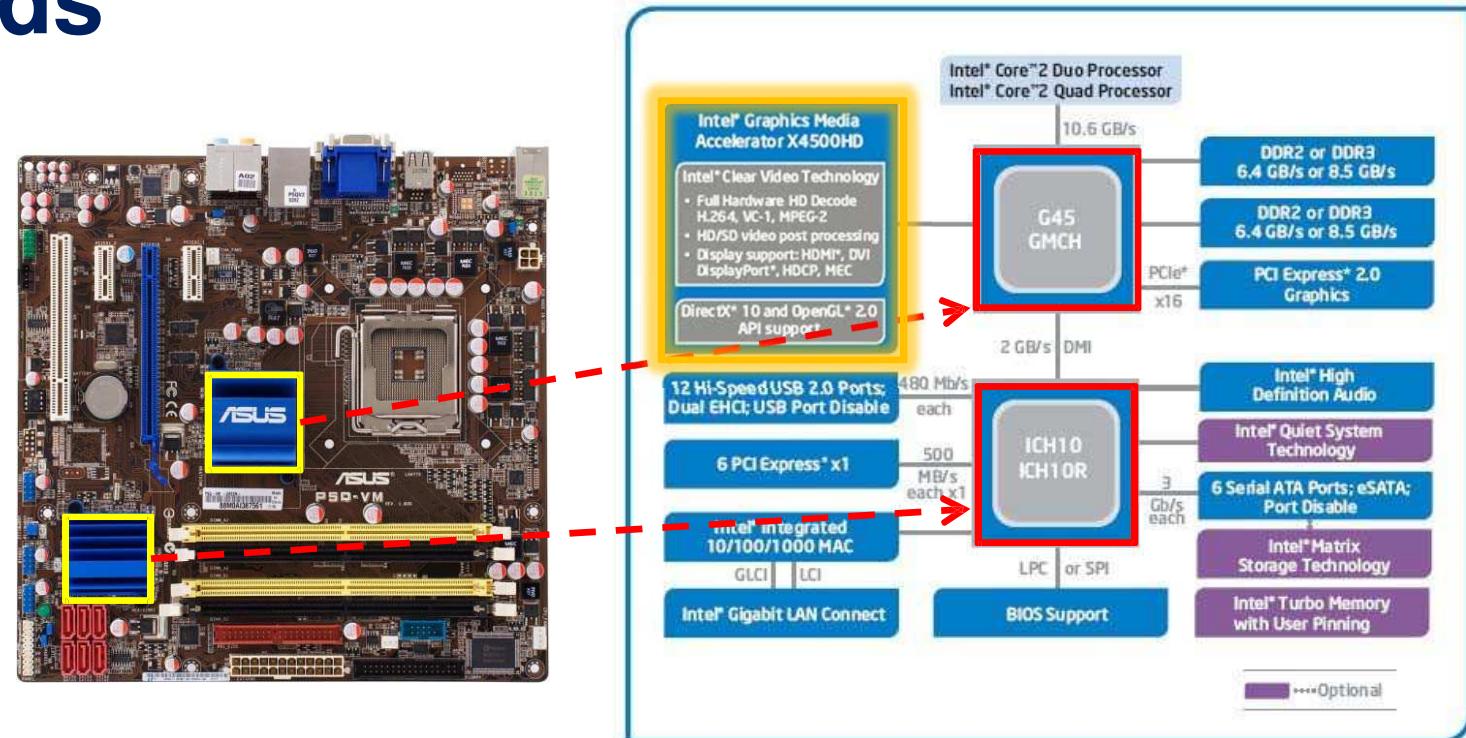
Where is GPU



- ◆ Graphics Cards
- ◆ Chipset
- ◆ CPU
- ◆ SoC



NVIDIA Tegra 2



GPU Everywhere

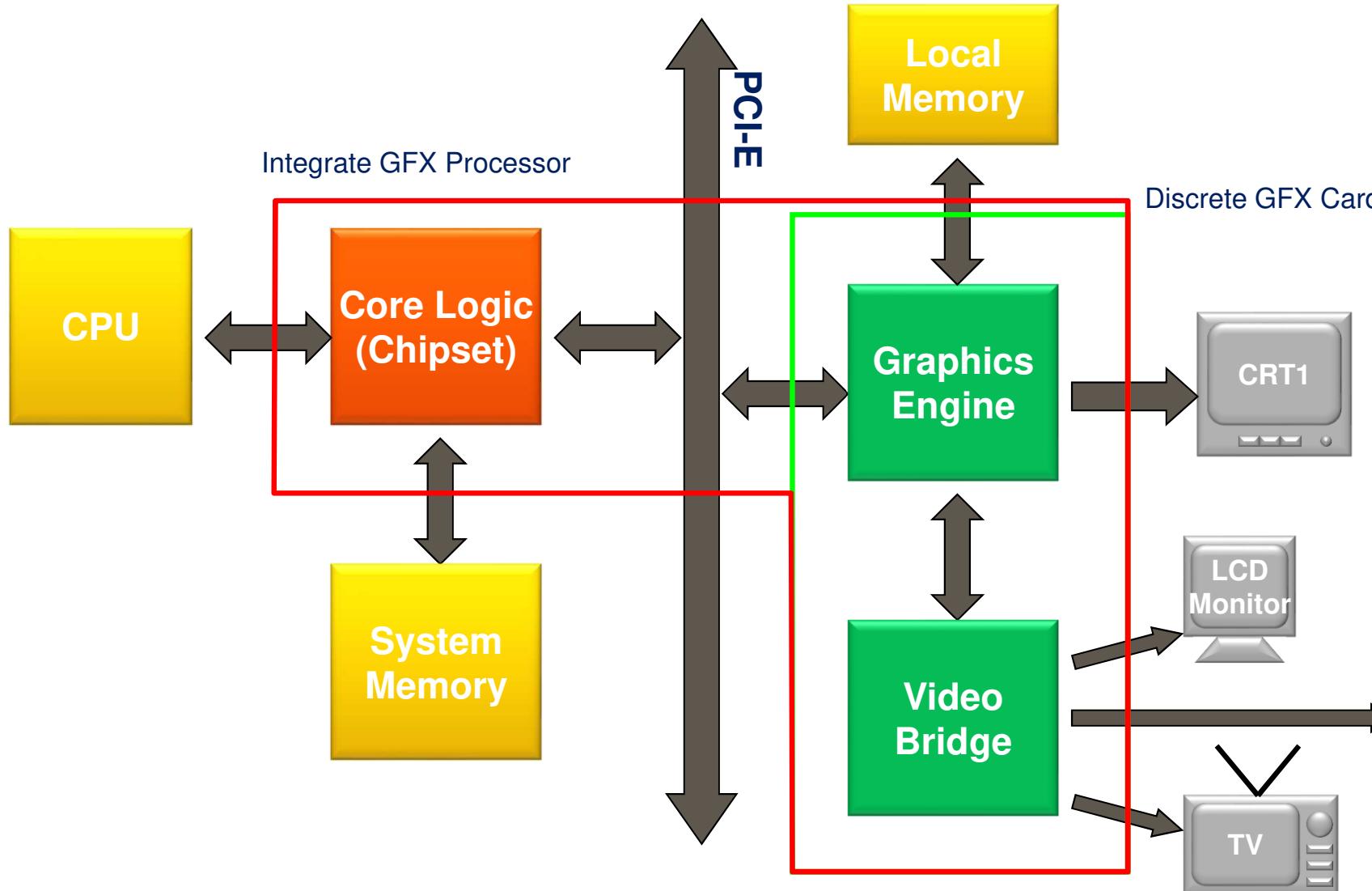


- ◆ Nowadays, almost every device, that supports output to a display, equips with a GPU

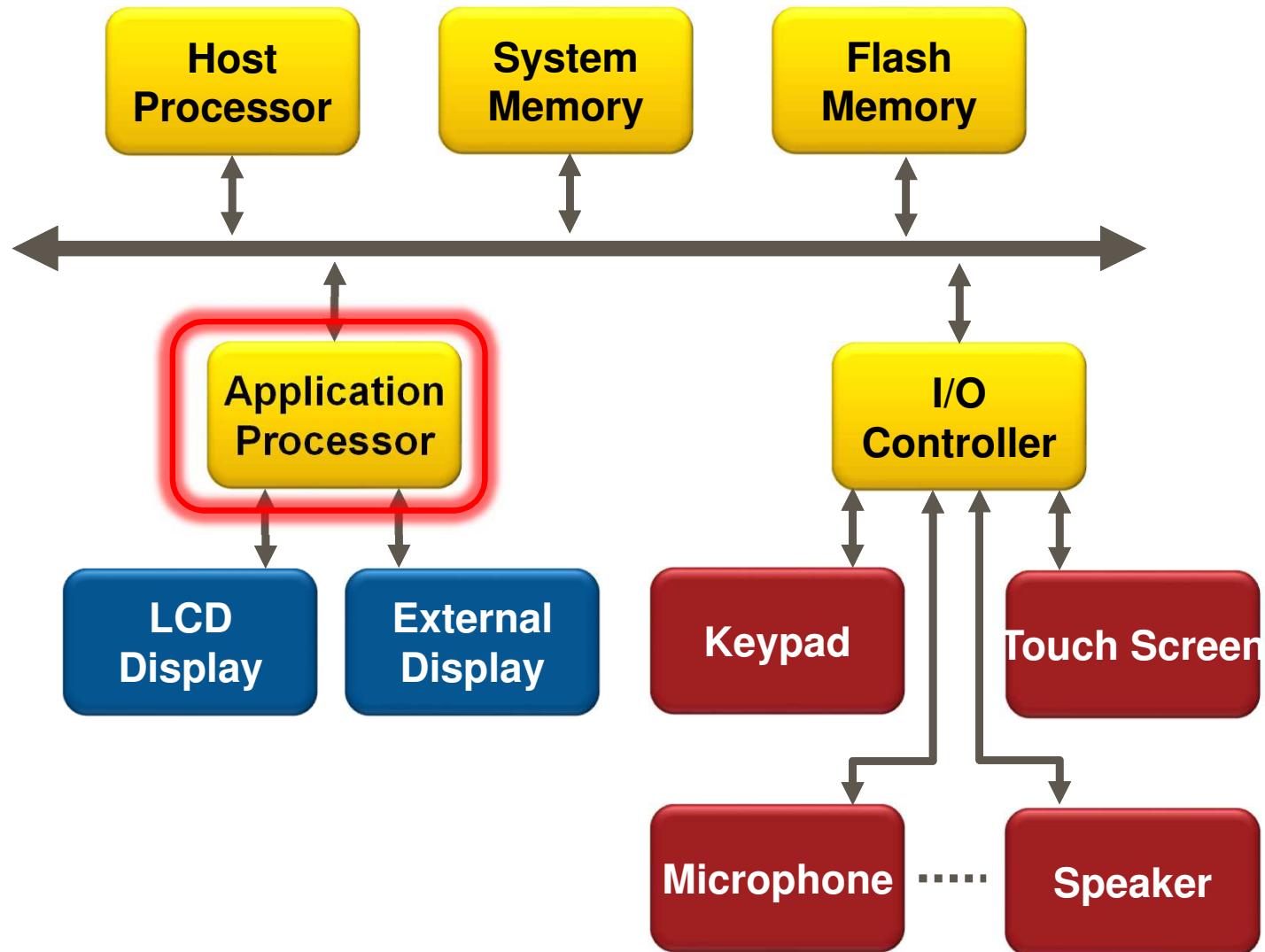
- Desktop PCs
- Notebooks
- Mobile phones
- Tablets
- Smart TVs
- Set-top boxes
- Game consoles
- Wearable devices
- ...



