



# 5CM507 Graphics

## Introduction of Computer Graphics and the Graphics Pipeline

Dr Youbing Zhao

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# Instructor



Dr Youbing Zhao

- ▶ PhD, State Key Lab. of Computer-aided Design and Computer Graphics, Zhejiang University, China, 2005
- ▶ Researcher, Siemens Research China, 2005 - 2008
- ▶ Research Fellow in Centre for Computer Graphics and Visualisation (CCGV), University of Bedfordshire, 2008 - 2018
- ▶ Lecturer, Communication University of Zhejiang, 2019 - 2024
- ▶ Lecturer, University of Derby, 2024 -

# Overview



1. An Overview of Computer Graphics
2. A Very Brief History of Computer Graphics (self-learning)
3. Computer Graphics Applications (self-learning)
4. Rendering Pipelines
5. Module Outline (Autumn 2025)
6. Lab session

# An Overview of Computer Graphics

# Computer Graphics

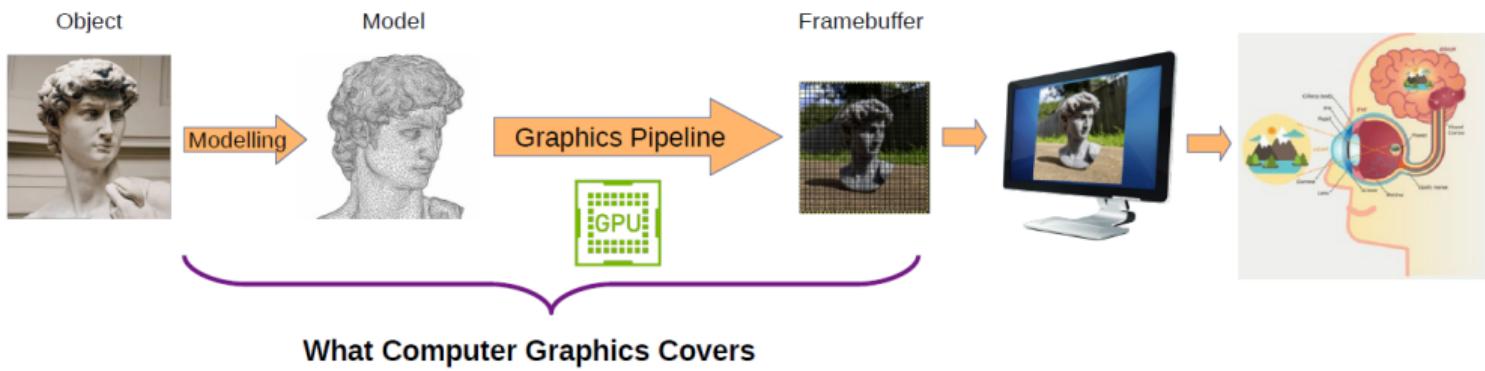


## Definition

**Computer Graphics** /kəm'pjū:tə 'grafiks/ 1963—

- ▶ coined by William Fetter in 1960 when he worked for Boeing
- ▶ Oxford English Dictionary (OED)
  - ▶ (Computer Graphic) A **visual image** produced or modified by means of a **computer**, or generated as part of a computer program.
- ▶ Dictionary.com
  - ▶ The use of **computers** linked to display screens to generate and manipulate **visual images**.

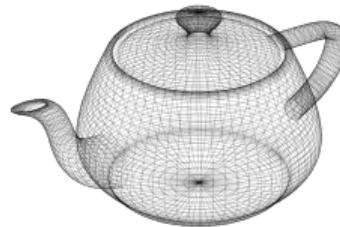
# From Models to Images, to the Human Visual System



## From Models to Images, to the Human Visual System

# Most Common 3D Model Representation

- ▶ Geometry : Meshes Composed of Basic Units (Primitives)
  - ▶ Triangular Meshes
  - ▶ Quadrilateral Meshes
- ▶ Material
  - ▶ Colour Model
  - ▶ Reflectance
- ▶ Other Attributes
  - ▶ Texture
  - ▶ Bump Map
  - ▶ ...



