# Introduction to Graphics Programming and its Applications

# 繪圖程式設計與應用

## Syllabus

**Hung-Kuo Chu**

Department of Computer Science

National Tsing Hua University

CS4505

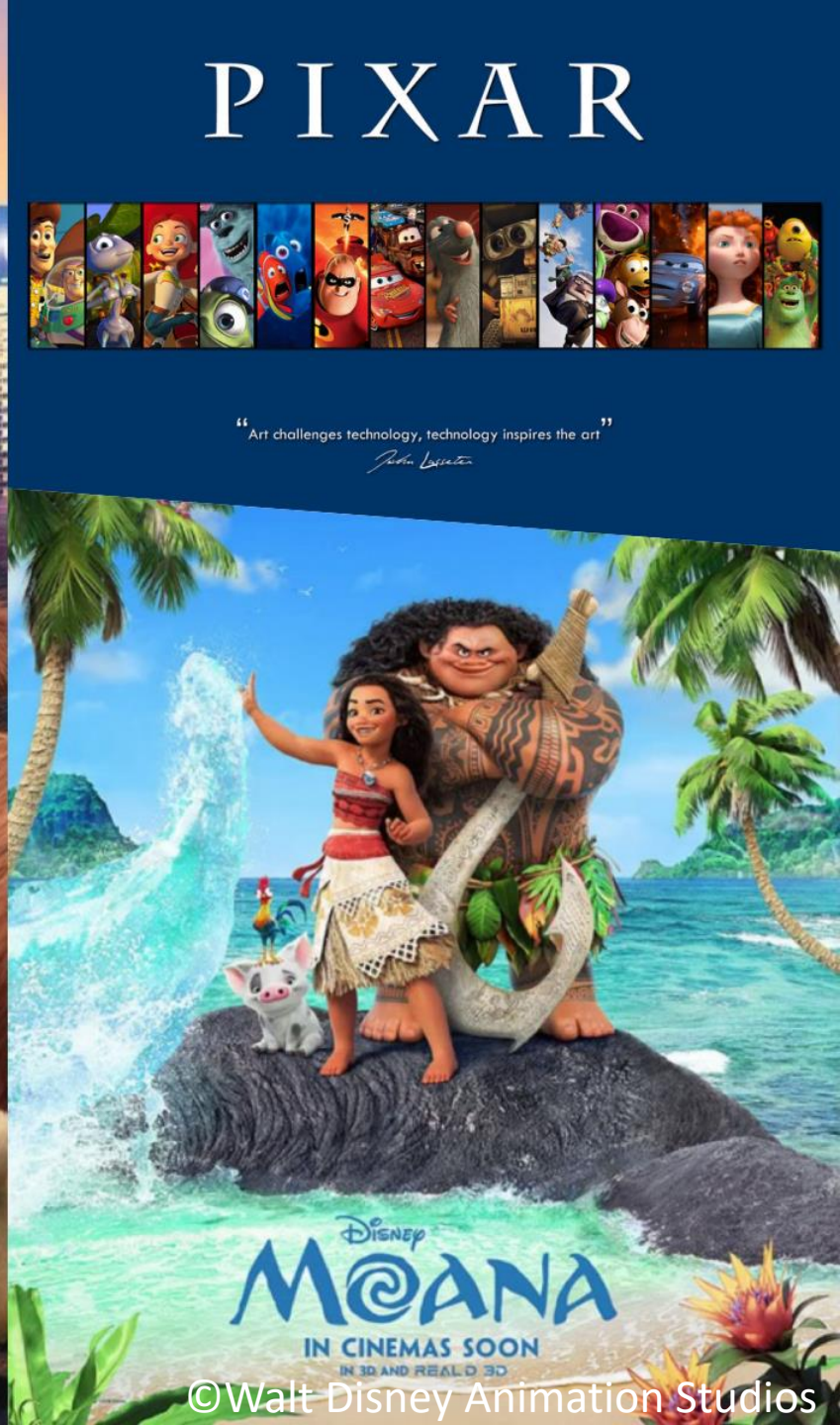
# What is Computer Graphics?