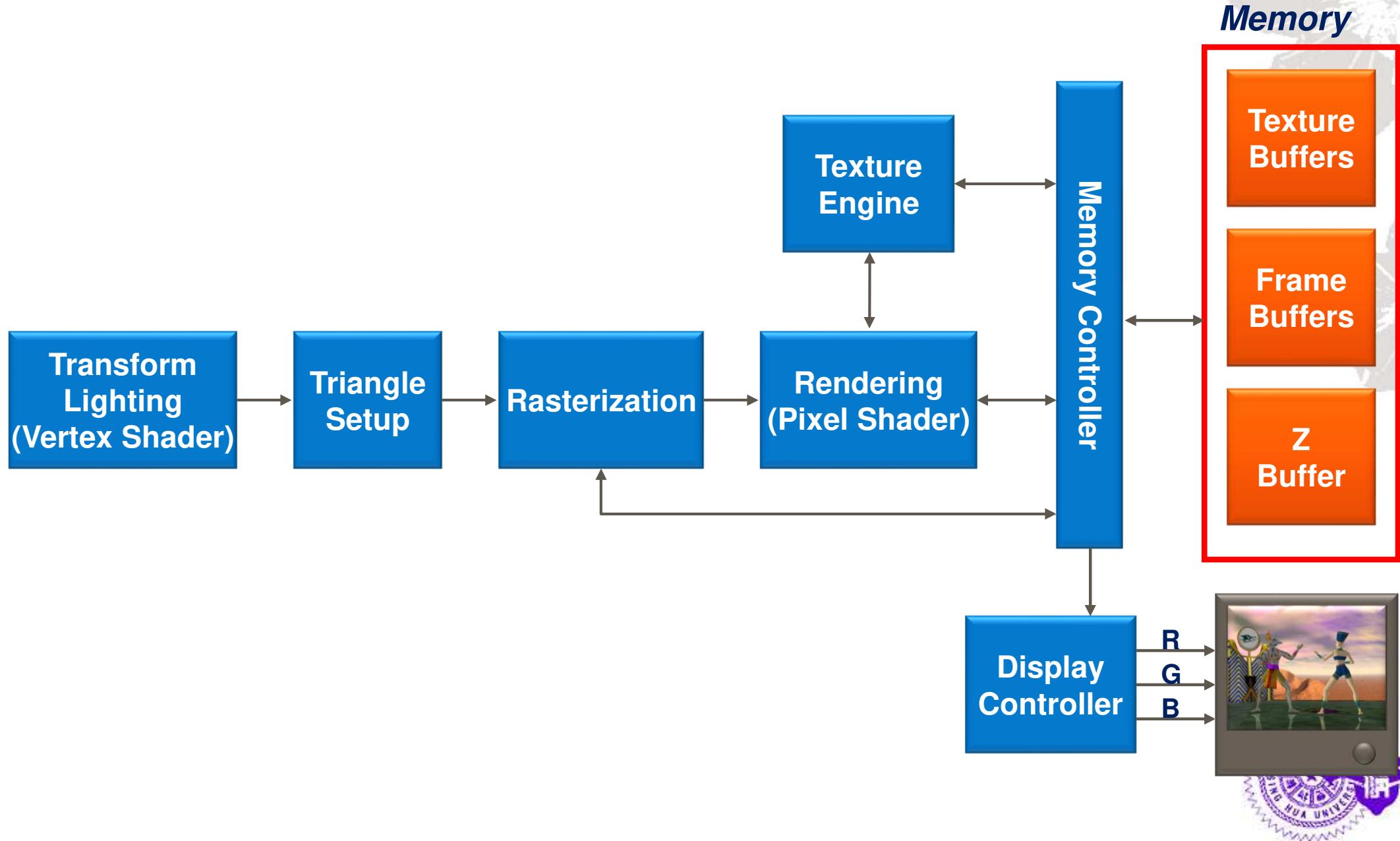
PC Graphics System



Mobile Graphics System



A Generalized Graphics Sub-System



Pixel

- ◆ Each pixel is consisting of red, green, and blue color components



Frame Buffer

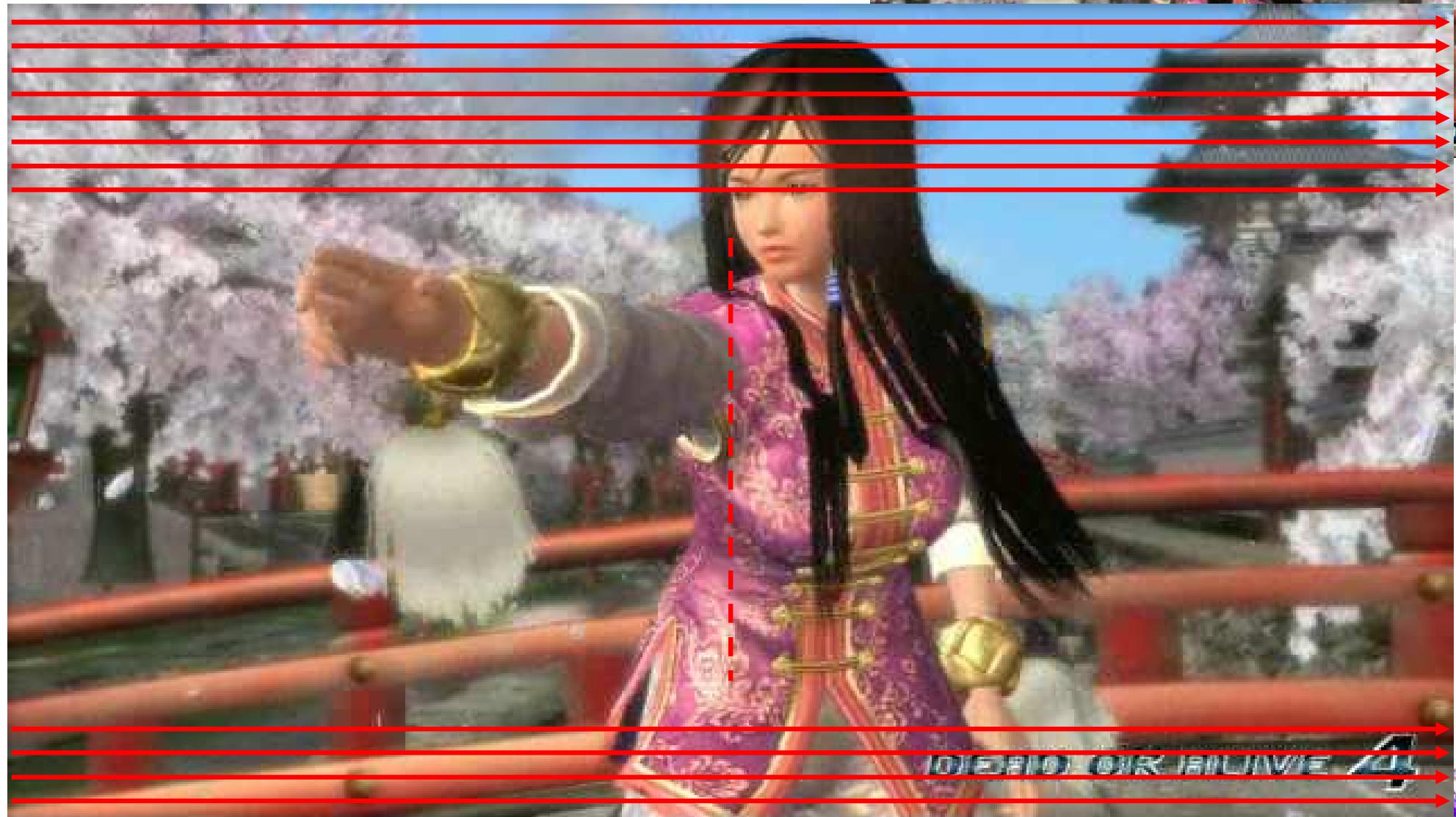
- ◆ Memory location for storing display data during processing
 - Front buffer (Current display buffer)
 - Back buffer (Next display buffer)



Memory

R	G	B	A
R	G	B	A
R	G	B	A
R	G	B	A

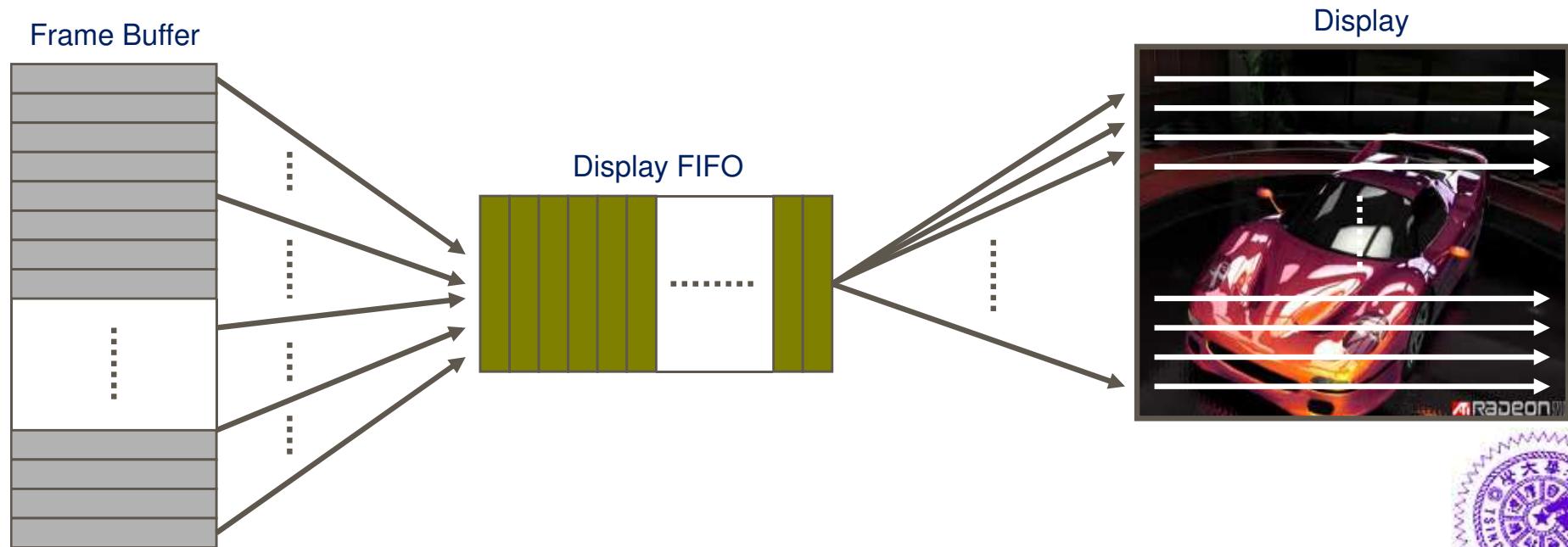
Display Buffer



DISPLAY OR BUFFER

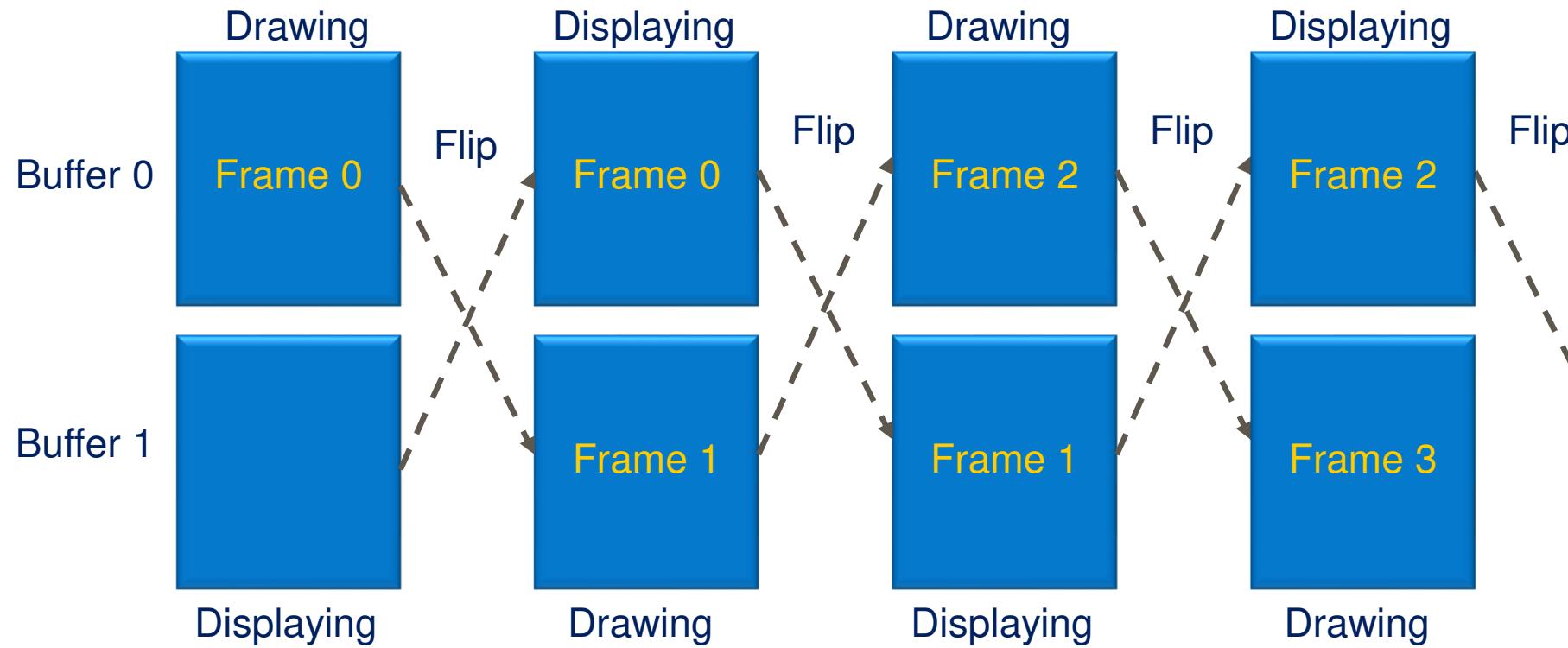
Screen Refresh

- ◆ Retrieve front buffer pixels for displaying pixel colors on screen
- ◆ Constant refresh rate (60Hz for LCD display)
- ◆ Scan-line based display



Double Buffering

- ◆ A technique to prevent from displaying incomplete frame

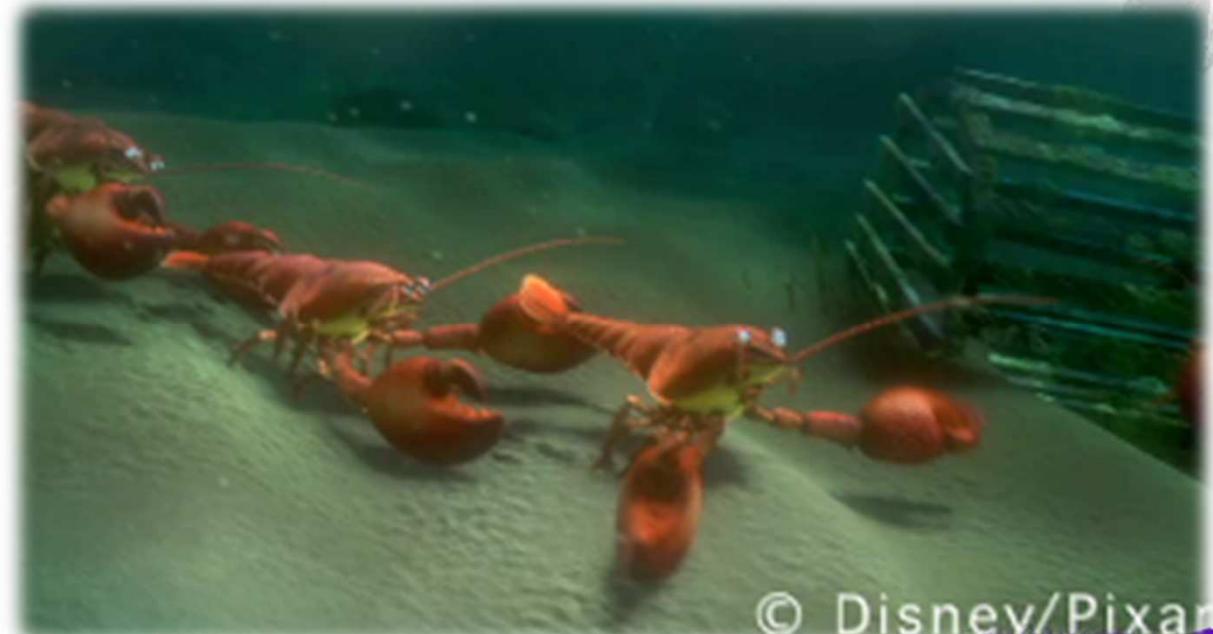


Full Screen Display

◆ Full Screen Display

- Uses double buffering or triple buffering
- Flip display by changing display base address to corresponding buffer

Display →



Full Screen Display

◆ Full Screen Display

- Uses double buffering or triple buffering
- Flip display by changing display base address to corresponding buffer



Display →



Window Mode Display

- ◆ **Window Mode Display**
 - **Uses double buffering or triple buffering**
 - **Flip display by using 2D Bitblt to move back buffer frame on to front buffer display**