Utah Teapot in Wireframe



Utah Teapot with Texture

# Digital Raster Images

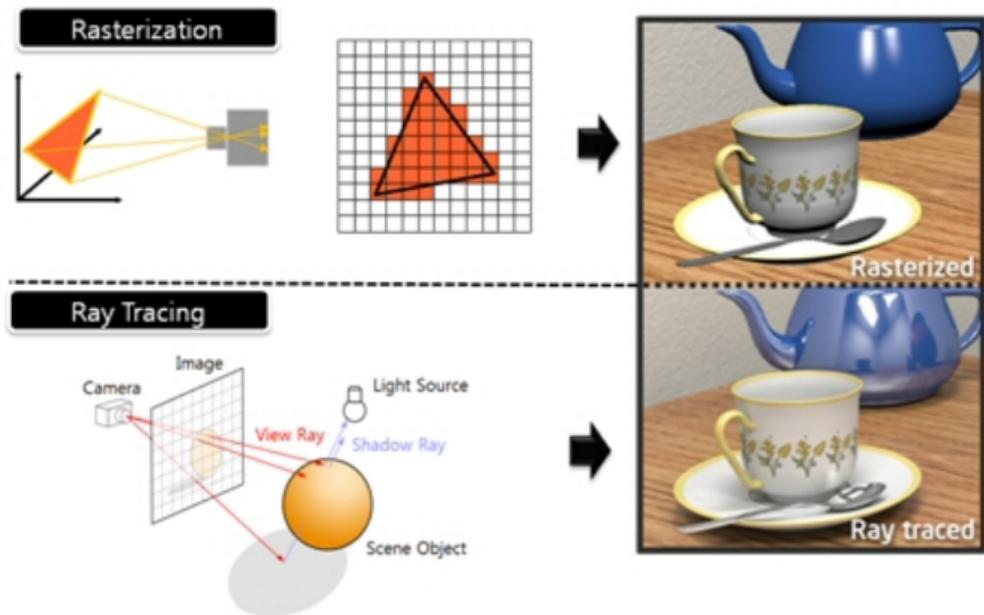


Raster images: the cat whiskers in detail

# How Raster Images are generated

## An Overview of Computer Graphics

- ▶ Classical: Rasterisation
  - ▶ Projection based
  - ▶ (Autumn semester)
- ▶ More advanced ? Ray-based
  - ▶ Ray tracing
  - ▶ Path tracing
  - ▶ (Spring semester)



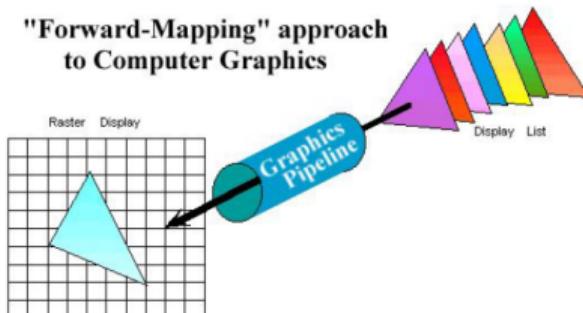
Rasterisation vs Ray tracing

# Rasterisation vs Ray-based

## Rasterisation: Projecting primitives

```
for each triangle
    for each pixel
```

- ▶ Project scene to the screen
- ▶ Scan conversion each triangle
- ▶ Completed by GPU