# Game Industry

# Movie Industry

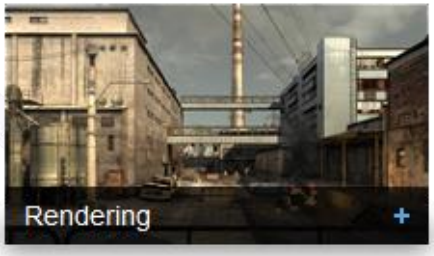

©Illumination Entertainment



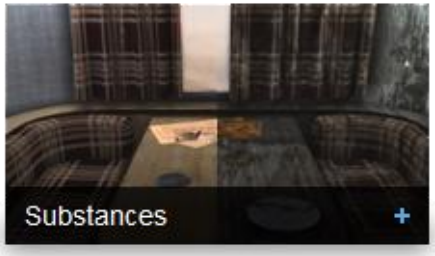

©Walt Disney Animation Studios

# Game Engines

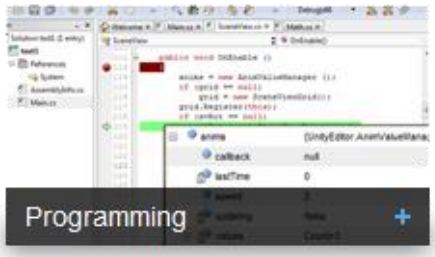










unity 5


Adam

POWERED BY

UNREAL
ENGINE

# Infiltrator

# Virtual Reality

©HTC vive

©Oculus Rift

©Samsung Gear VR

# Augmented Reality


©IKEA

©Pokemon GO

# Mixed Reality



Project Tango
Lenovo

# 3D Authoring Tools

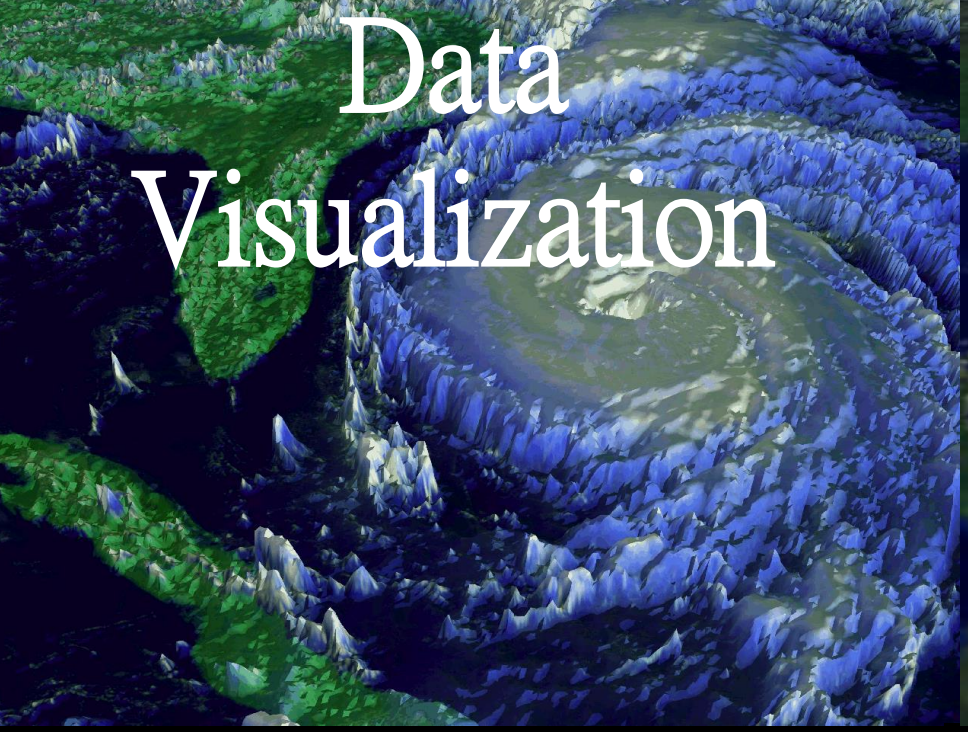

AUTO
Show Reel 2016

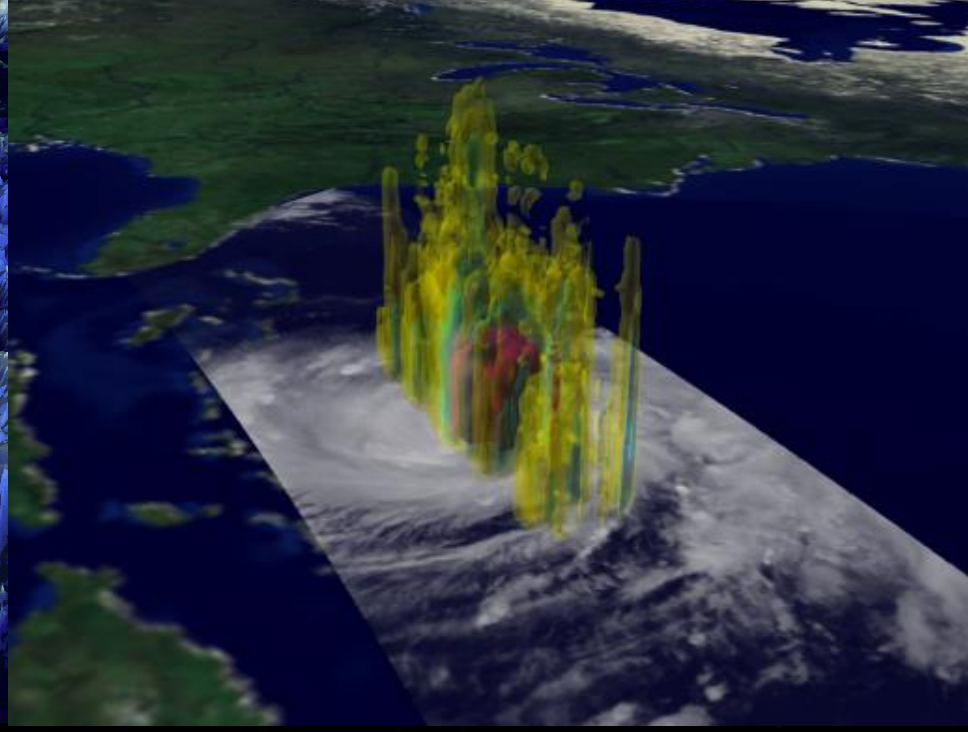

Make Ideas Real
vino
01:15
-00:15

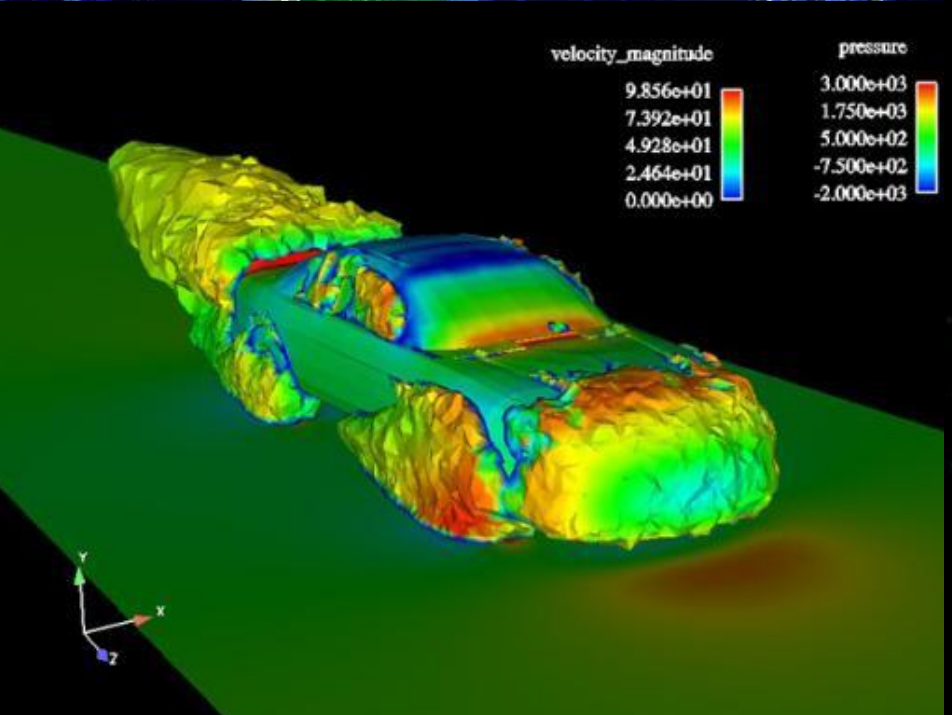

Human Computer Interaction

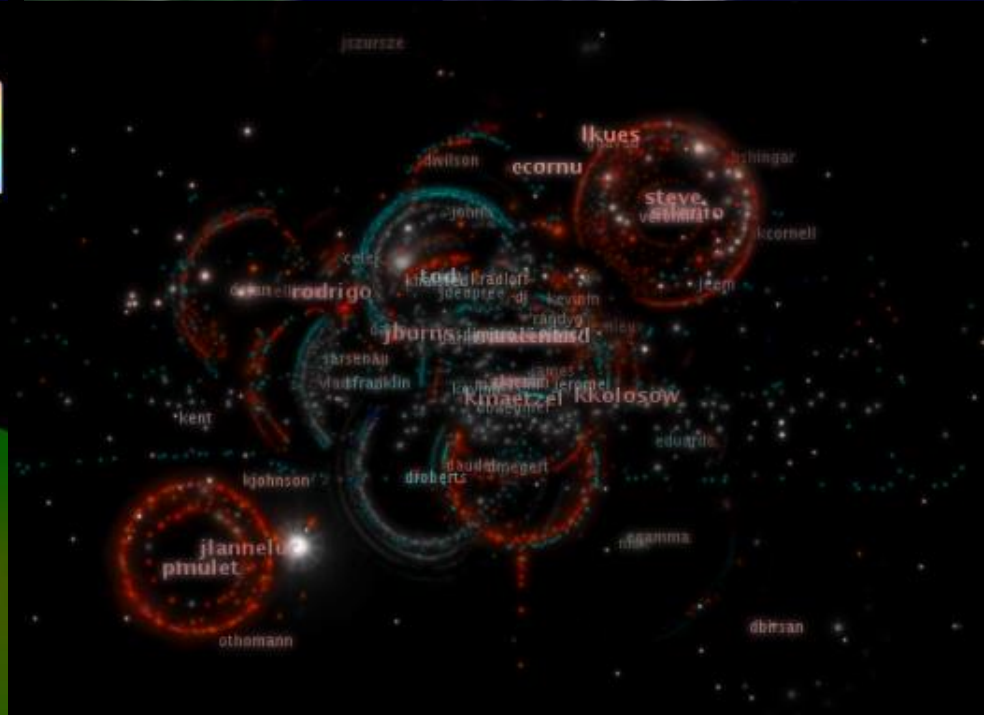
# Medical Image

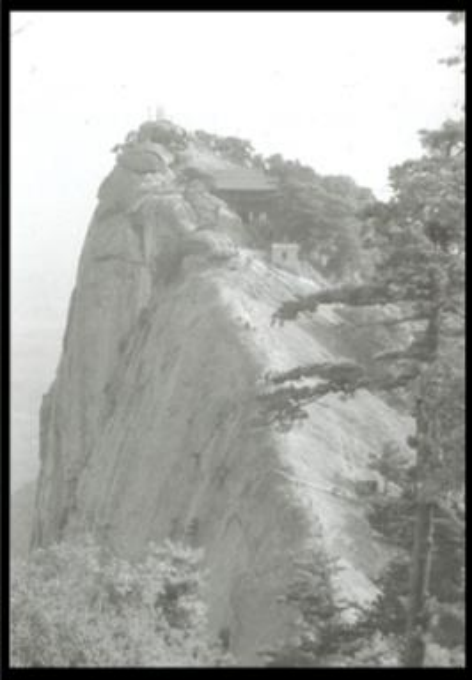
# Data Visualization









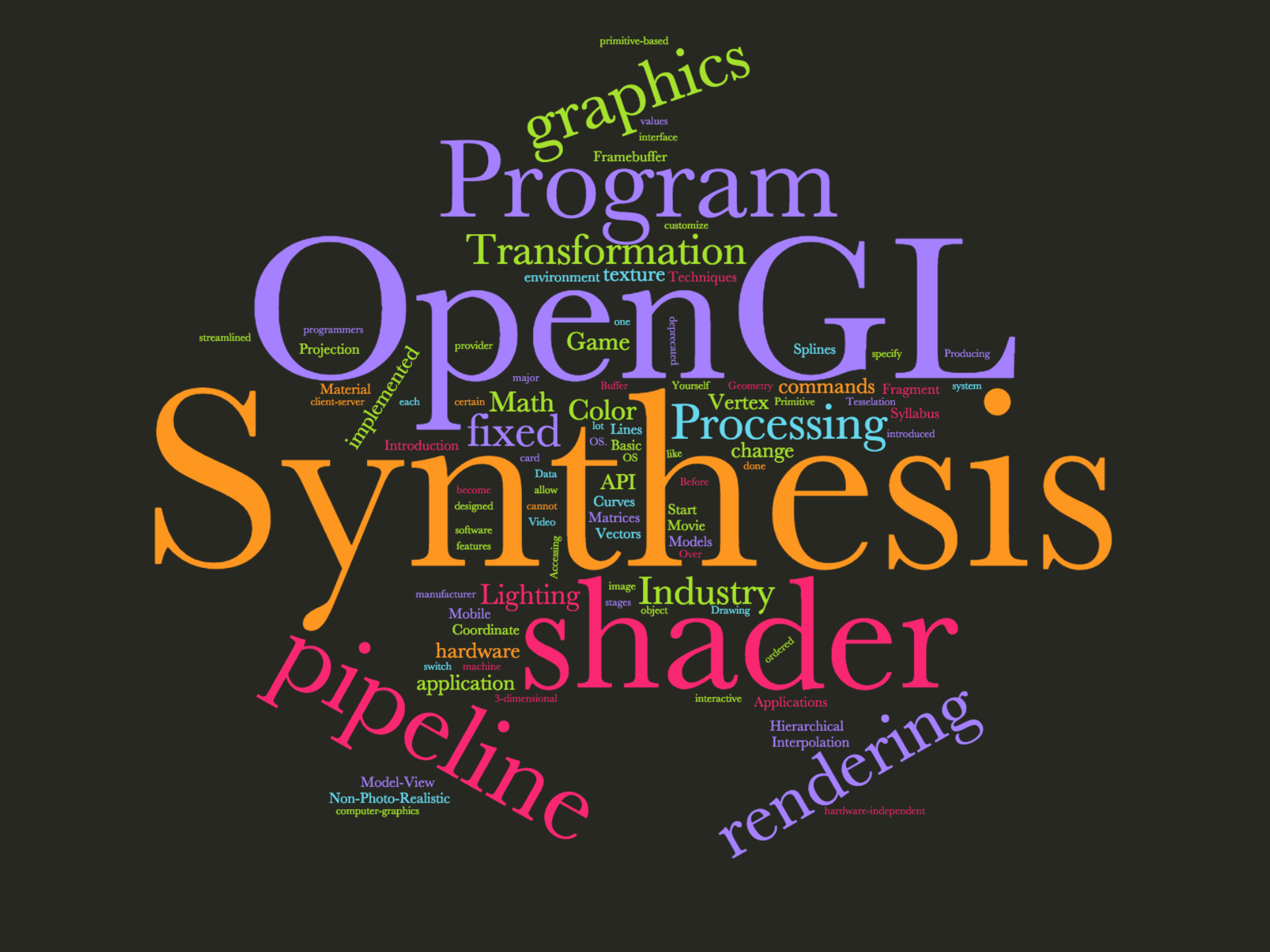



# Non-Photorealistic Rendering

So…

Computer Graphics

is all about


primitive-based
graphics
values
interface
Framebuffer
Program
customize
Transformation
environment
texture
Techniques
OpenGL
streamlined
programmers
Projection
provider
one
Game
deprecated
Splines
specify
Producing
implemented
Material
client-server
each
certain
major
Buffer
Yourself
Geometry