Display →



Bitblt



Window Mode Display

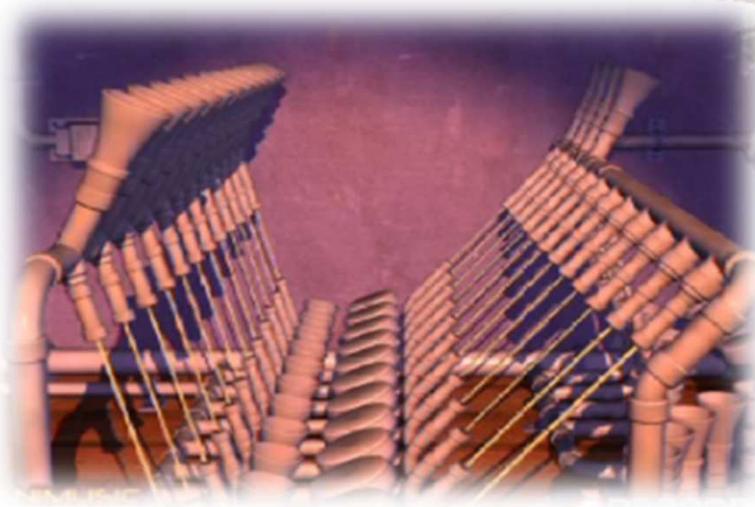
- ◆ **Window Mode Display**
 - **Uses double buffering or triple buffering**
 - **Flip display by using 2D Bitblt to move back buffer frame on to front buffer display**



Display →



Hardware Capabilities



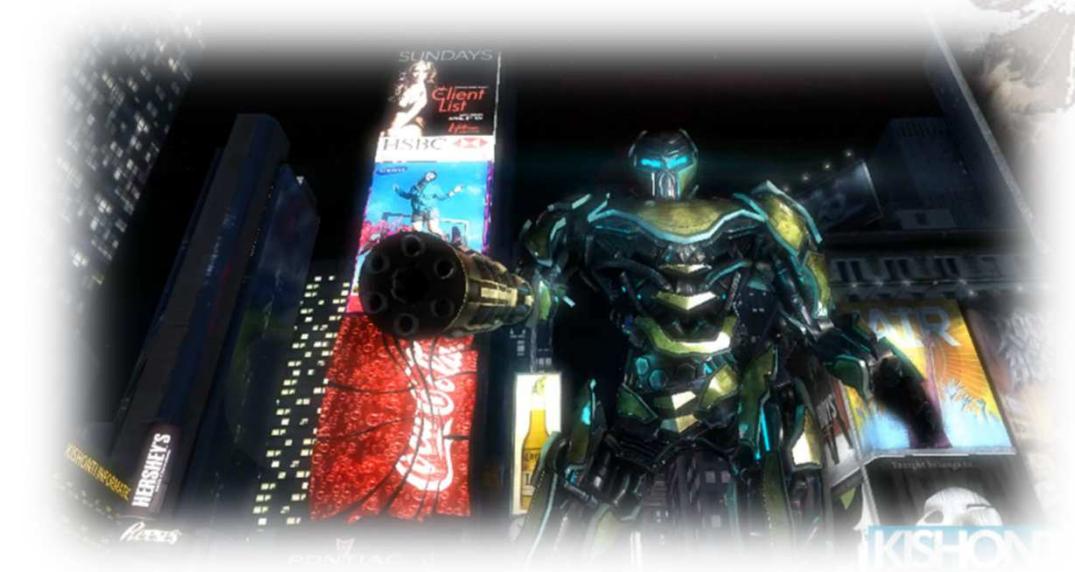
Benchmarks

- ◆ Set the Level of Quality and Performance
 - PC Graphics Benchmarks



Benchmarks

- ◆ Set the Level of Quality and Performance
 - Mobile Graphics Benchmarks



Heart of the GPU – A 3D Graphics Pipeline

*What is the 3D Graphics Pipeline
Inside a 3D Graphics Pipeline
Programmable Shaders*



What is the 3D Graphics Pipeline

- ◆ The one who renders the frames (images) you see on the display
 - Almost everything you see on the display is processed by the graphics pipeline
 - It is realized by graphics hardware (GPU) or by software (CPU)