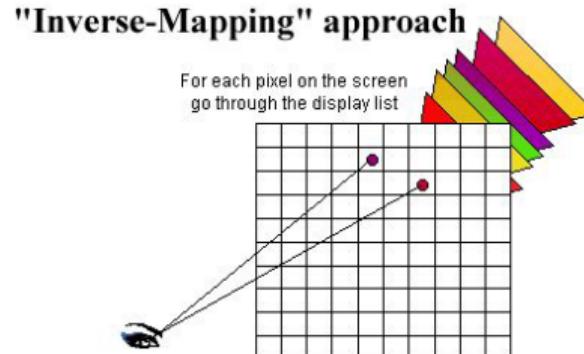


## Ray-based : Casting rays

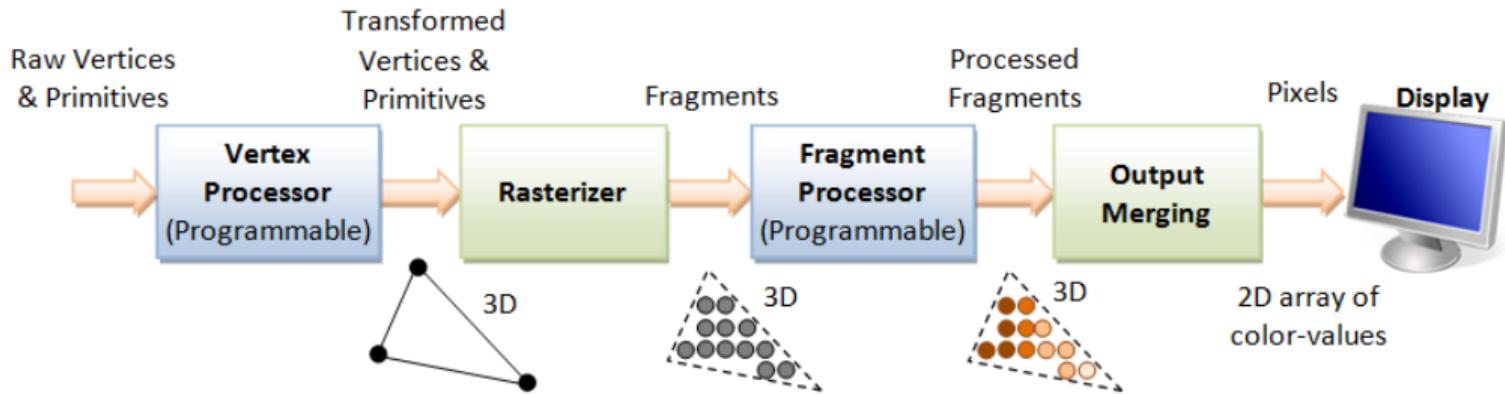
```
for each pixel
    for each object
```

- ▶ Send rays into the scene
- ▶ A process of sampling

## "Inverse-Mapping" approach



# Rasterisation Pipeline



**3D Graphics Rendering Pipeline:** Output of one stage is fed as input of the next stage. A vertex has attributes such as  $(x, y, z)$  position, color (RGB or RGBA), vertex-normal  $(n_x, n_y, n_z)$ , and texture. A primitive is made up of one or more vertices. The rasterizer raster-scans each primitive to produce a set of grid-aligned fragments, by interpolating the vertices.

## Rasterisation Pipeline

# Programmable GPUs with Shaders

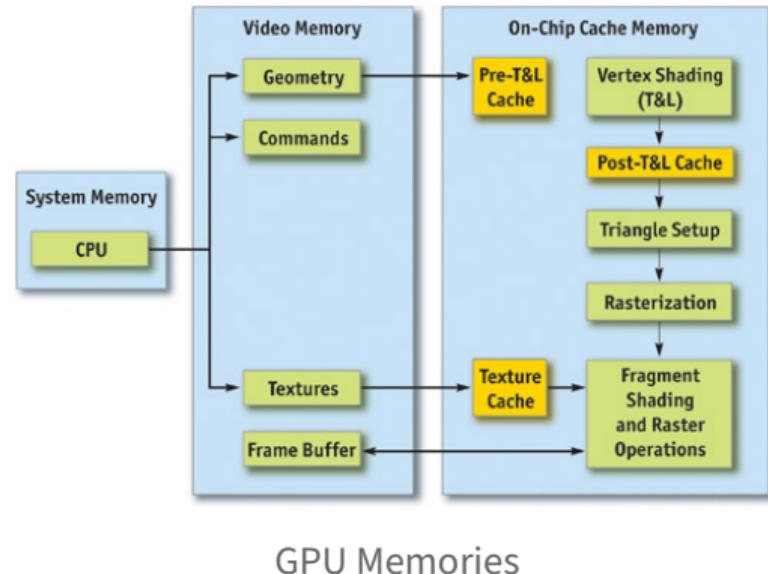
## An Overview of Computer Graphics

### Graphics Processing Unit (GPU)

- ▶ First released in Nvidia's GeForce 3 in 2001
- ▶ Single Instruction Multiple Data Parallelism (SIMD)
- ▶ General Programming, GPGPU (CUDA) (2007)
- ▶ Wide applications in AI (from 2010s)

"GPUs are the only type of parallel processor that has ever seen widespread success... because developers generally don't know they are parallel!"