commands
Fragment
system
Math
Color
Vertex
Primitive
Tesselation
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fixed
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Introduction
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Basic
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Data
API
Before
become
allow
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Curves
Start
Video
Matrices
Movie
software
Vectors
Models
features
Accessing
Over
manufacturer
Lighting
image
Industry
stages
object
Drawing
Mobile
Coordinate
shader
hardware
ordered
switch
machine
application
3-dimensional
interactive
Applications
pipeline
Hierarchical
Interpolation
rendering
Model-View
Non-Photo-Realistic
computer-graphics
hardware-independent

# Synthesis / Rendering

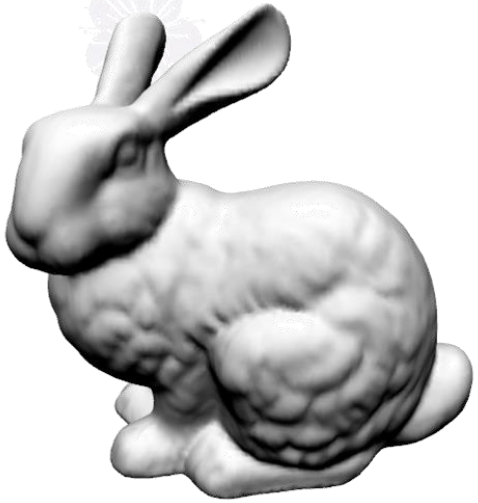
Data

You

?



Hardwares



Image

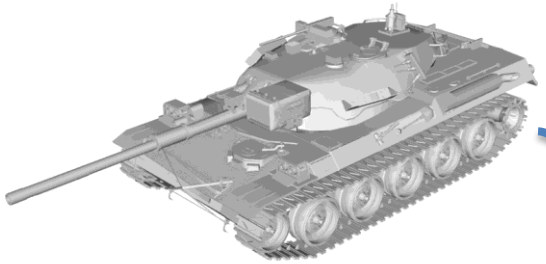
Introducing…


# Open Graphics Library

# What is OpenGL?

- OpenGL is an *application programming interface (API*)
- Accessing features in graphics hardware
- Over 500 commands to specify image, texture, object and shader programs
- Producing interactive 3-dimensional computer-graphics applications
- Latest version: OpenGL 4.5