Windows UI

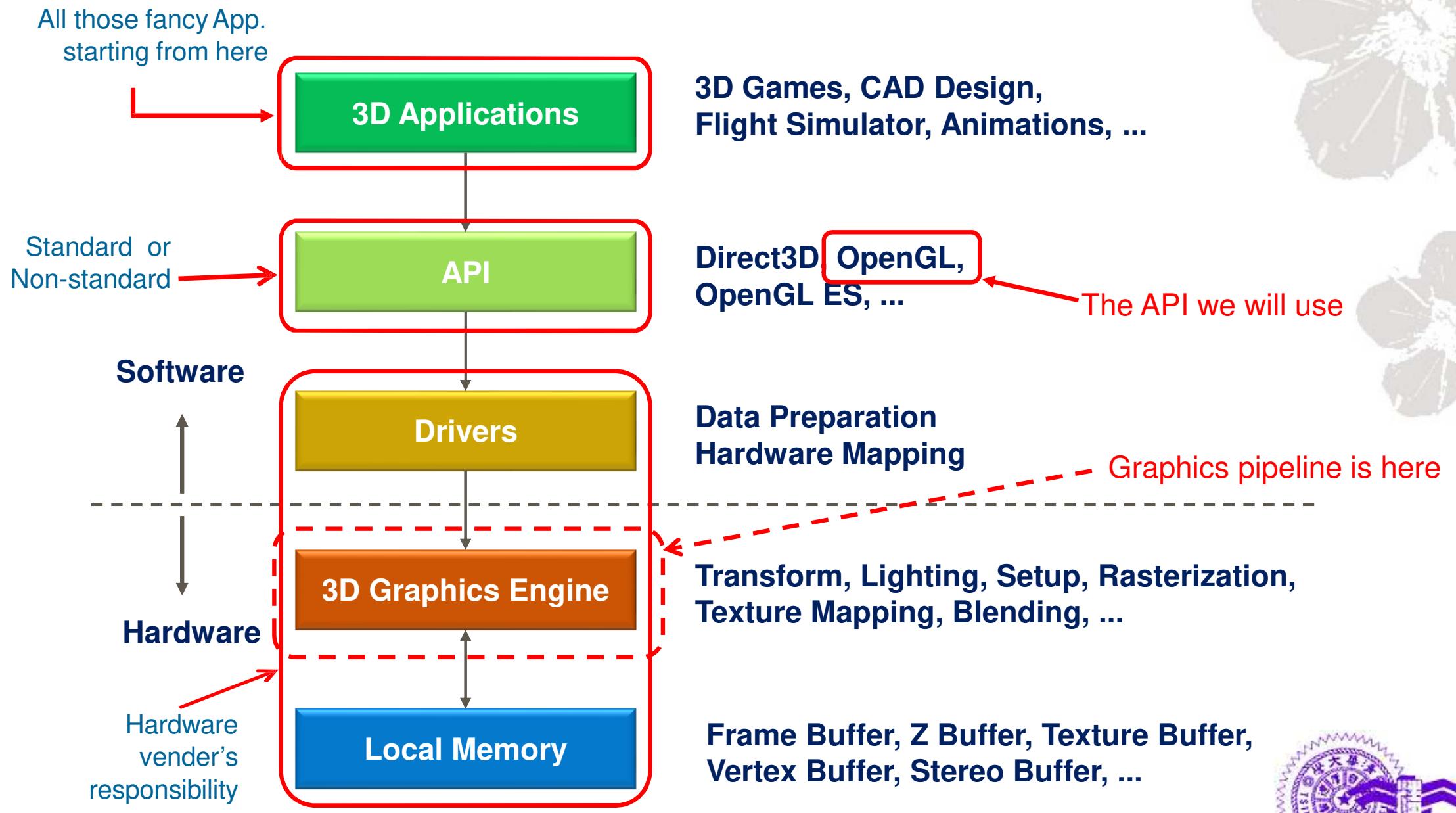


Video Games

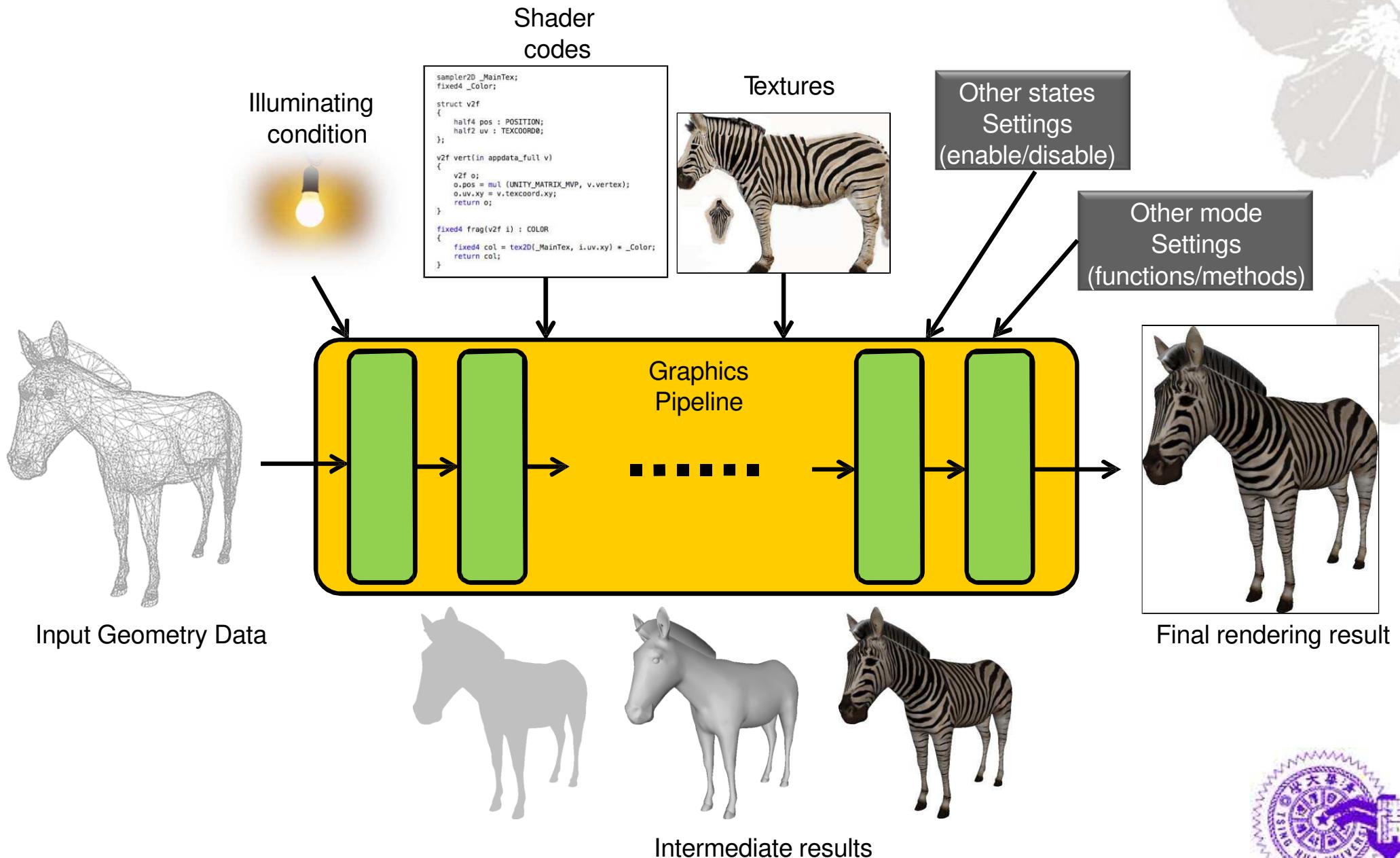


Photo
Browser

Graphics Rendering Process



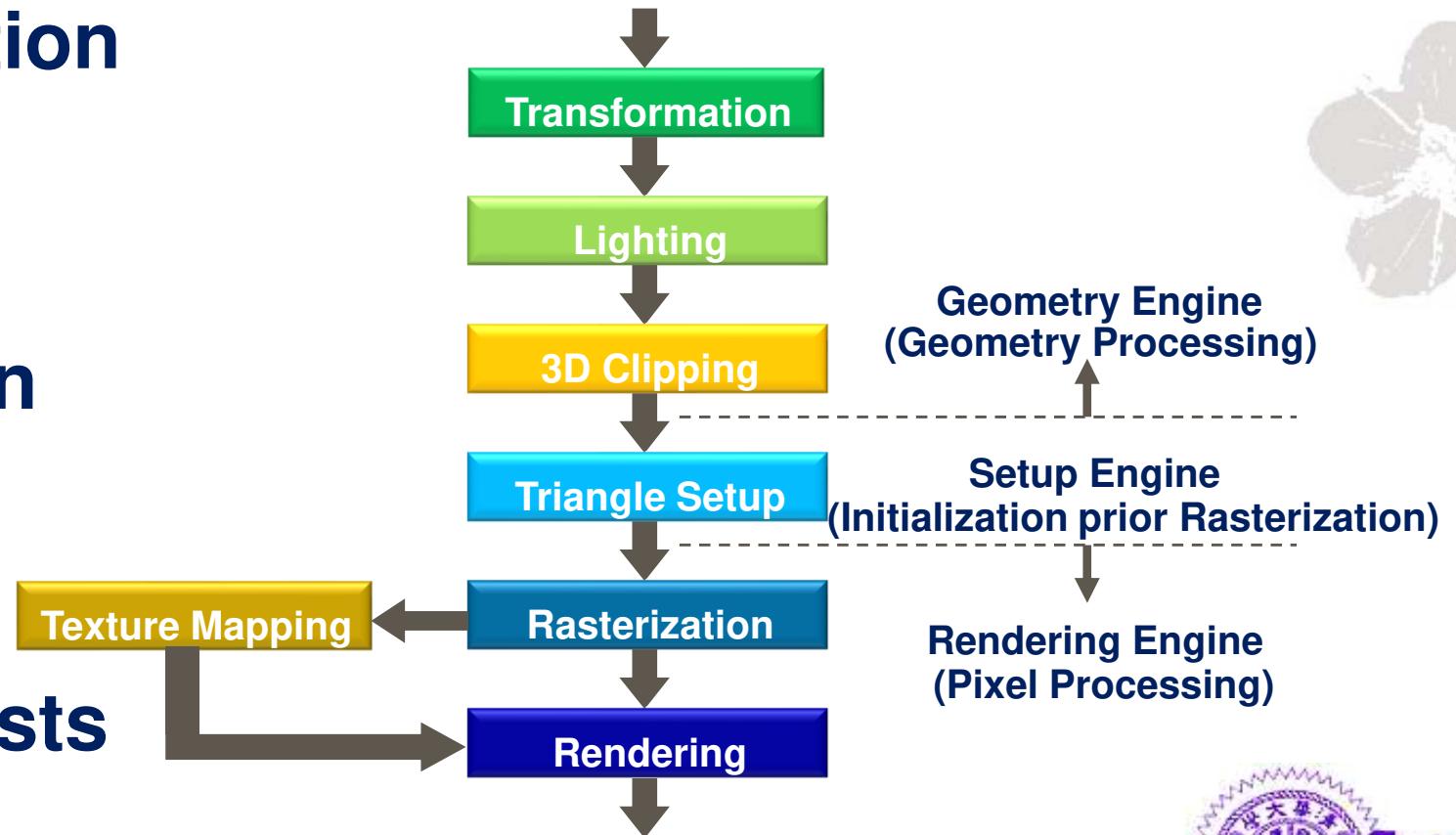
Basic 3D Graphics Programming



Inside a 3D Graphics Pipeline

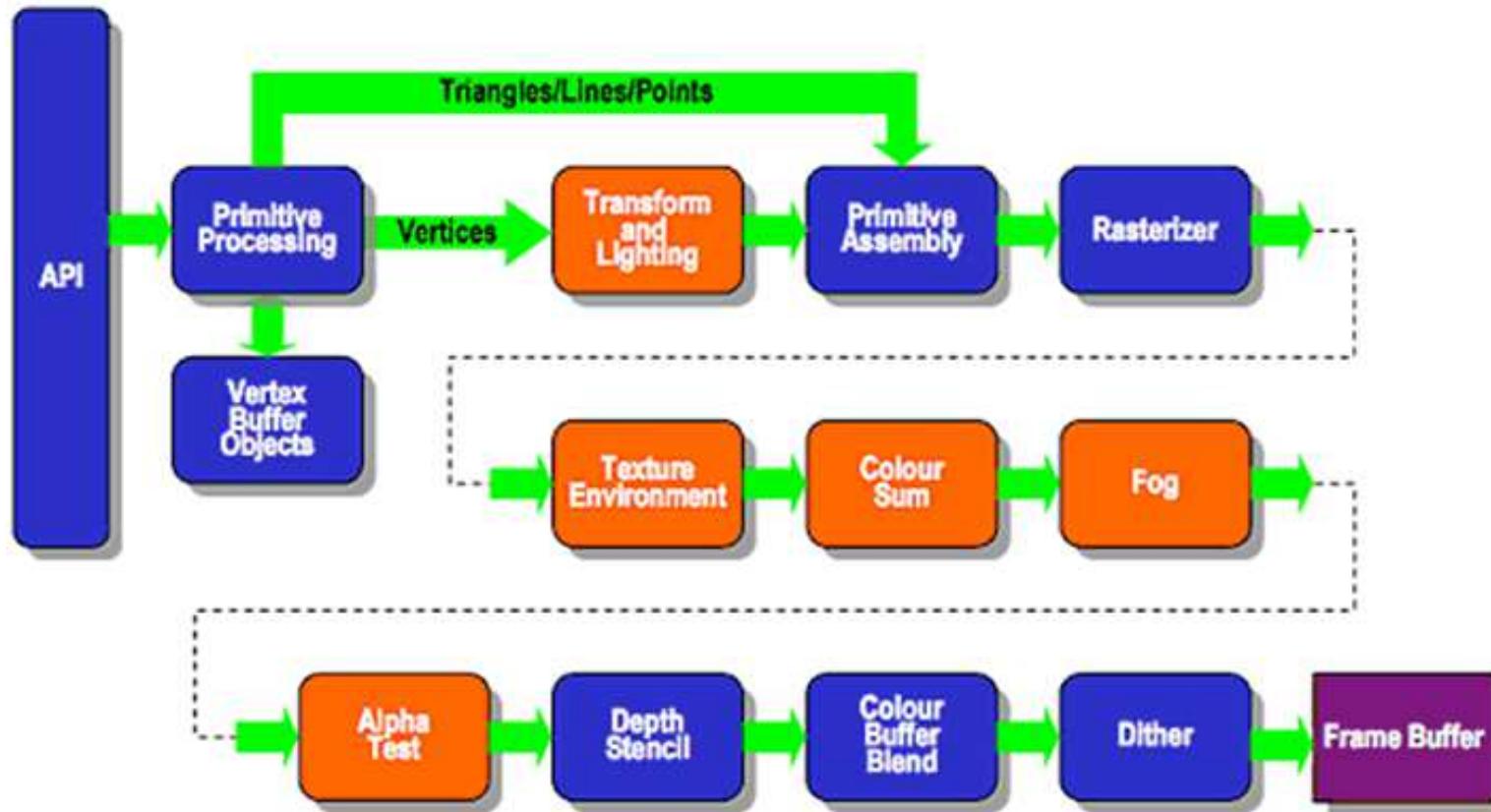
- ◆ A pipeline consisting of several modules to accomplish the 3D rendering tasks

- Transformation
- Lighting
- Setup
- Rasterization
- Texturing
- Blending
- Fragment tests
- Shaders



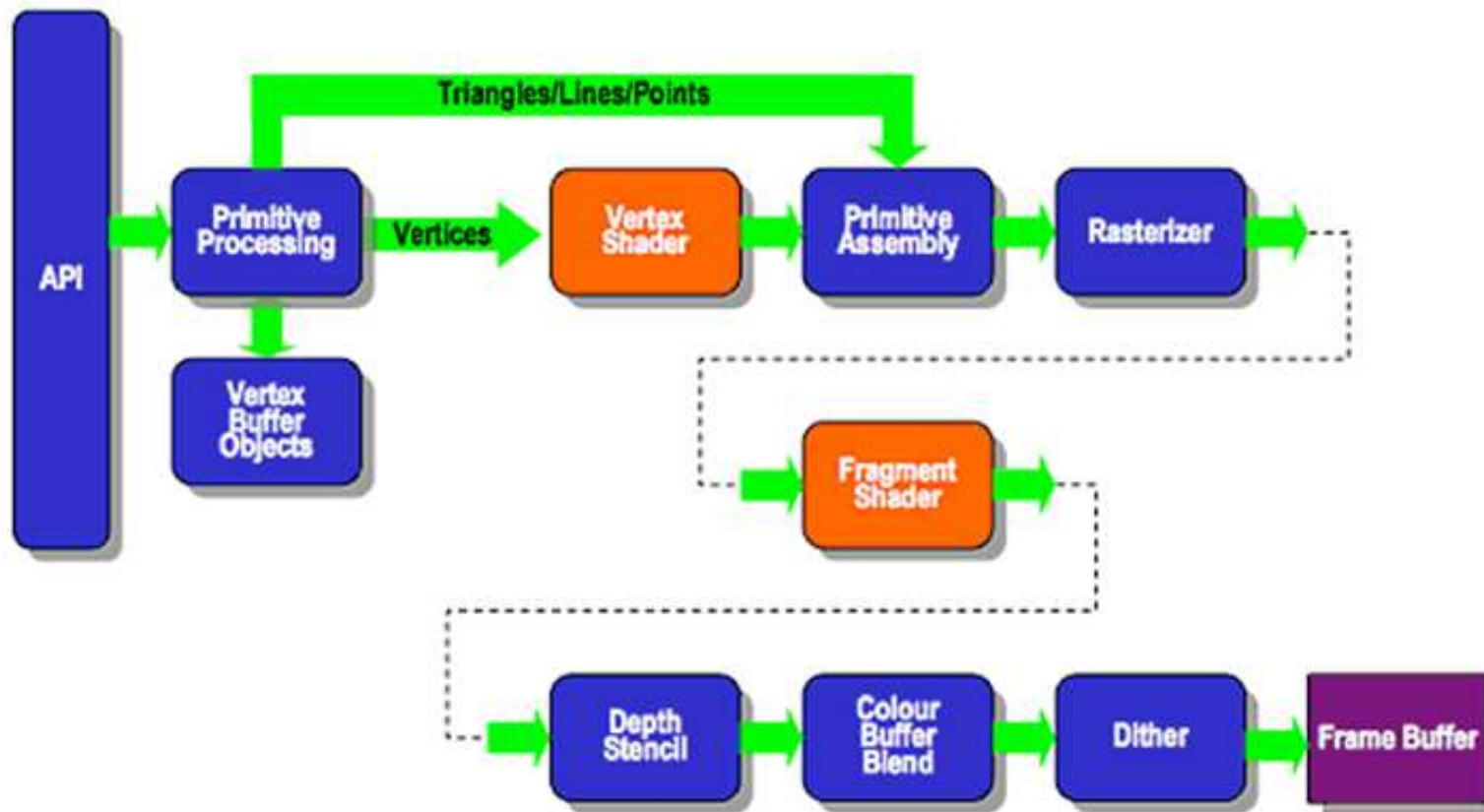
Example of a 3D Graphics Pipeline

- ◆ OpenGL ES v1.1 (fixed function pipeline)

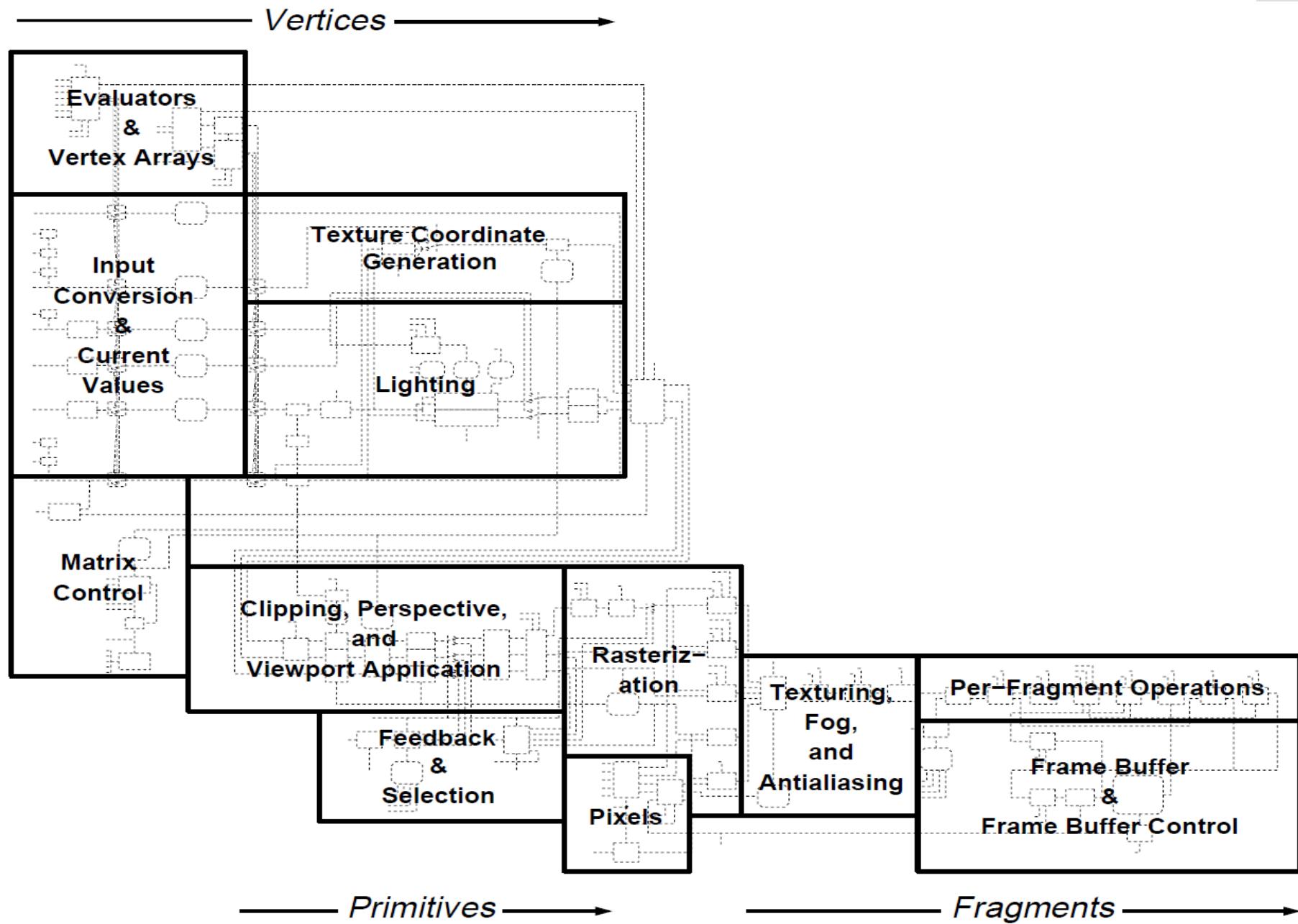


Example of a 3D Graphics Pipeline

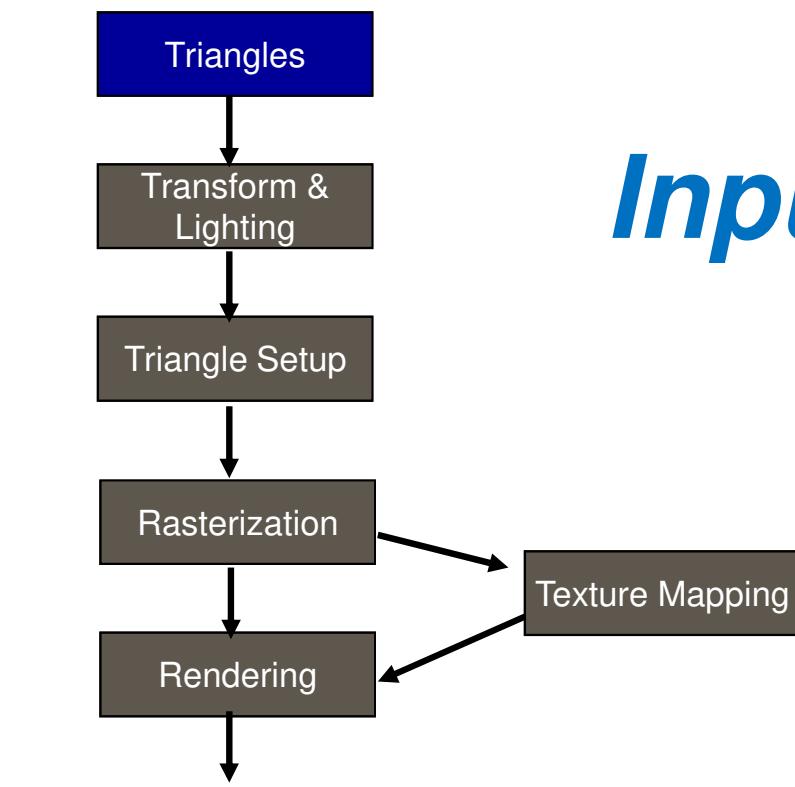
- ◆ OpenGL ES v2.0 (programmable pipeline)



OpenGL 3D Graphics Pipeline (v1.1)