*Matt Pharr, circa 2008*



GPU Memories

# Computer Graphics Topics



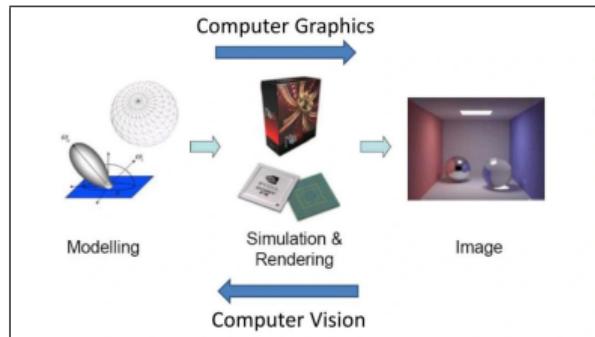
- ▶ Object representation - modelling
  - ▶ Explicit : Mesh
  - ▶ Implicit: ...
- ▶ Rendering (Focus)
  - ▶ Rasterisation (shader programming)
  - ▶ Ray tracing / Path tracing (Spring)
- ▶ Lighting (Focus)
  - ▶ Basic lighting models
  - ▶ Physically-based lighting models
  - ▶ Global illumination (Spring)
- ▶ Animation (Spring)
  - ▶ Character animation
  - ▶ Motion Capture
- ▶ Physically-based simulation (Spring)
  - ▶ Collision
  - ▶ Cloth, smoke, fire, water ...

# Computer Graphics - Comparison

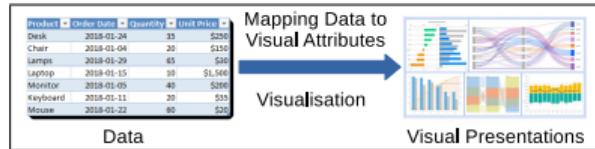
## An Overview of Computer Graphics



- ▶ Computer Graphics
  - ▶ (Real-world 2D or 3D) Models => Visual images
- ▶ Computer Vision
  - ▶ Visual images => Real-world (3D) models
  - ▶ The reverse of Computer Graphics
- ▶ Visualisation
  - ▶ (Not directly visible) Data => Visual images
  - ▶ by mapping data to visual attributes.



Computer Graphics vs Computer Vision



Visualisation

# A Very Brief History of Computer Graphics (self-learning)

# Computer Graphics - the Beginning

Father of Computer Graphics - Ivan Edward Sutherland



- ▶ PhD from MIT (1963)
- ▶ Turing Award (1988)
- ▶ Sketchpad : Predecessor of Graphical User Interface
- ▶ PhD Thesis Supervisor : Claude E. Shannon
  - ▶ Father of Information Theory
- ▶ Student : Alan Kay
  - ▶ Inventor of Smalltalk, the first Object-Oriented Language, predecessor of C++



Ivan Edward Sutherland



Sketchpad

# Computer Graphics : A Brief History



## Origins

Analog vector display was one of the early graphics processing's focus.

Flight simulation was one of the earliest applications driving the development of computer graphics.

# 1960s

Algorithms of projecting 3D object to 2D plane were developed.

## Uncovering Fundamentals

Semiconductor with memory made the transition from vector display to raster display possible.

Raster scan displays scanned an electron beam from left to right and top to bottom to display an image.