# What is OpenGL?



3D Model

Texture

Light =(1.5, 0.6, 0.2)
Material=……

OpenGL®

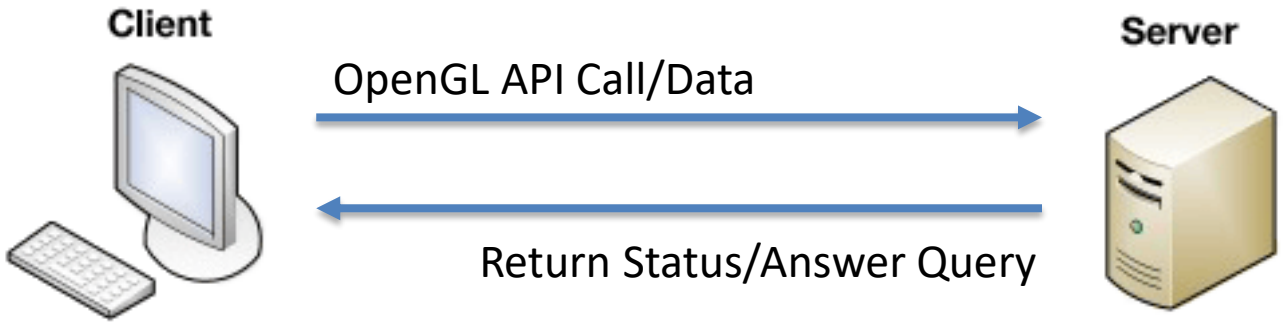
Your OpenGL application

Rendered image

# What is OpenGL?

- OpenGL is designed as:
  - A streamlined, hardware-independent API
  - A primitive-based rendering pipeline
  - A client-server system
- OpenGL is implemented by:
  - Video card manufacturer for each hardware/OS
    - Nvidia, AMD
  - OS provider (software rendering)
  - Yourself! (***Computer Graphics CS 5500***)

# What is OpenGL?




Your Application Code

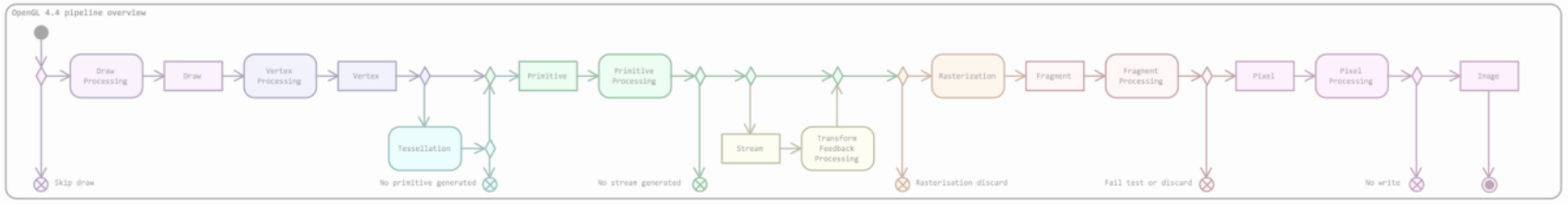
Rendering Algorithm
Load Data from Hard Disk
…

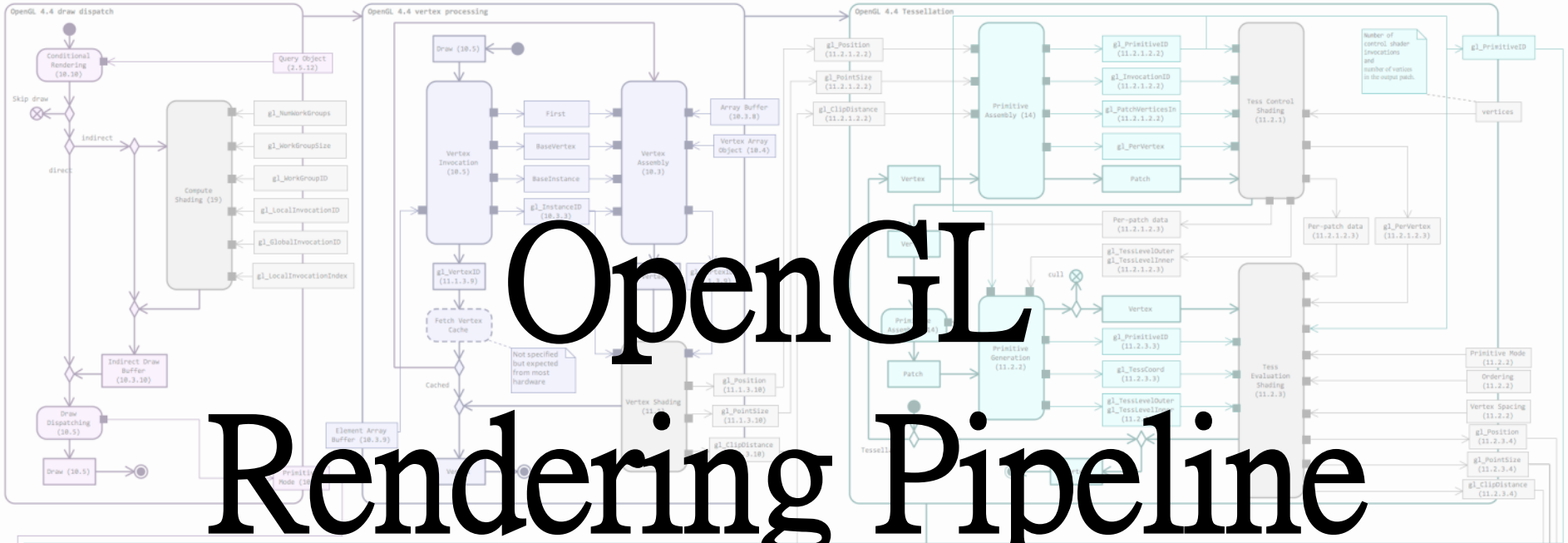
OpenGL Implementation
(AMD/NVIDIA Driver)

OpenGL States:
DEPTH_TEST=ON
Shader ID=1
…

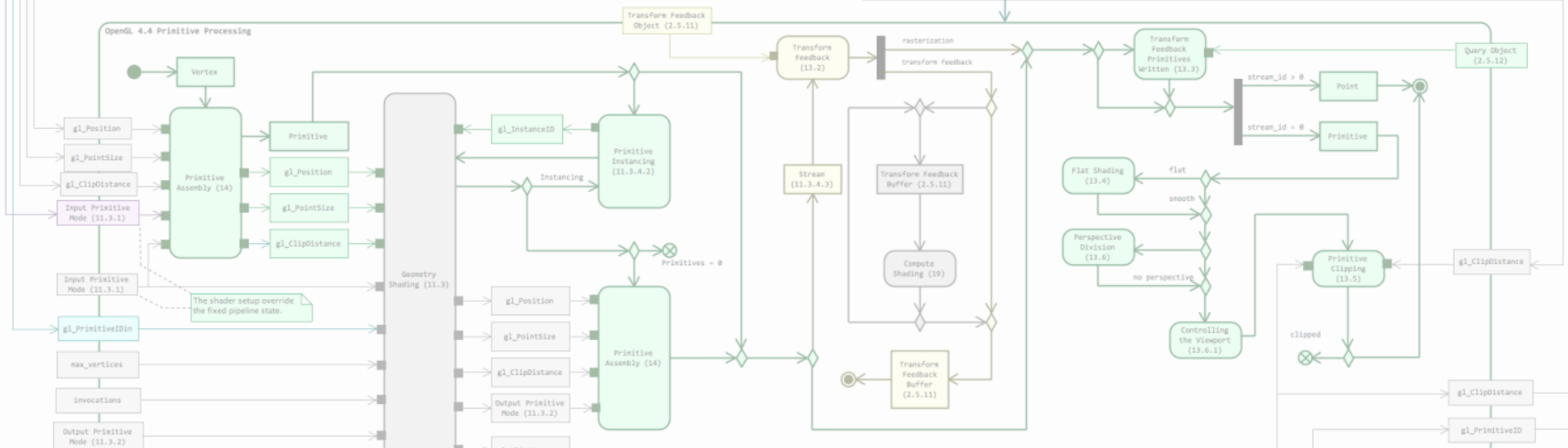
# Vulkan

- A.K.A. OpenGL Next
- Idea similar to AMD Mantle and Direct3D 12
- A Fully cross-platform API
  - Windows, Linux, Android…
  - Google has acquired the mobile group of LunarG, the develop team of the Vulkan driver