Preview of a 3D Graphics Pipeline



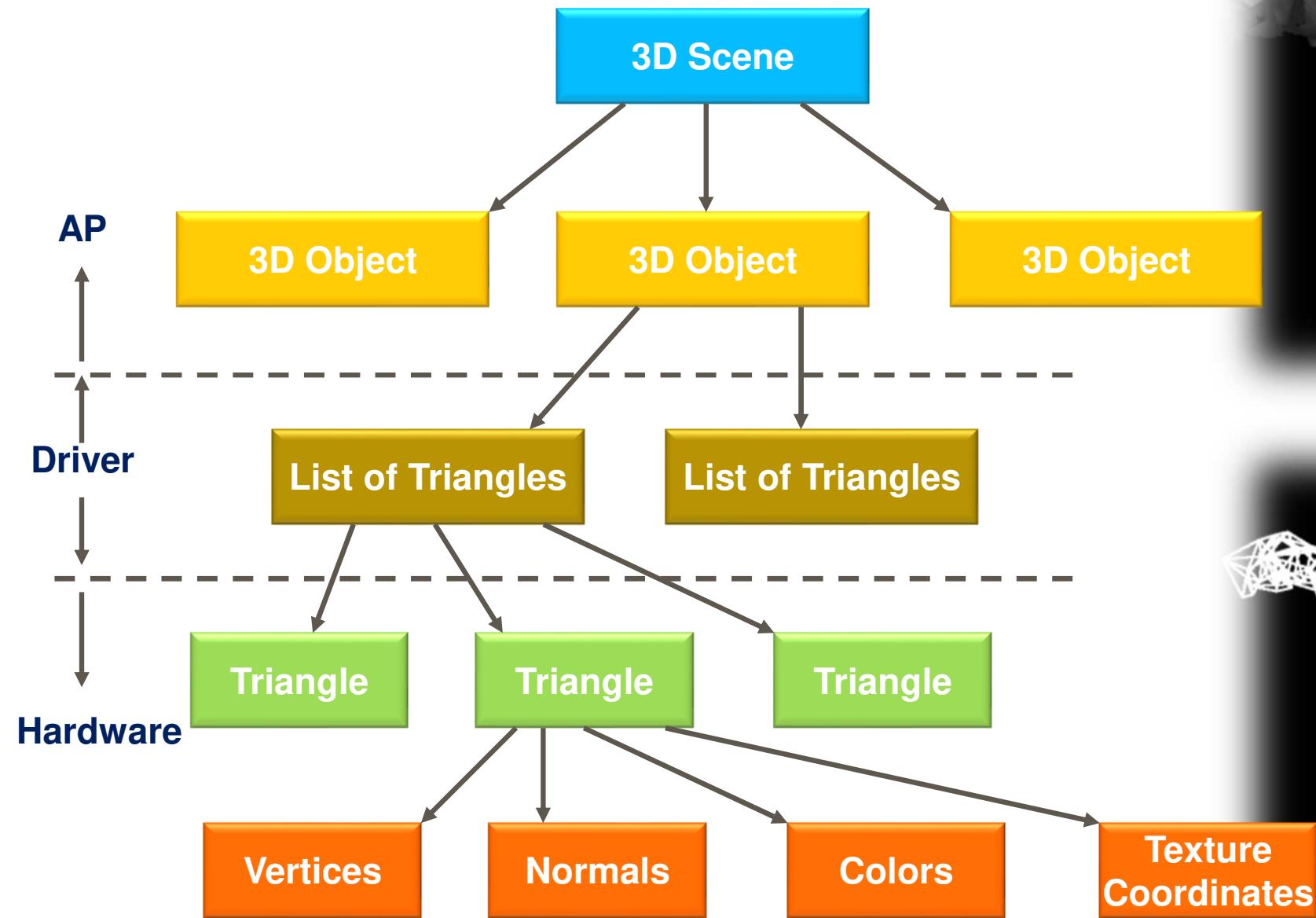
Input Triangles

Conventional 3D Graphics Pipeline

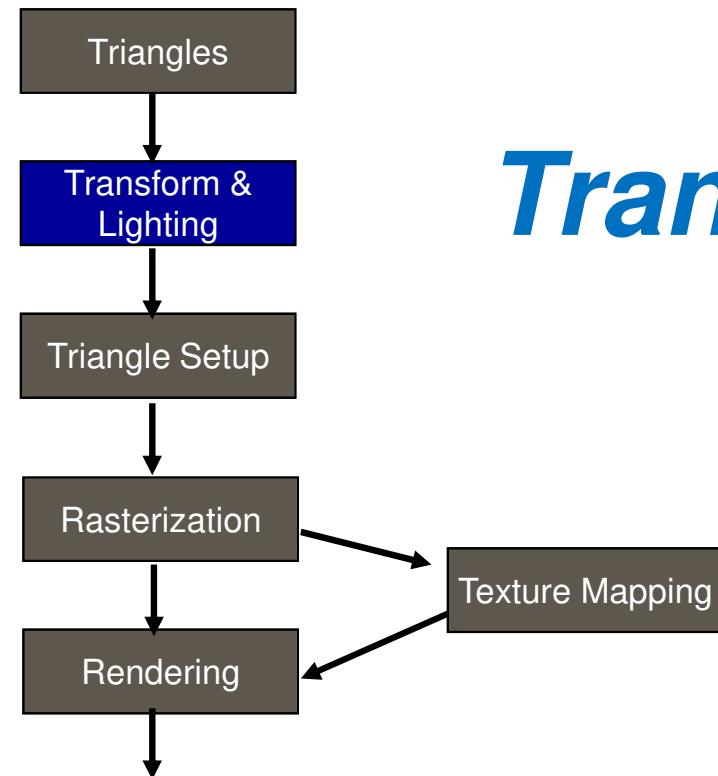
**Vertices
Attributes**



Modeling



Preview of a 3D Graphics Pipeline



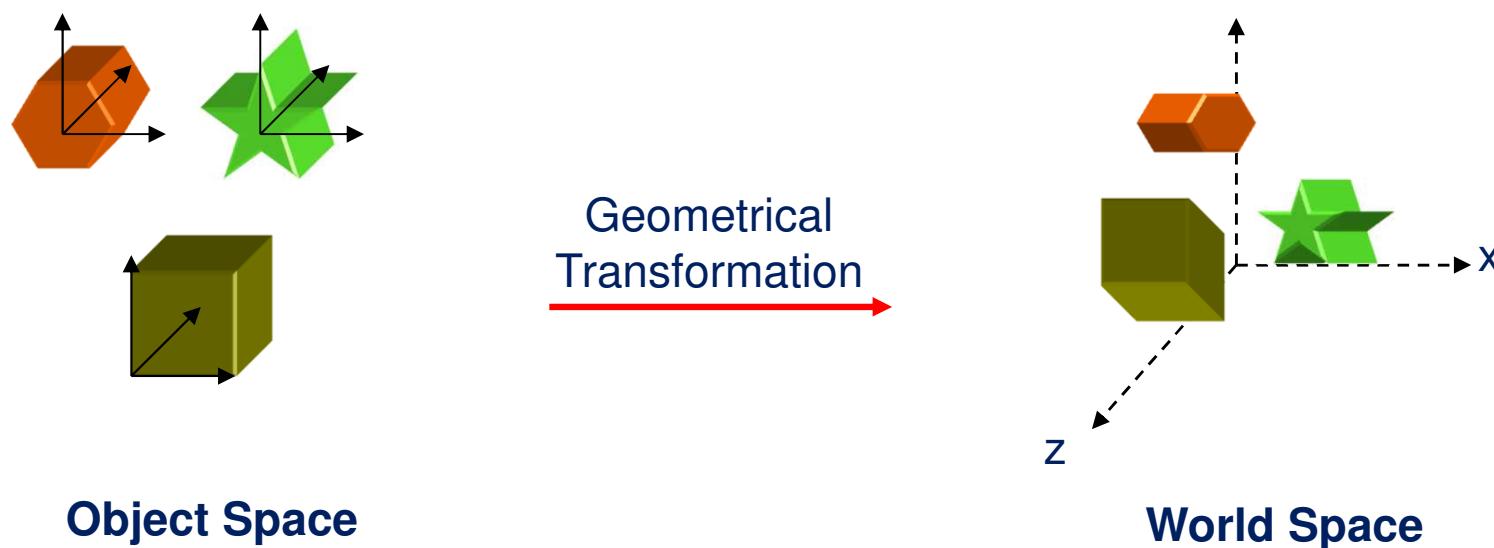
Transformations

Geometrical transformations
Viewing transformations



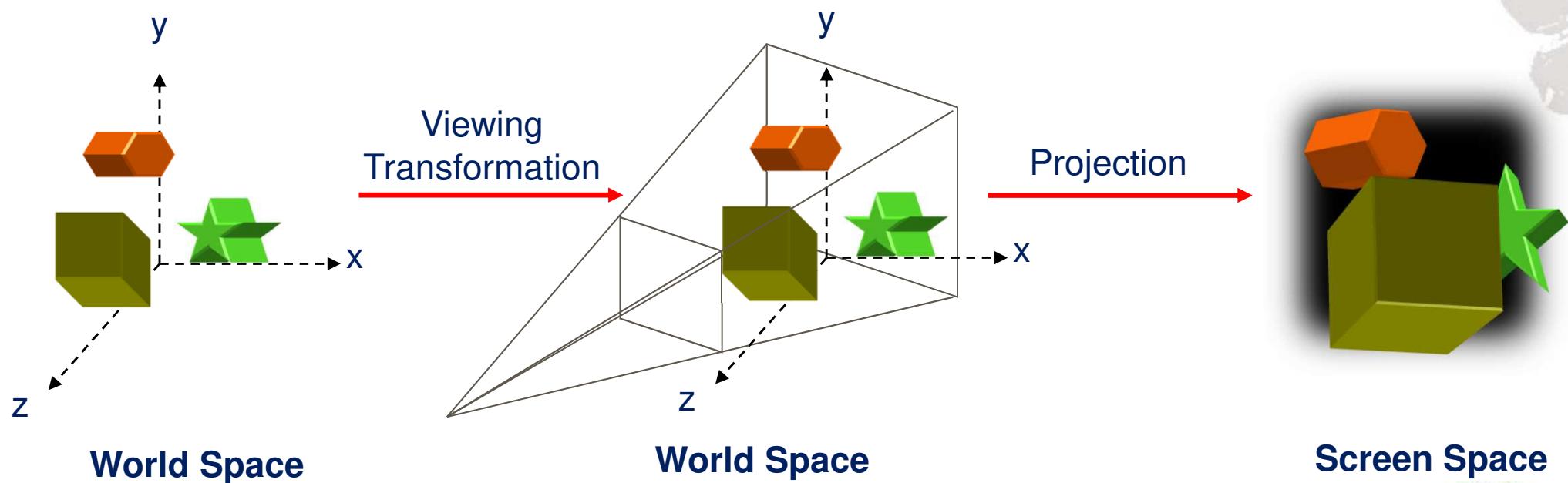
Transformation

- ◆ Geometrical Transformation
 - From Object Space to World Space

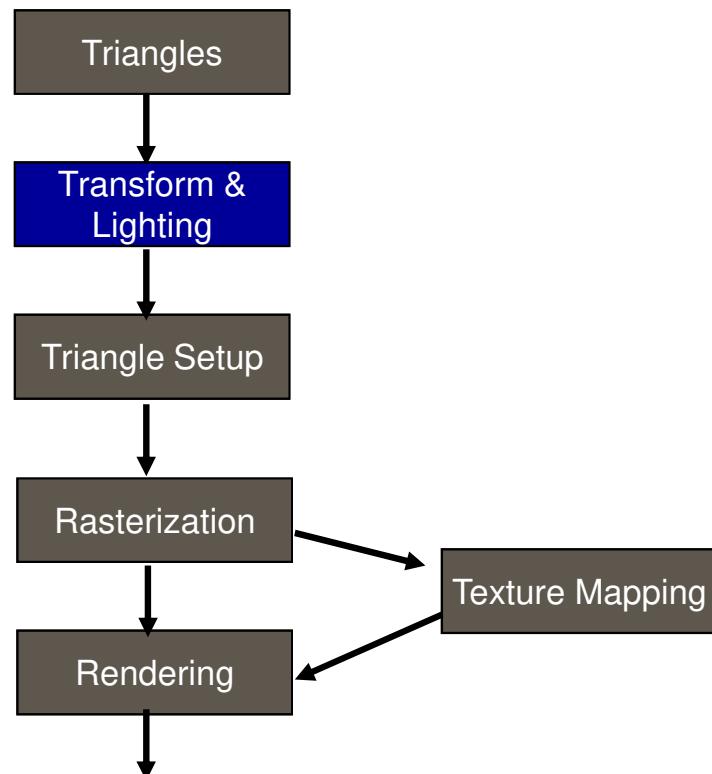
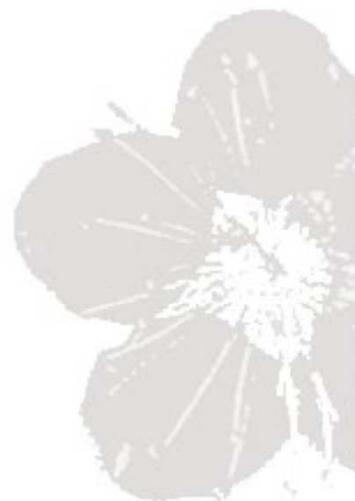


Transformation

- ◆ Viewing Transformation
 - From World Space to Screen Space



Preview of a 3D Graphics Pipeline



Lighting

Illumination model



Lighting

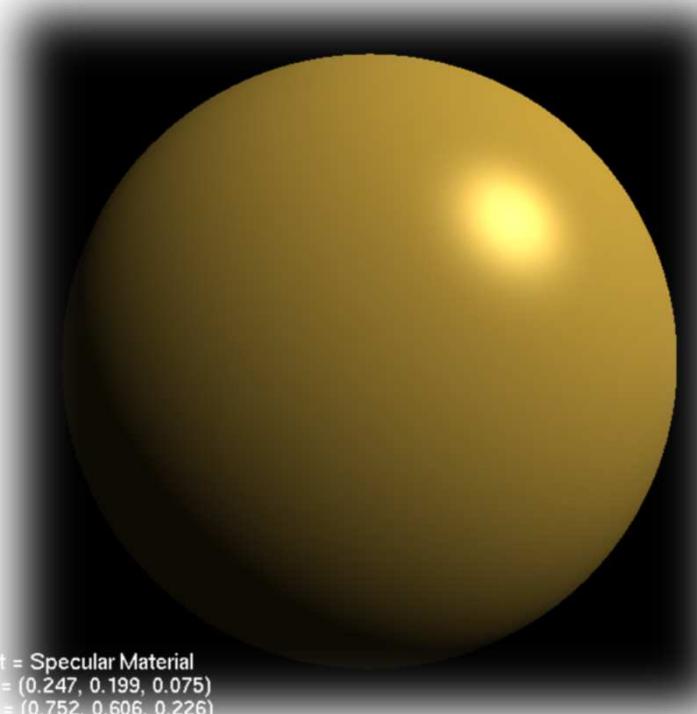
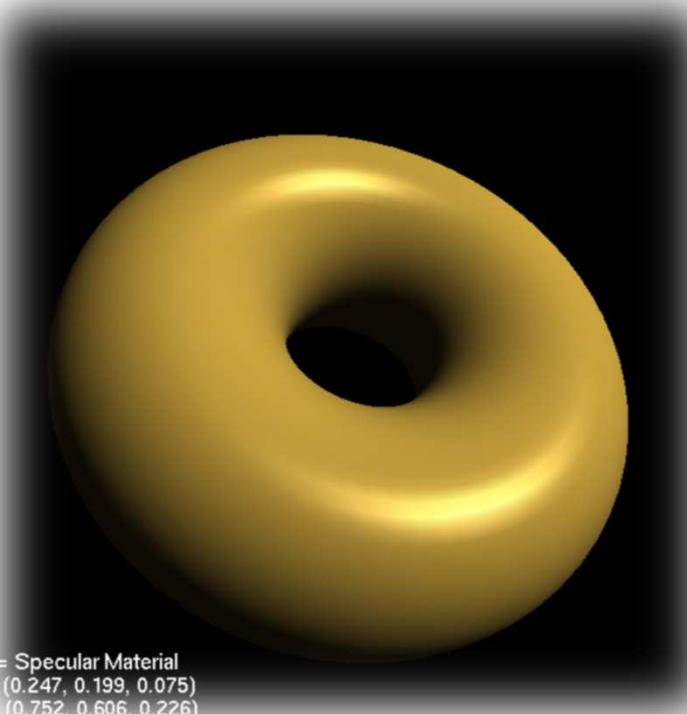
- ◆ Simulate the Effect of Light-Object Interaction