# 1970s

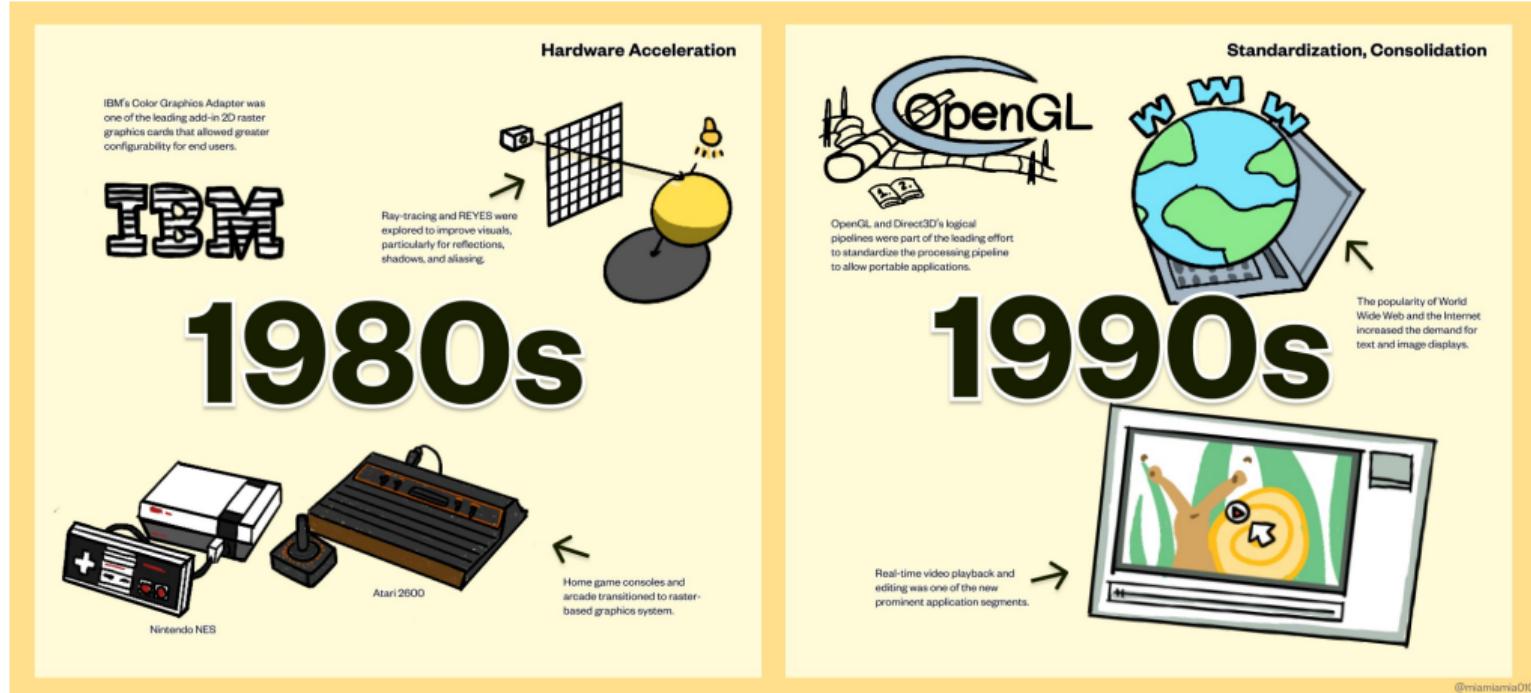
Whereas vector images are drawn using mathematical formulas,

raster images are arranged in a rectangular grid of pixels.

@miamiamia0103

From Oscilloscopes to Raster Images and CRTs

# Computer Graphics : A Brief History



IBM's Color Graphics Adapter was one of the leading add-in 2D raster graphics cards that allowed greater configurability for end users.

**1980s**

Ray-tracing and REYES were explored to improve visuals, particularly for reflections, shadows, and aliasing.

Hardware Acceleration

IBM

Nintendo NES

Atari 2600

Home game consoles and arcade transitioned to raster-based graphics system.

OpenGL

Standardization, Consolidation

OpenGL and Direct3D's logical pipelines were part of the leading effort to standardize the processing pipeline to allow portable applications.