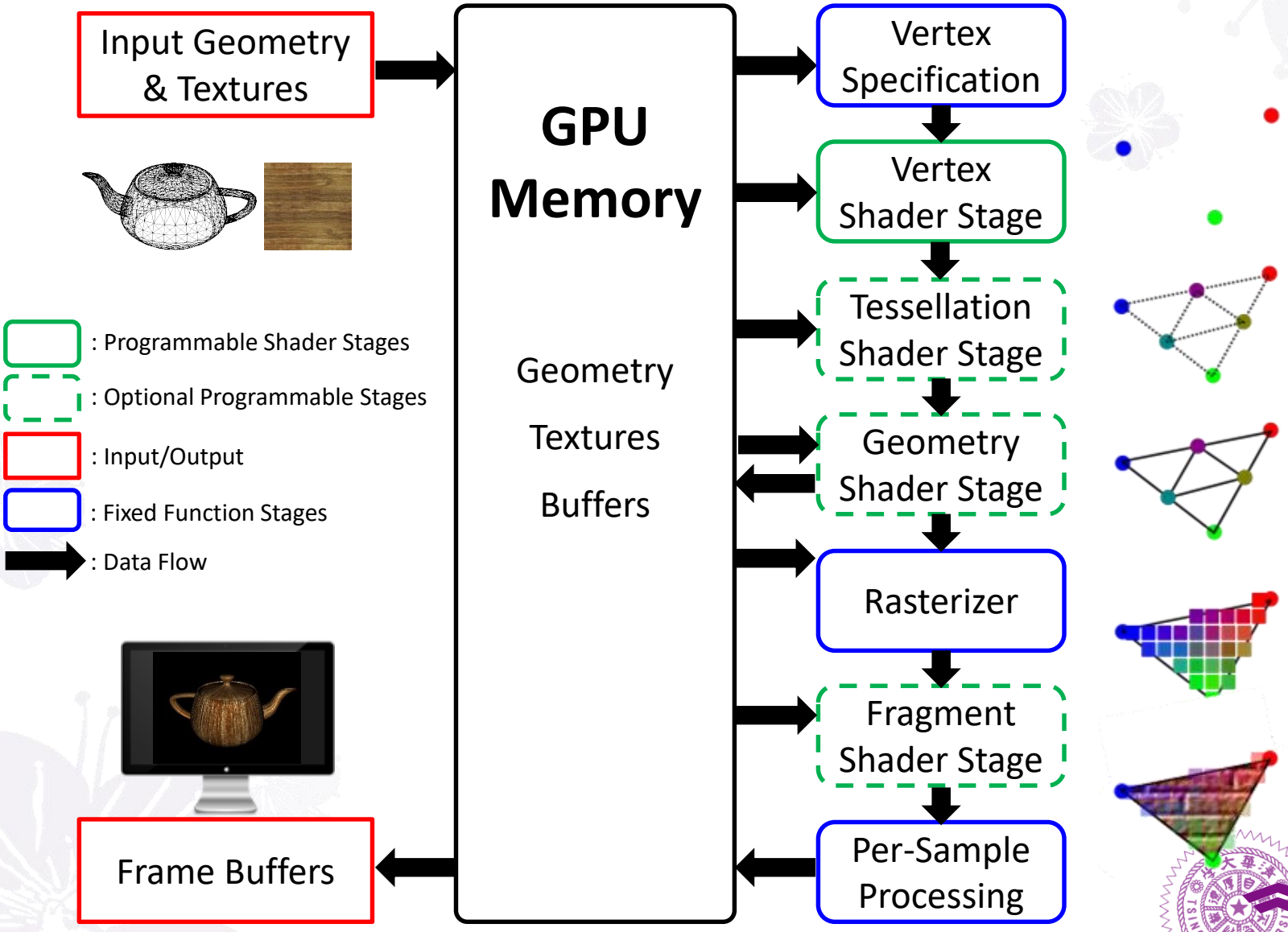

# OpenGL Rendering Pipeline



# Rendering Pipeline

- Pipeline: consists of multiple stages. Data flows in, being processed in each stages, then flows out
- Stages: each stage represents an unique function to process the input data
  - **Fixed function** stages: limited customization capability, typically exposes states for configuration
  - **Programmable shader** stages: allow custom shader programs to be executed within, providing broader capability of customization

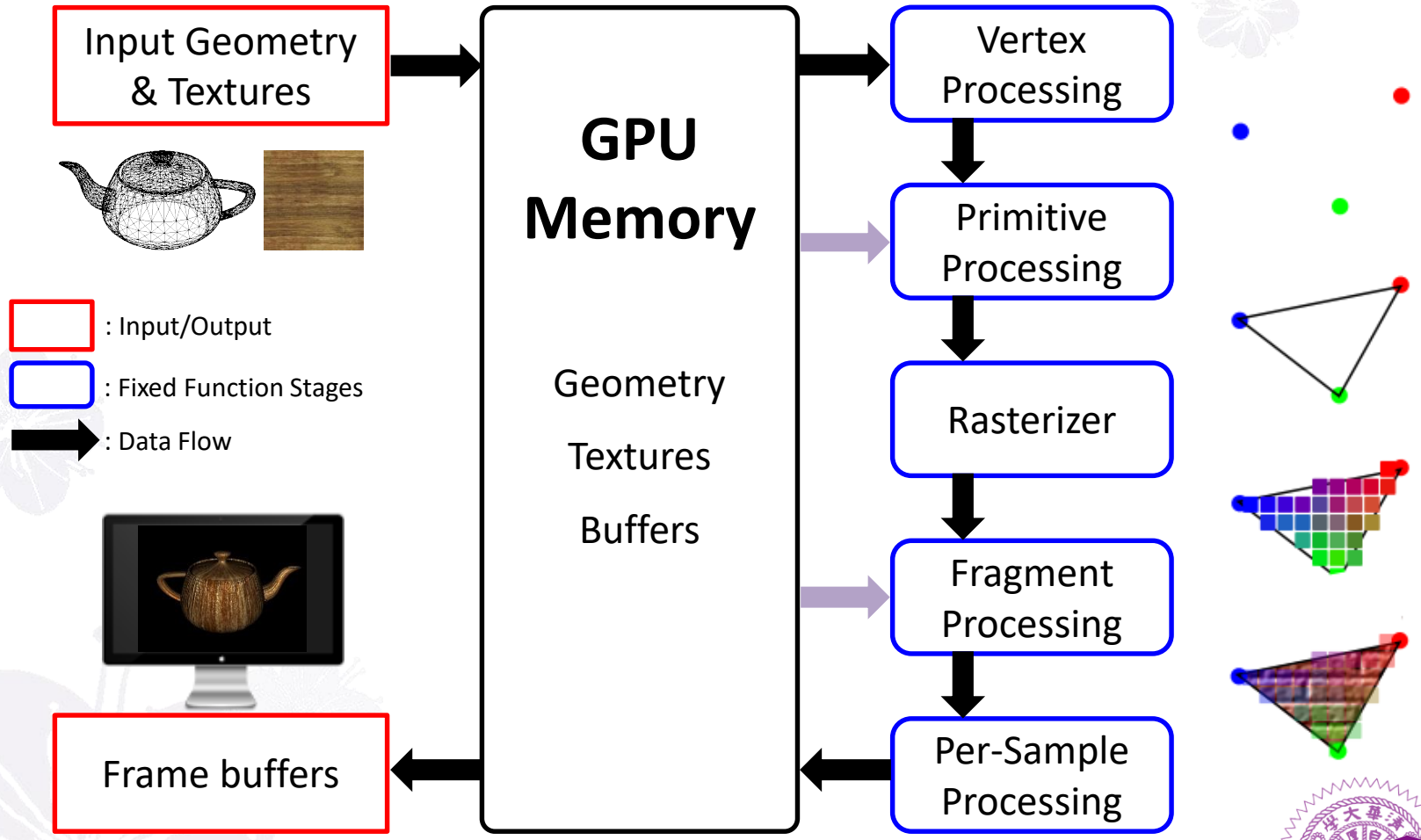
# The OpenGL Rendering Pipeline



# Fixed Function Pipeline (Legacy)

- Before OpenGL 3.0, OpenGL rendering is done in a fixed function pipeline
- Fixed pipeline is like an machine with a lot of switches/values to configure
- One cannot change how the function is implemented as well as the order of execution