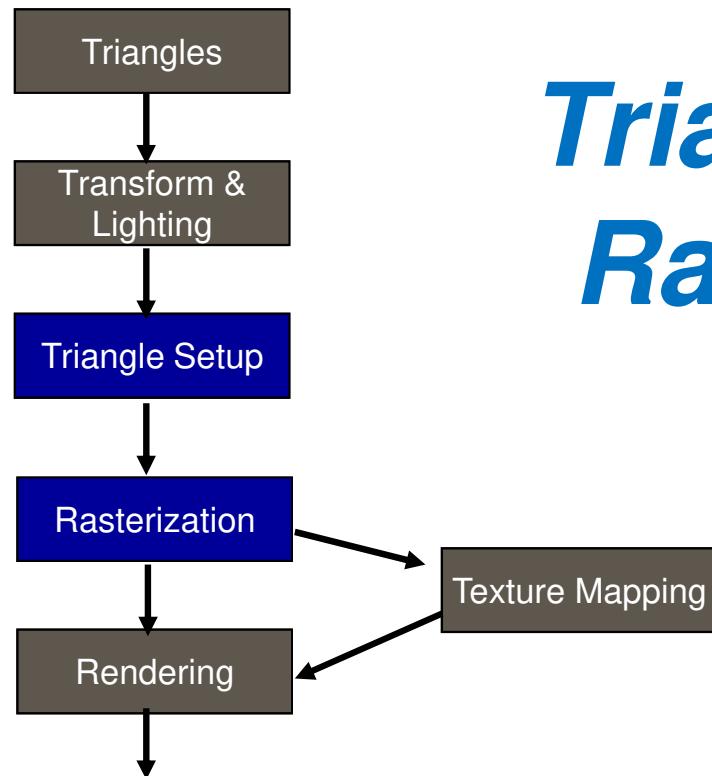
by Gilles Tran

Lighting

◆ Ambient + Diffuse + Specular Reflection



Preview of a 3D Graphics Pipeline



Triangle Setup and Rasterization

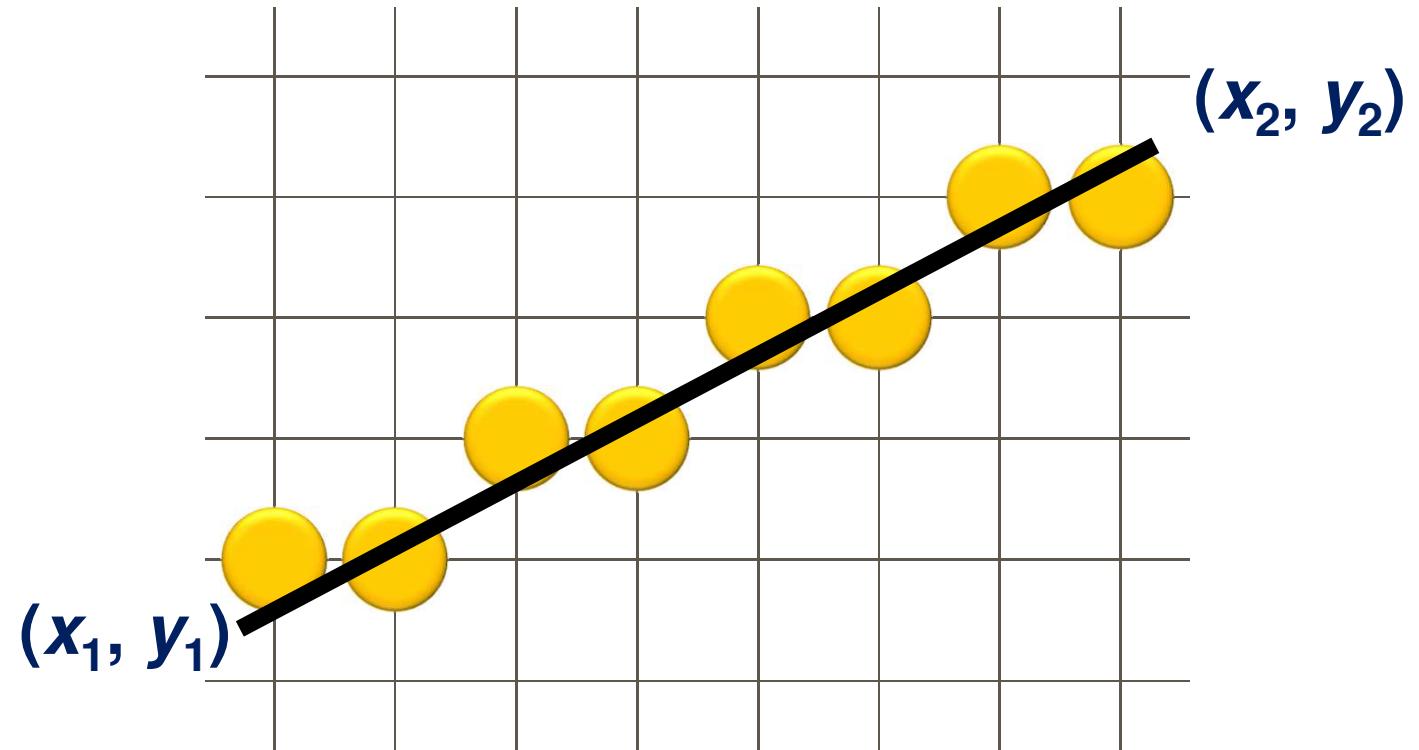
Conventional 3D Graphics Pipeline

*Initial setup
Rasterization*



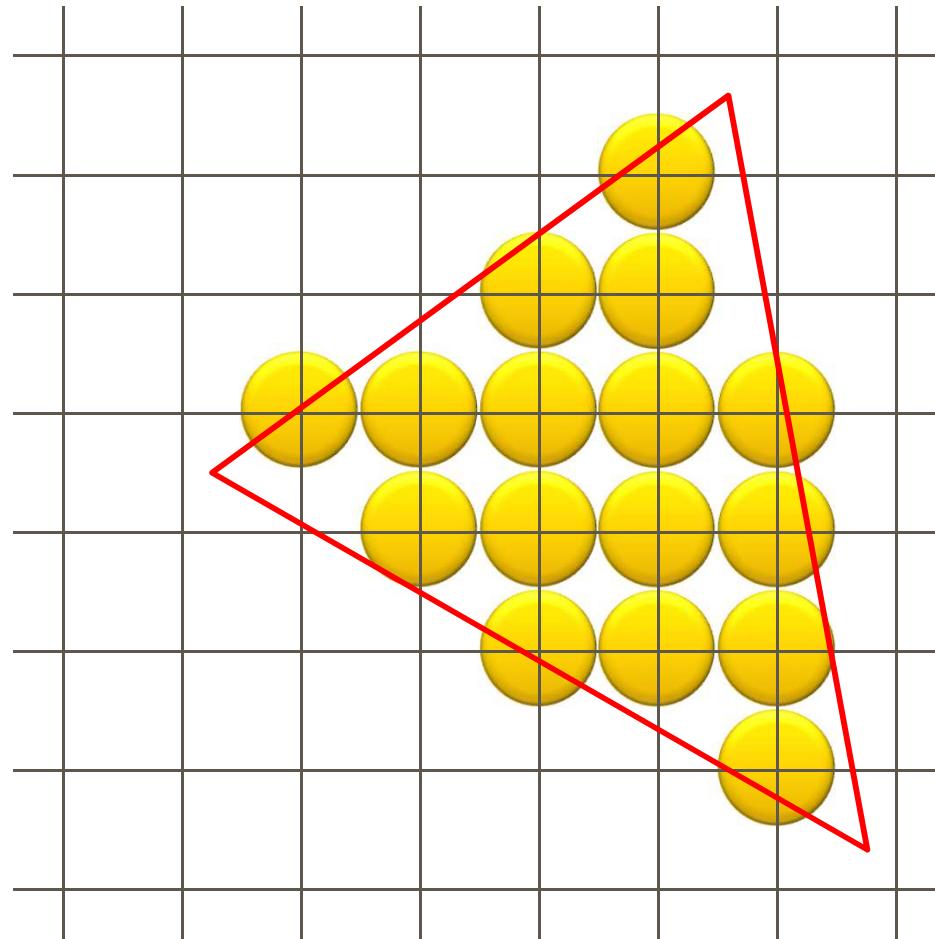
Rasterization

- ◆ Line Rasterization: draw from (x_1, y_1) to (x_2, y_2)

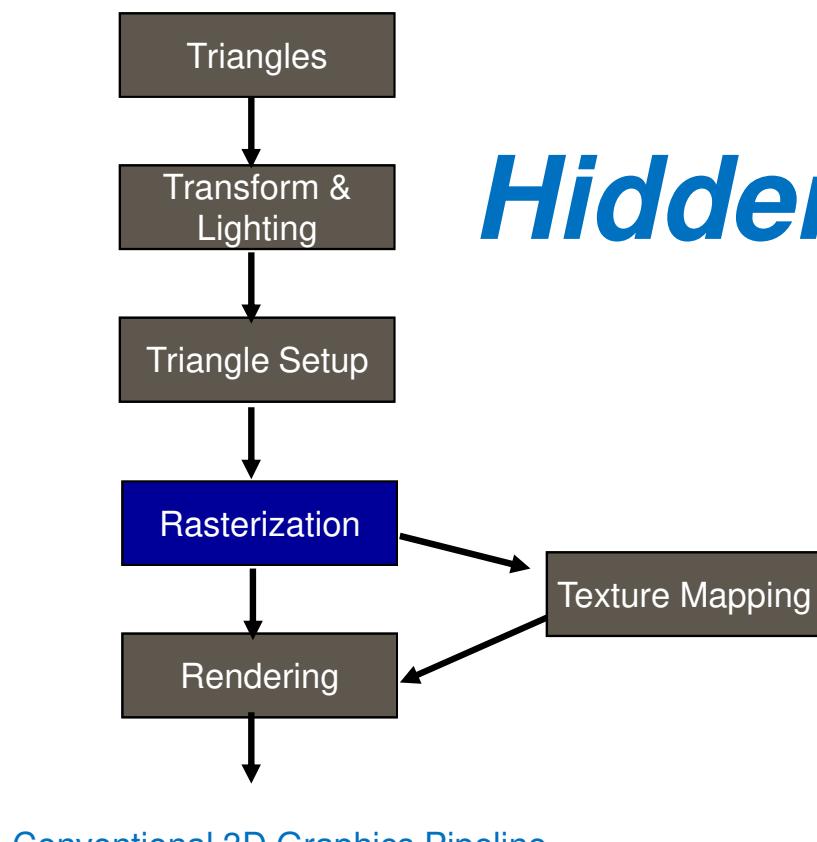


Rasterization

- ◆ Generate Interior Pixels of a Triangle



Preview of a 3D Graphics Pipeline



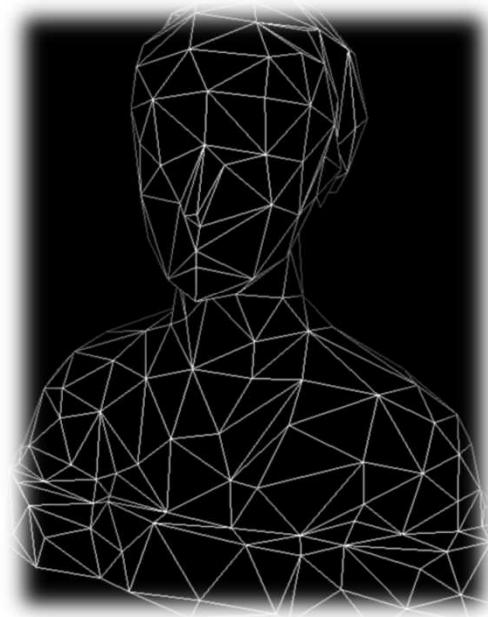
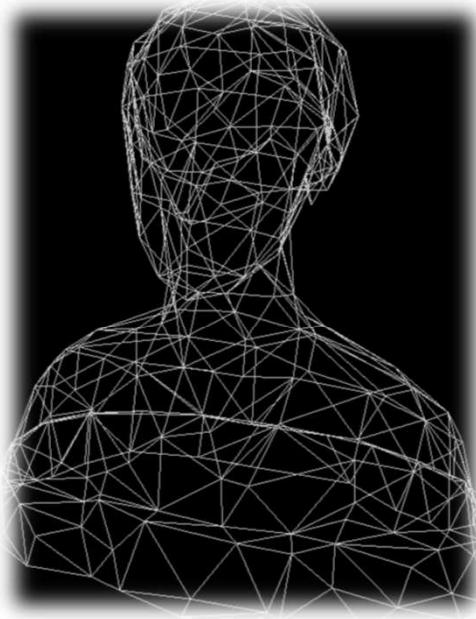
Hidden Surface Removal