1990s

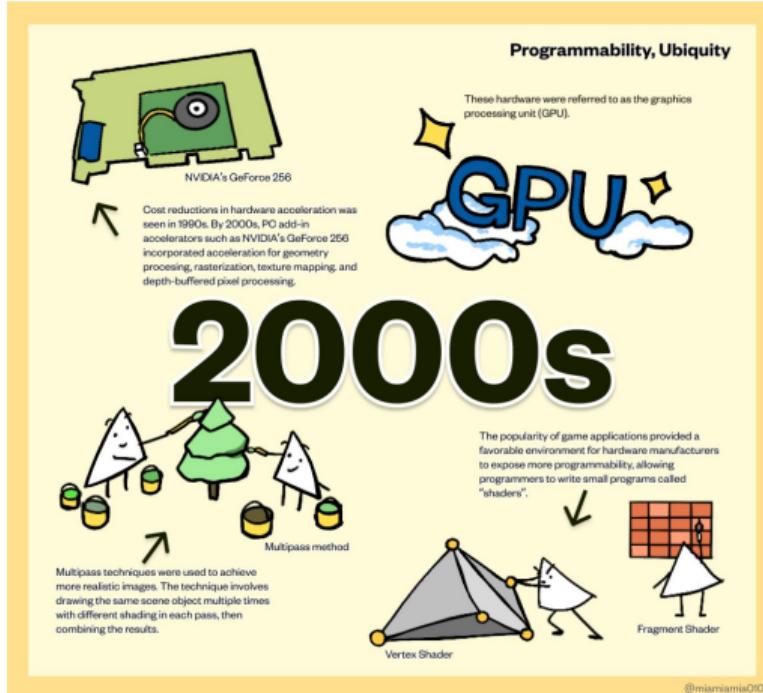
The popularity of World Wide Web and the Internet increased the demand for text and image displays.

Real-time video playback and editing was one of the new prominent application segments.

@miamiamia0103

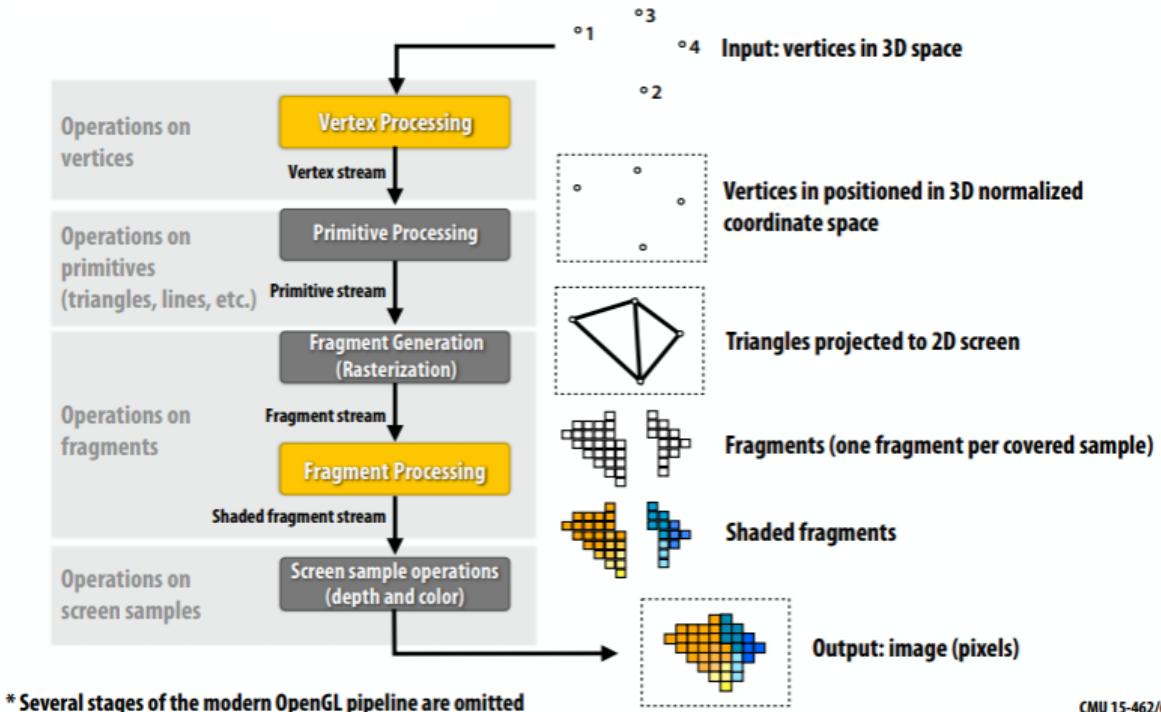
Graphical Adaptors and Graphics APIs

# Computer Graphics : A Brief History



From Graphical Processors and Adaptors to Programmable GPUs

# Graphics Pipeline : From Fixed to Programmable



# Computer Graphics Applications (self-learning)

# Applications



- ▶ Graphical User Interface
- ▶ Entertainment Industry
  - ▶ Video Games
  - ▶ Movies
  - ▶ Animations
- ▶ Computer-aided Design
- ▶ Visualisation
- ▶ Virtual Reality (VR) / Augmented Reality (AR)
- ▶ Simulation

# Video Games



1961: The first video game, SpaceWar, ran using an oscilloscope as a display.