# Fixed Function Pipeline (Legacy)



# Fixed Function Pipeline: Metaphor

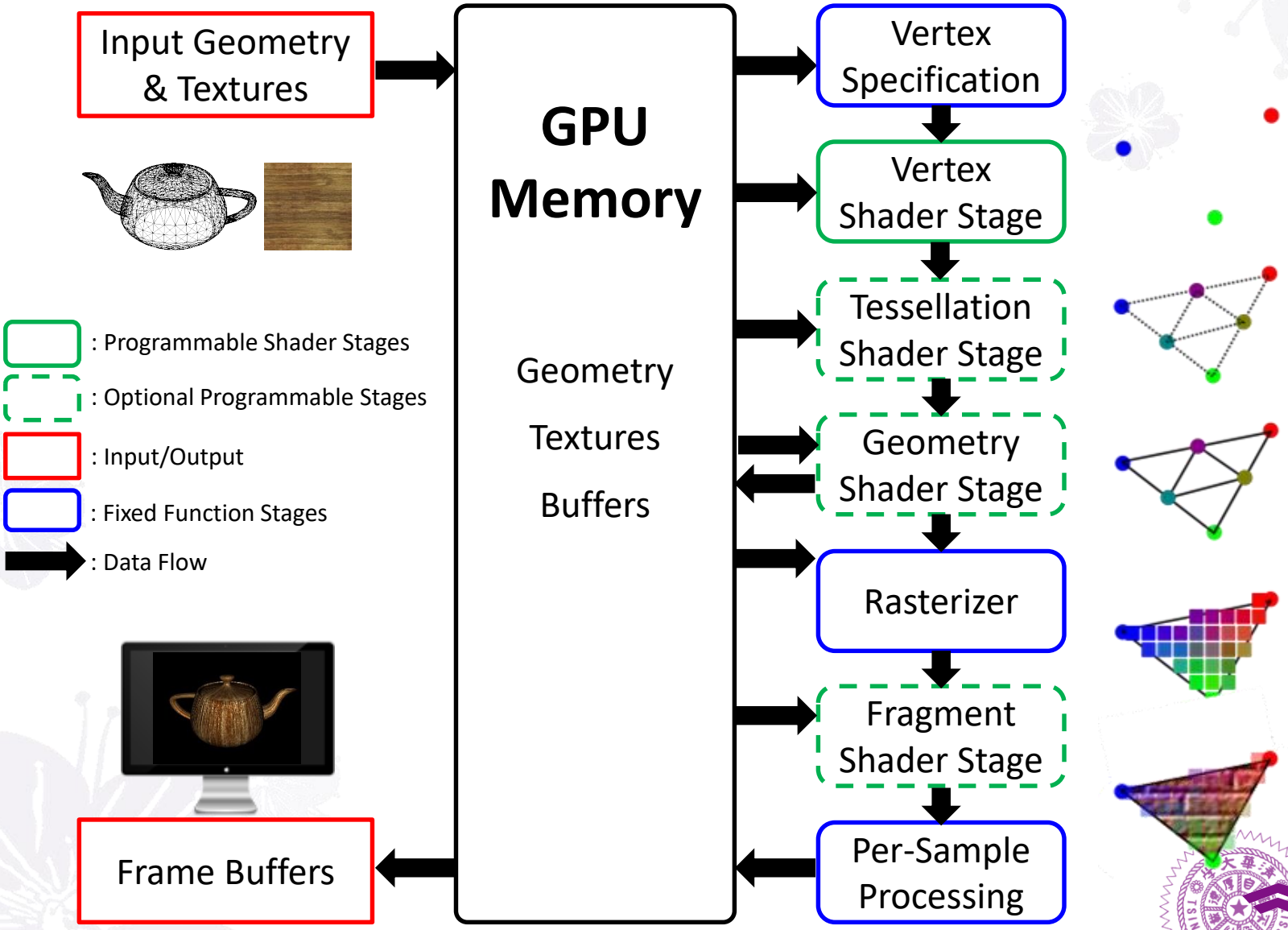
OpenGL Fixed Function Pipeline


How do I press these buttons to get desired effect?

# Programmable Pipeline

- Shader programs are introduced in OpenGL 2.0, and included in the core profile in OpenGL 3.0
- Fixed function pipeline is deprecated since OpenGL 3.0
- Shader programs, written in OpenGL Shading Language(GLSL), allow the programmers to customize certain stages in the OpenGL rendering pipeline

# The OpenGL Rendering Pipeline



# Programmable Pipeline: Metaphor

Shader Programs

```
uniform float t;     // Time (passed in from the application)
attribute vec4 vel; // particle velocity

const vec4 g = vec4( 0.0, -9.80, 0.0 );

void main()
{
    vec4 position = gl_Vertex;
    position += t*vel + t*t*g;

    gl_Position = gl_ModelViewProjectionMatrix * position;
}
```

Let's write a program
to create the effect!

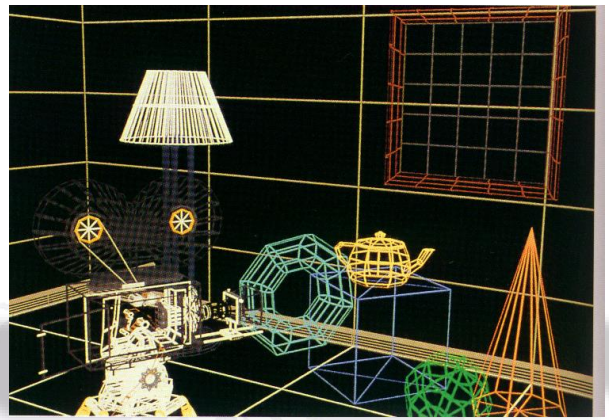
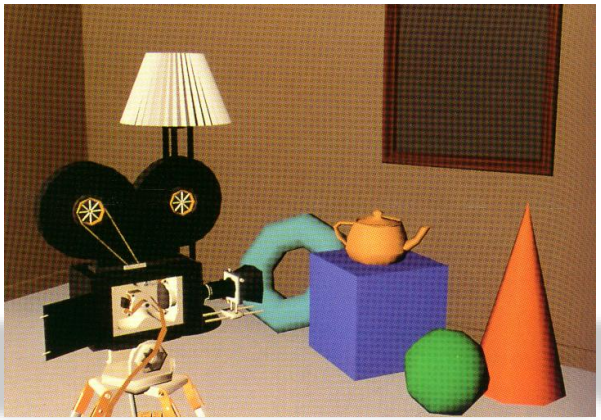
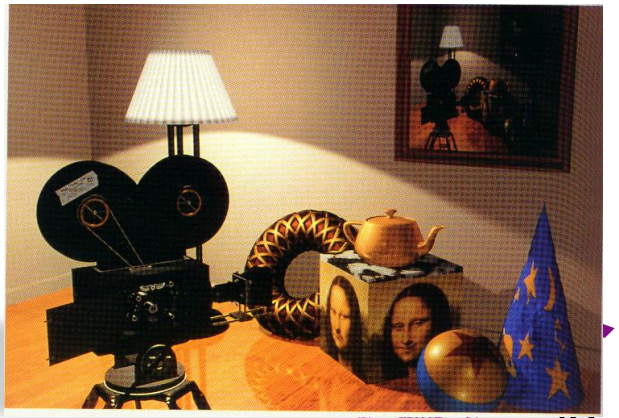
# Programmable Pipeline V.S. Fixed Function Pipeline

| | Programmable Pipeline | Fixed Function Pipeline |
|---|---|---|
| Flexibility | +implement various algorithms in shader programs | -limited customization capability |
| For Simple Application | -must configure the whole pipeline | +performs simple task with less configurations |
| For Complex Application | +can achieve various effects | -most advanced effects are impossible |
| Learning Curve | -one must have full knowledge of the pipeline and GLSL before writing an application | +can create simple applications without much knowledge |
| Deploy | -should consider all graphics driver environment | +works in most graphics driver environment |