Remove hidden pixels / primitives

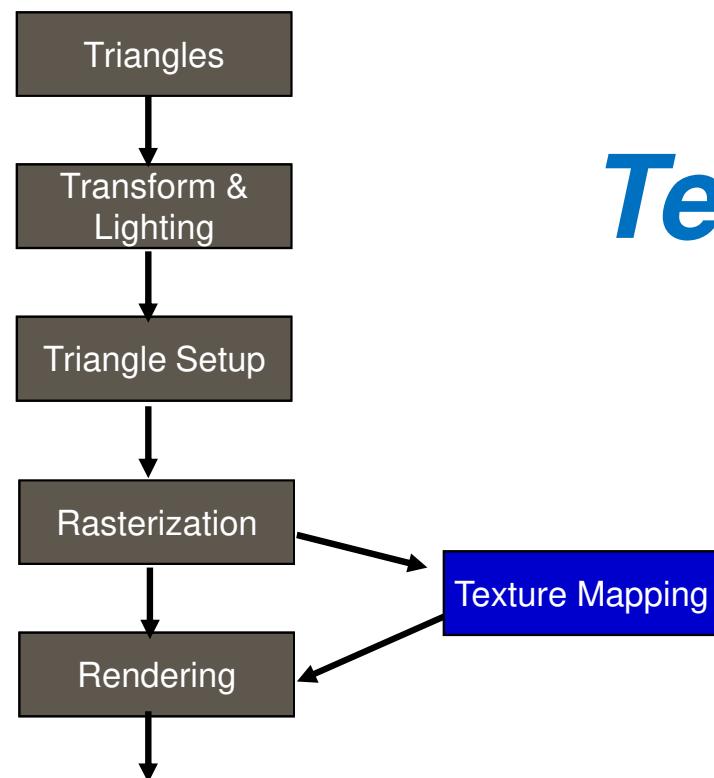
Conventional 3D Graphics Pipeline



Hidden Surface Removal



Preview of a 3D Graphics Pipeline



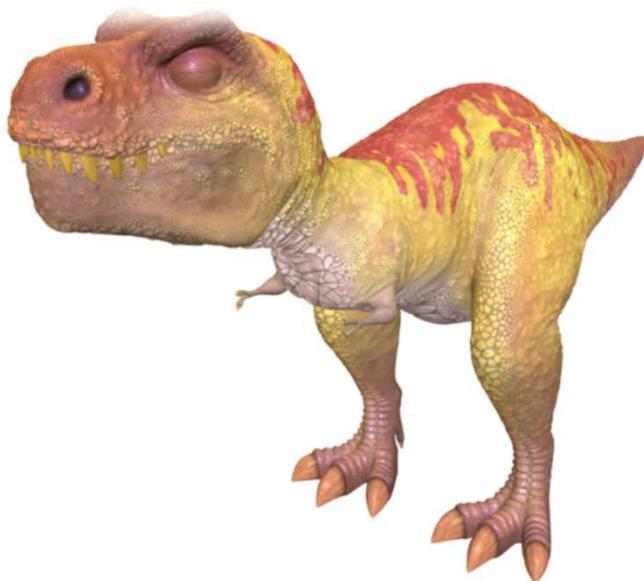
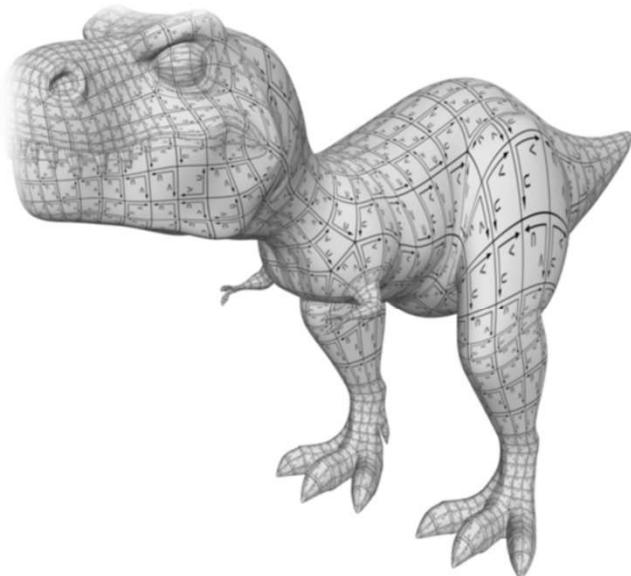
Texture Mapping

Add some detail textures

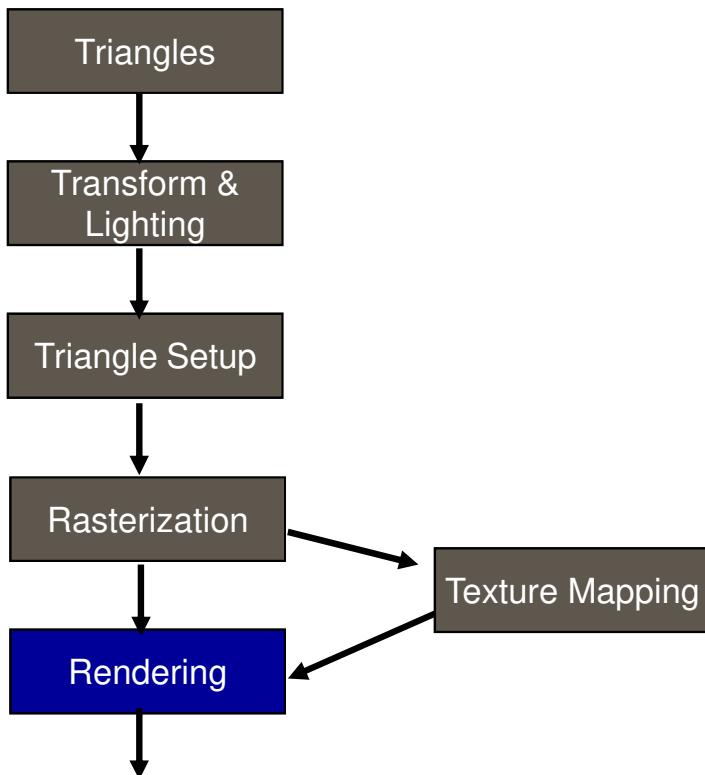


Texture Mapping

- ◆ Adding Realism



Preview of a 3D Graphics Pipeline



Rendering

Color Composition and Blending

Conventional 3D Graphics Pipeline



Color Composition

- ◆ Render with lighting and texturing



Lighting

Texturing

Lighting + Texturing

Blending

◆ Translucent Effect

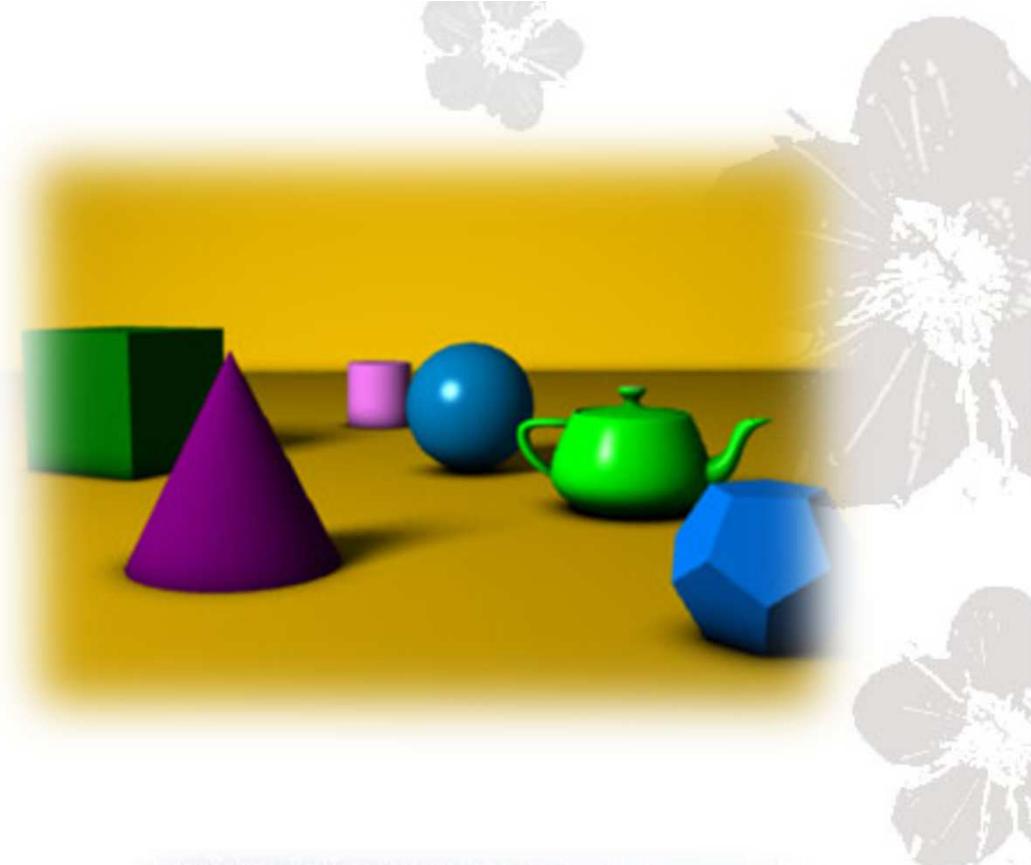
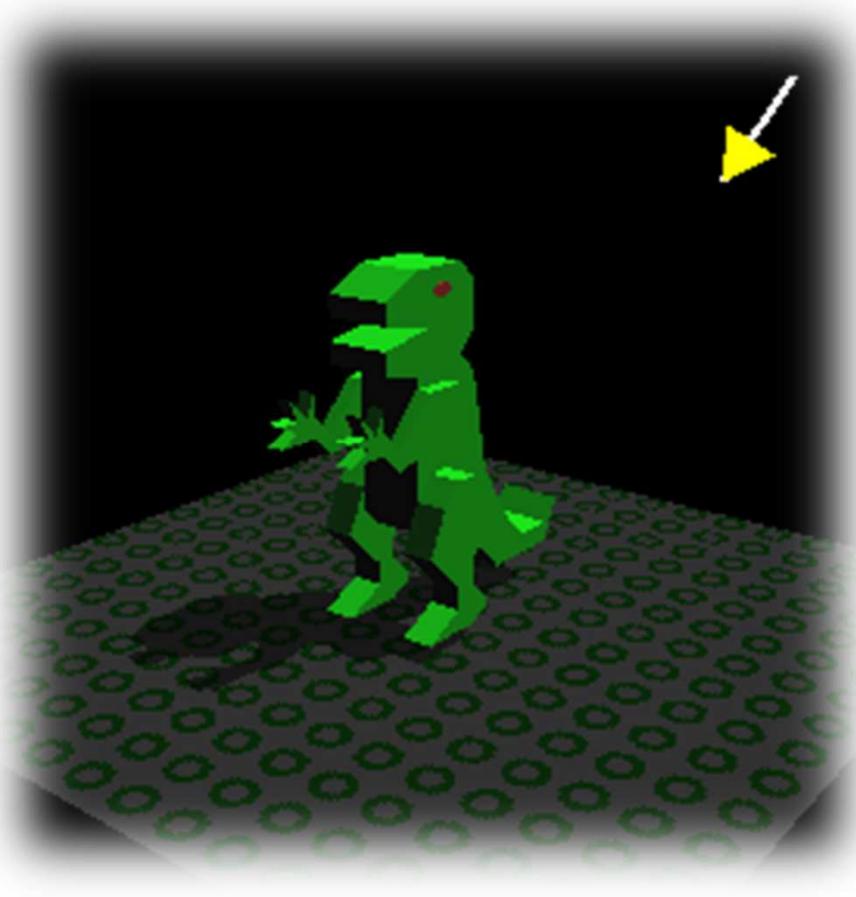


Advanced Features

*Shadow
Anti-aliasing
Shaders*



Shadow



Shadow Volume, Real time shadow, Occlusion culling,...

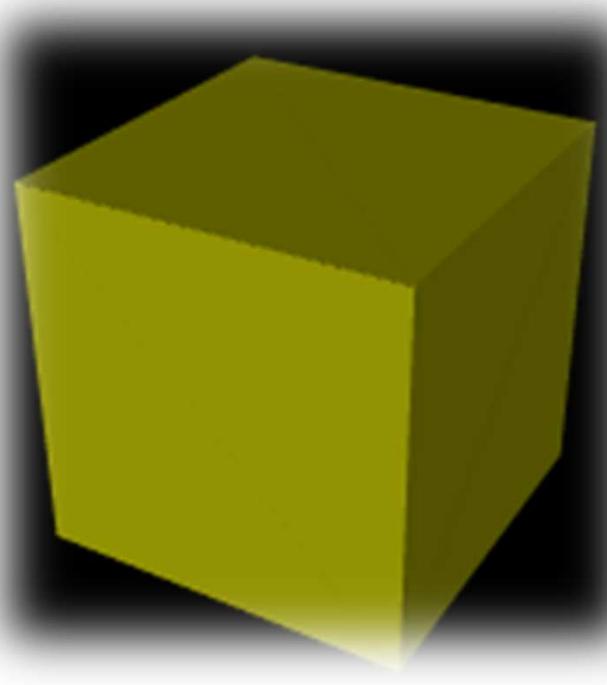
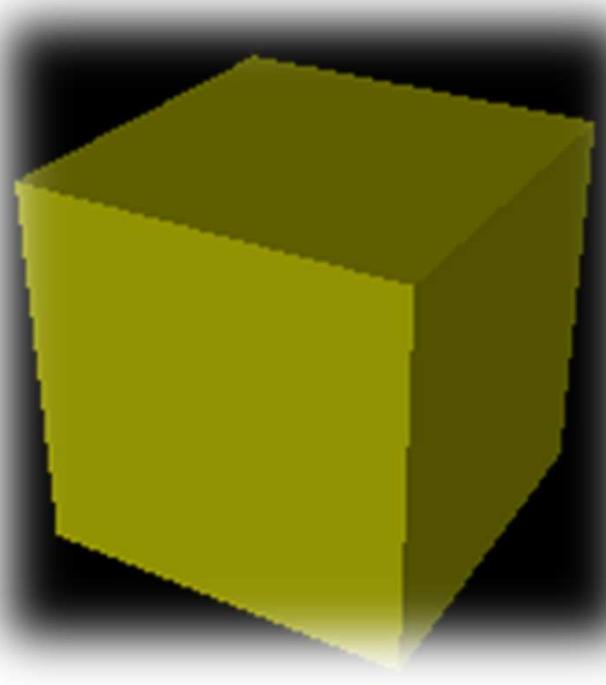
File