# COURSE OUTLINES

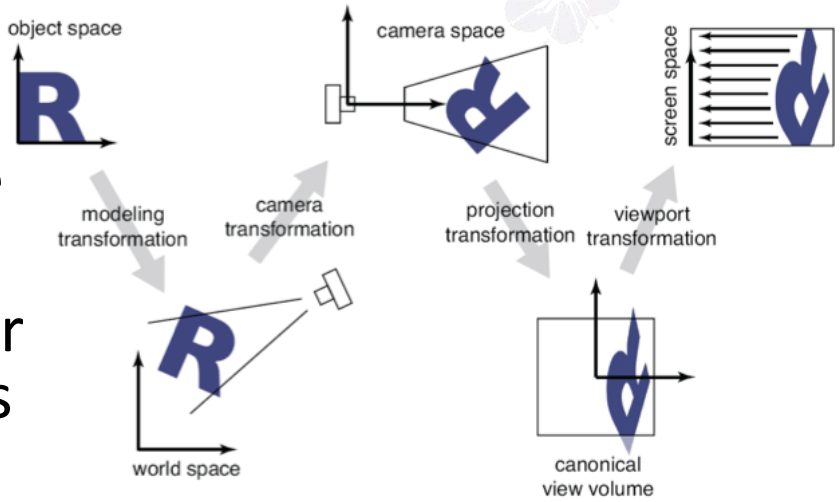
# Fundamental of Computer Graphics

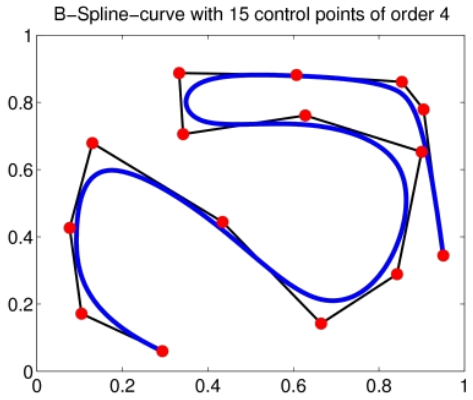
- 3D geometry representation
- 3D projection and transformation
- Color, material and lighting
- Texture mapping
- Recommend ***Computer Graphics (CS 5500)***

# Shader Programming (OpenGL)

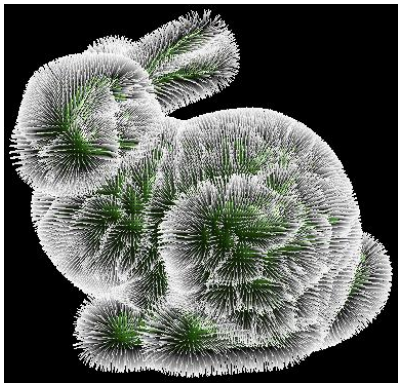
- Rendering Pipeline
  - Configuring the pipeline
  - OpenGL Shading Language (GLSL) basics
  - Writing shader program for each programmable stages
- Math
  - Vectors and matrices
  - Coordinate spaces and transformations
  - Higher-order lines, curves, splines

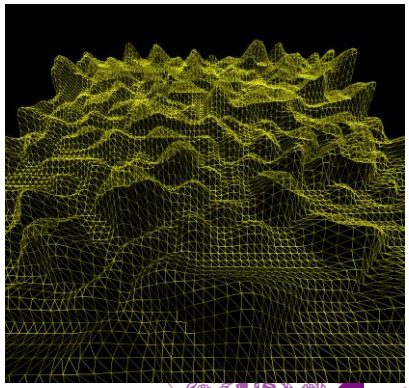


# Shader Programming (OpenGL)

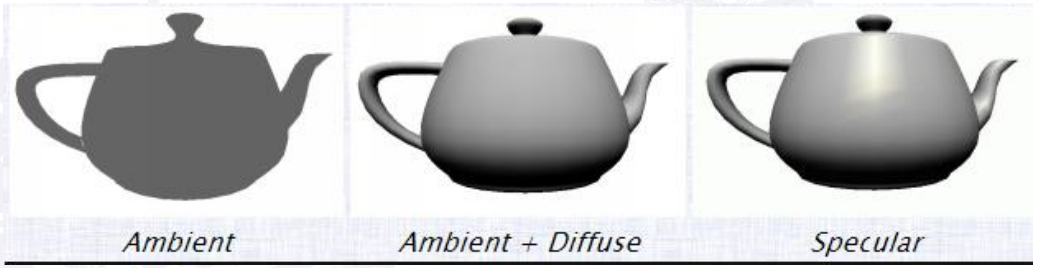
- Data
  - Buffer
  - Texture
- Vertex Processing
  - Vertex shader
  - Drawing commands
- Primitive Processing
  - Geometry shader
  - Tessellation shader





# Shader Programming (OpenGL)

- Fragment processing
  - Color
  - Frame buffer processing
- Rendering techniques
  - Lighting models
  - Non-photorealistic rendering


# Schedule (Temporary)

| Date | Course | Quiz | Homework |
|---|---|---|---|
| 2/13 | Syllabus | | |
| 2/20 | Shader Pipeline | | |
| 2/27 | **2 / 28** 補假 | Quiz1 | |
| 3/06 | Projection and Transformation | | |
| 3/13 | Buffer, Texture and Uniform | | |
| 3/20 | Vertex Processing and Drawing Commands | | HW1 |
| 3/27 | Vertex Processing and Drawing Commands | Quiz2 | |
| 4/03 | 清明連假 | | HW1 Deadline |
| 4/10 | Fragment Processing and Frame Buffer | Quiz3 | |
| 4/17 | Fragment Processing and Frame Buffer | Quiz4 | |

# Schedule (Temporary)

| Date | Course | Quiz | Homework |
|---|---|---|---|
| 4/24 | Mesh Rendering | | HW2 |
| 5/01 | Tessellation Shader | Quiz5 | |
| 5/08 | Geometry Shader | | HW2 Deadline |
| 5/15 | Skinned Animation | | HW3 |
| 5/22 | Shadowing, Normal Mapping and SSAO | | |
| 5/29 | 端午節放假 | | HW3 Deadline |
| 6/05 | Compute Shader (Water, Cloth Simulation) | | |
| 6/12 | TBA | | |
| 6/19 | 暑假開始 **(Final demo)** | | Final Deadline |

# Prerequisites

- **C/C++** programming skill.
- Fundamental **linear algebra** knowledge.
- **Hard/smart working**.
- Enjoying the **programming**.
- Enthusiasm for **computer graphics**.

# Class Information

- Classroom
  - Lecture: 台達103
  - Quiz: 資電326, 328
- Class time (星期一):
  - Lecture: 15:30-18:20
  - Quiz: 17:30-18:20
  - LAB: 18:30-19:20
- Course webpage:
  - ILMS (http://lms.nthu.edu.tw/)

# Instructor & TAs

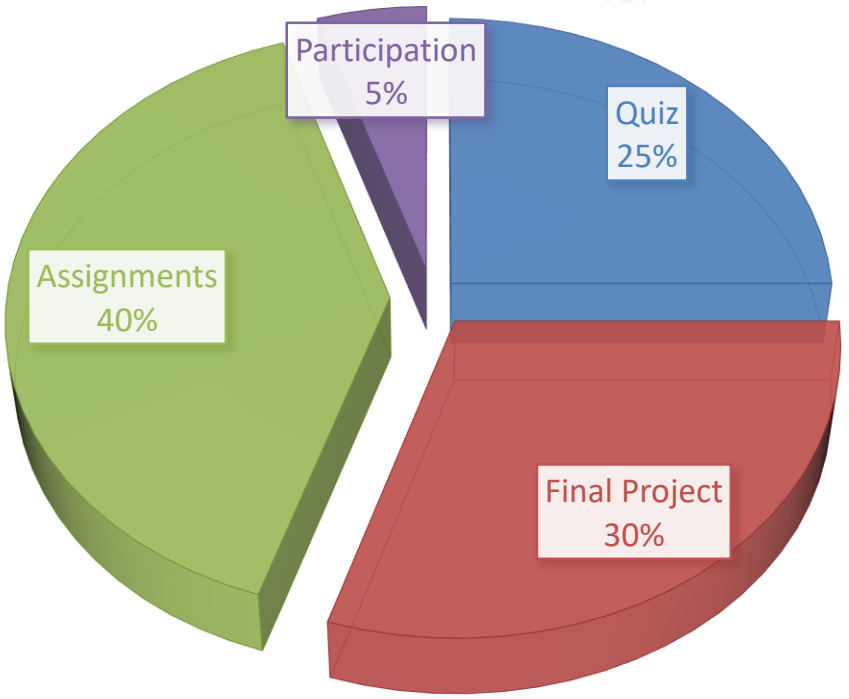
| Name | 朱宏國 | TAs |
|---|---|---|
| Office | 台達館641室 | 資電館839/840室 |
| TEL | 03-5731215 | 03-5733525, 03-5733531 |
| E-Mail | hkchu@cs.nthu.edu.tw | 林佑恩，張宏瑞，林育睿，楊尚達<br>**Contact TAs via ILMS** |
| Office Hours | Anytime (email me) | |

# Workload ?

Image courtesy of Stuart Miles / FreeDigitalPhotos.net

# Workload & Evaluation

- Final project (30%)
  - TBA
- Assignment (40%)
  - Homework: 3
- Quiz (25%)
  - In-class: 5
- Participation (5%)

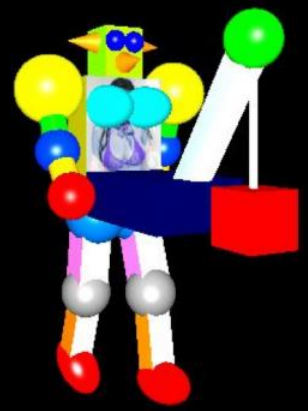


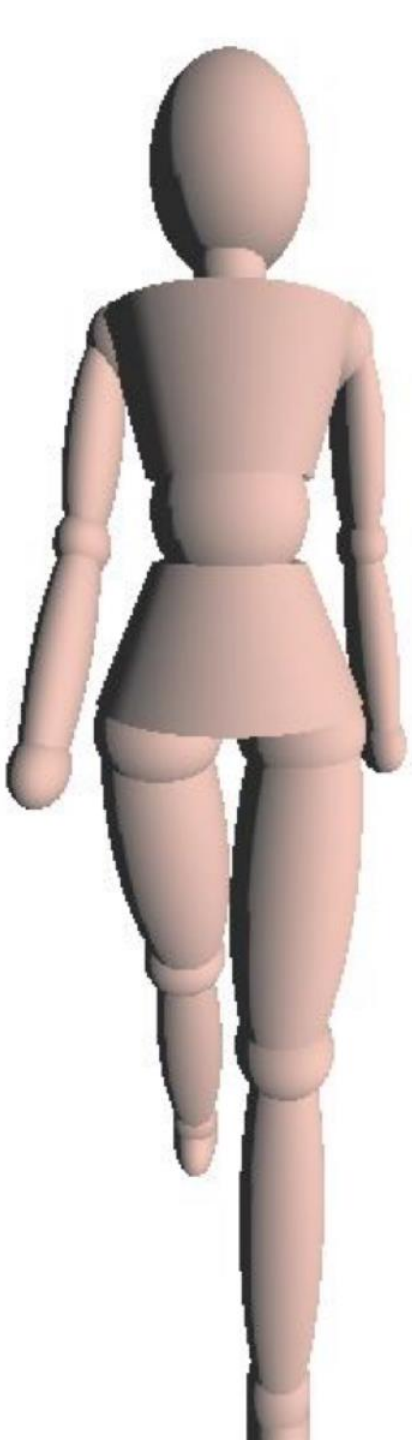
# Quiz Rules

- Time period: 5:30 P.M. – 6:20 P.M.
- Class room: 326 & 328
- Demo screen output to TAs before 6:20 P.M.
- Communication with classmates is forbidden.

# ASSIGNMENT AND FINAL PREVIEWS

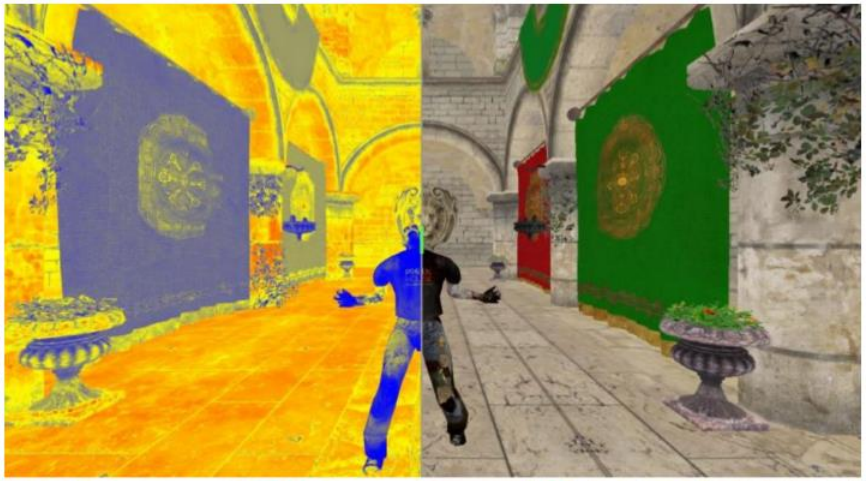
# Assignment: Animated robot

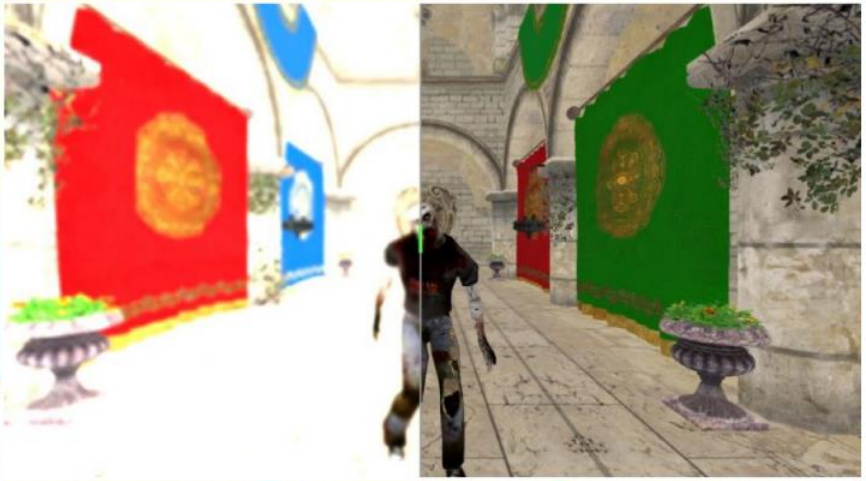




# Assignment:
# Create/Load a complex scene

# Assignment: Post processing






2016 Final Project: Theme park

# Final Project: TBA

Any suggestion is welcomed

# Minimal Requirement for Video Cards

NVDIA

https://developer.nvidia.com/opengl-driver

AMD

http://www.geeks3d.com/20130724/amd-catalyst-opengl-4-3-graphics-driver-7-new-opengl-extensions/


thank you!
Question?