54.22 fps (400x300x16) (D24S8)
HAL (hw vp): SiS Compatible VGA

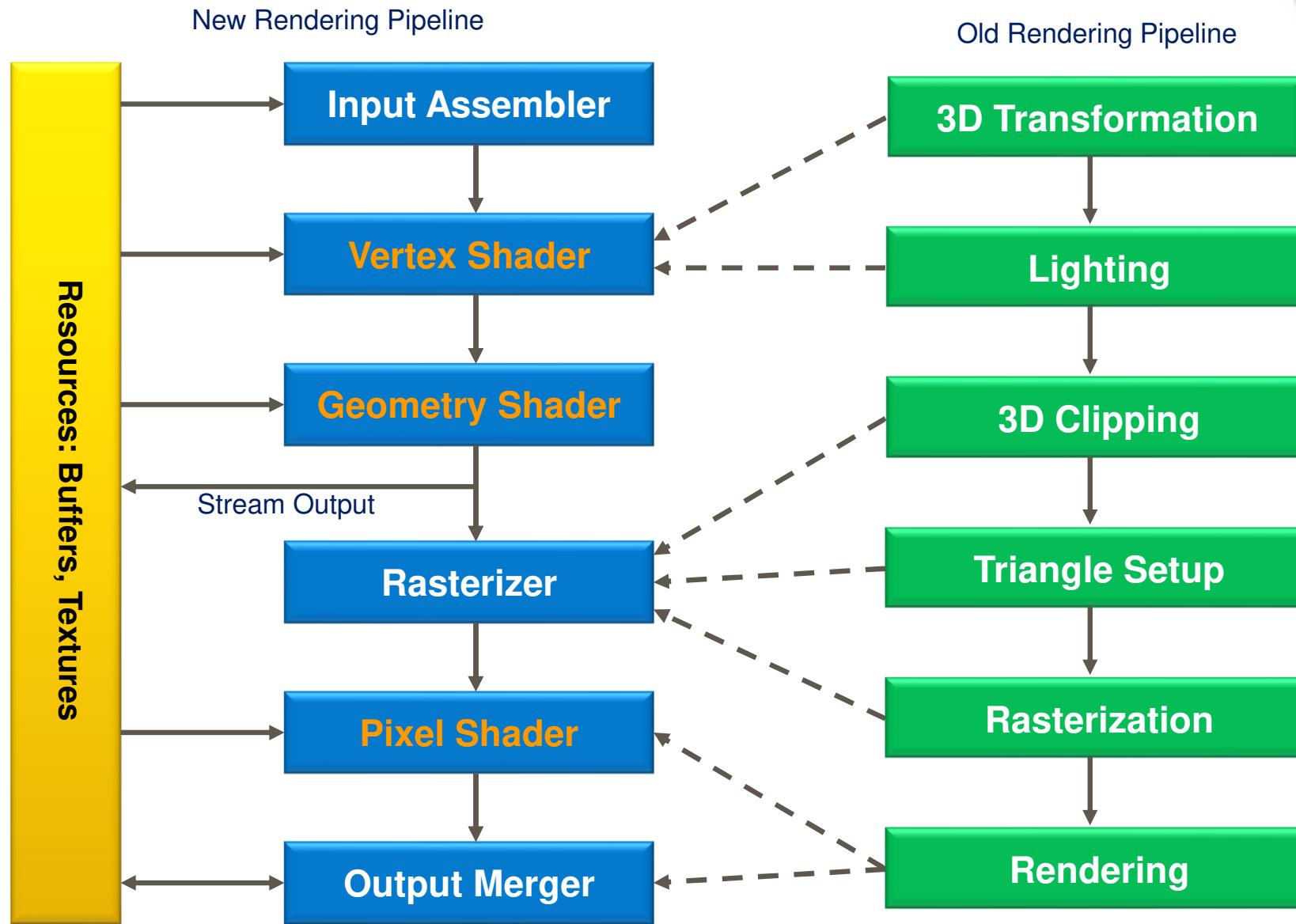


Anti-Aliasing

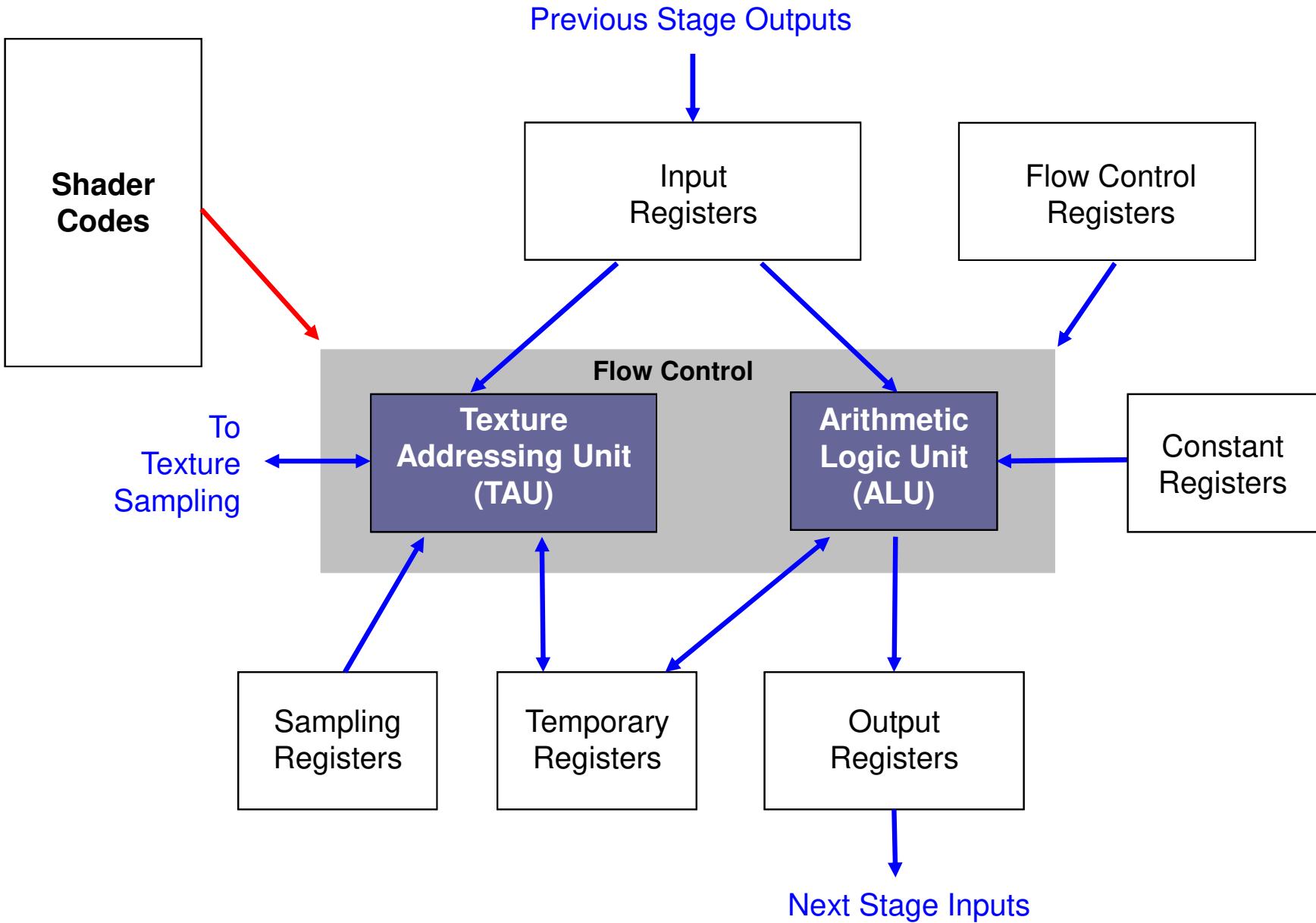
- ◆ Smooth out the Jaggy Edges



New Rendering Pipeline with Shaders

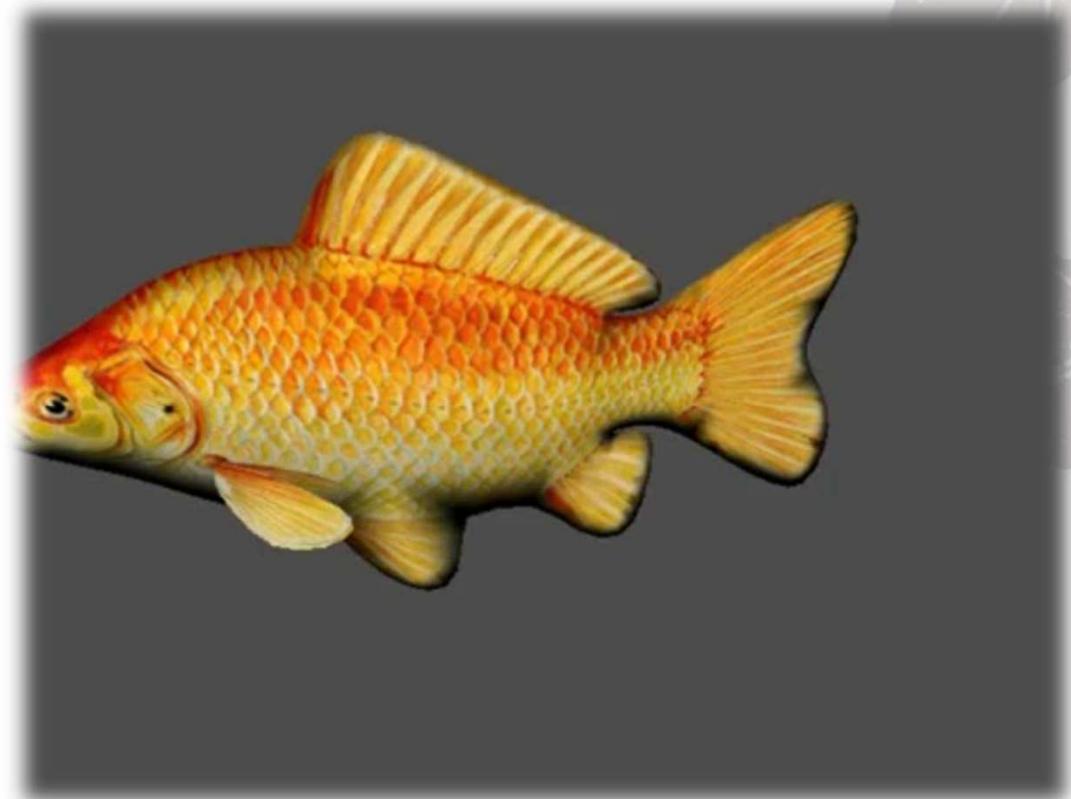


Shader Architecture



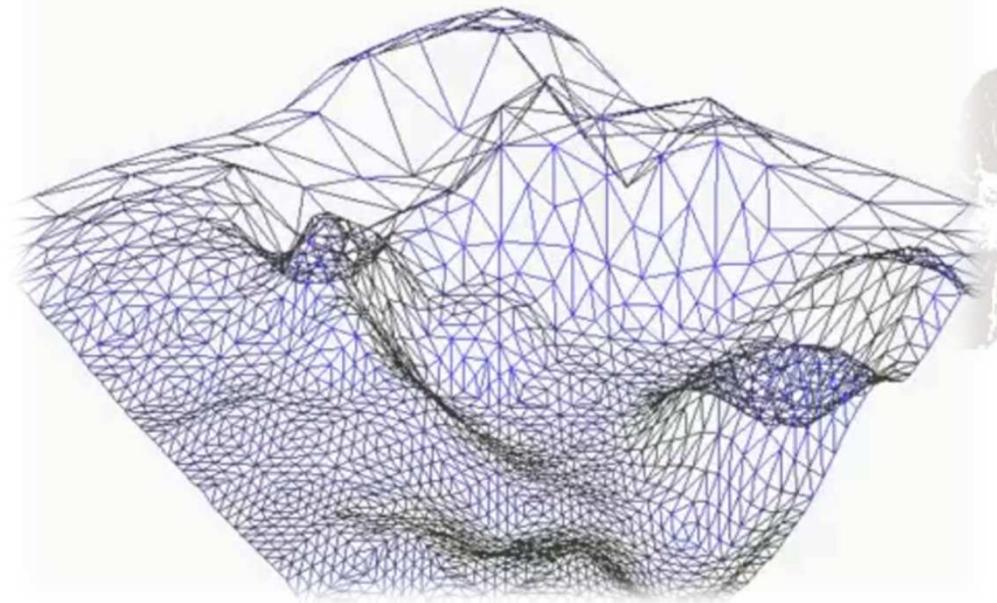
Vertex Shader

- ◆ Processes vertices
 - Transformation
 - Lighting
 - Displacement
- ◆ Operate on a single input vertex and produce a single output vertex



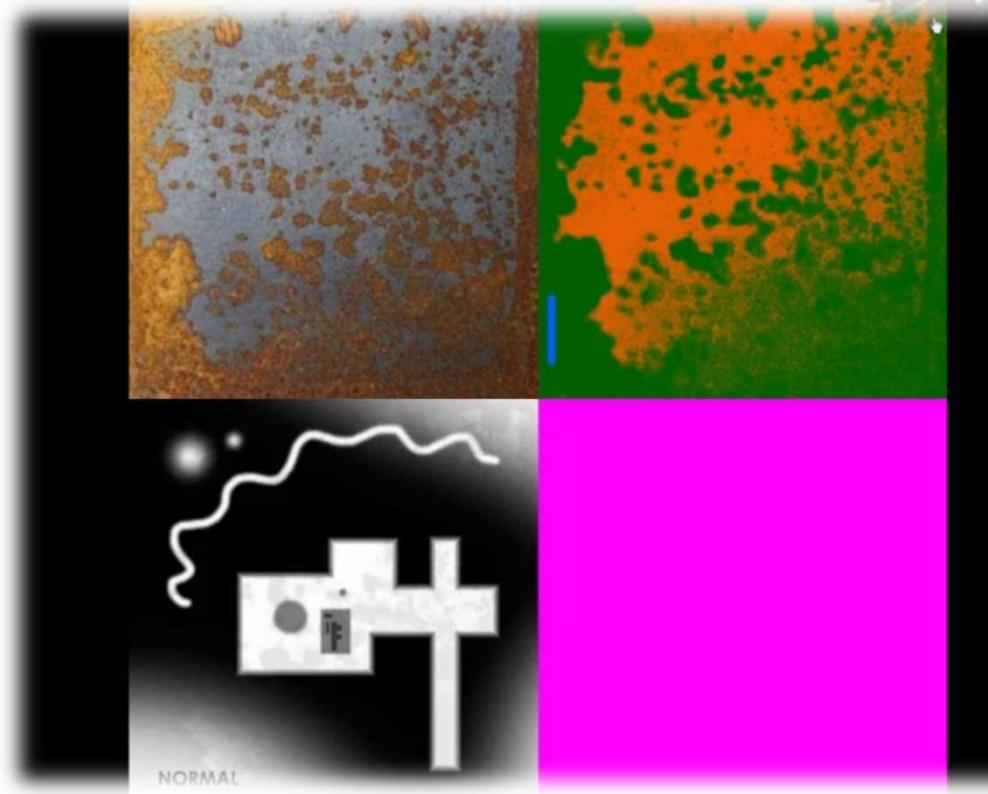
Geometry Shader

- ◆ **Process primitives**
 - Point sprite tessellation
 - Wide line tessellation
 - Shadow volume generation
 - Surface subdivision
- ◆ **Inputs one primitive.
Outputs can be more
than one primitives**



Pixel Shader

- ◆ **Process pixels**
 - **Texture mapping**
 - **Color combine**
 - **Per-pixel lighting**
 - ...
- ◆ **Inputs one pixel.**
Outputs one pixels at same position, or no pixel.



Q&A