Several versions of Lara Croft in Tomb Raider

# Movies



Motion Capture in Avatar

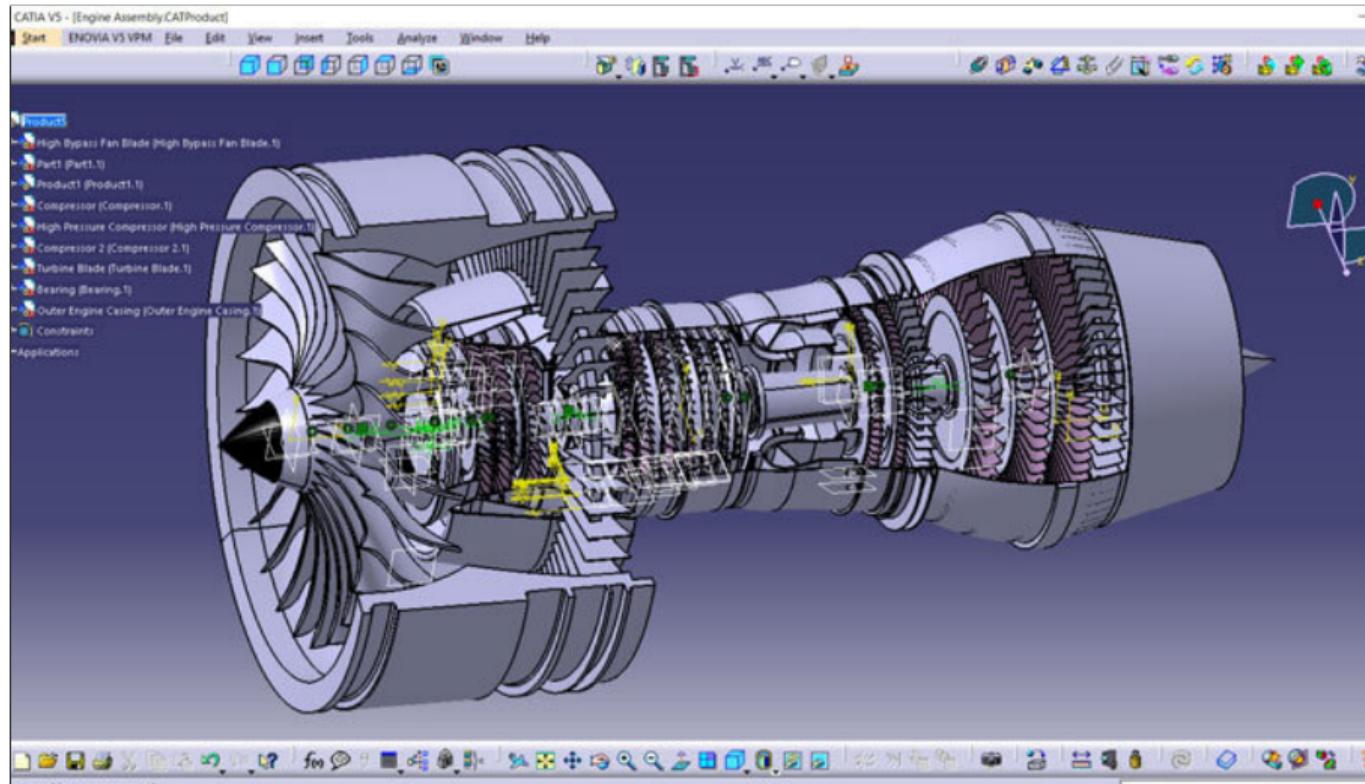
# Animation

(1995) Toy Story - the first ever full-length computer animated feature film.



Frozen II

# Computer-aided Design



Catia software

# Medical Visualisation



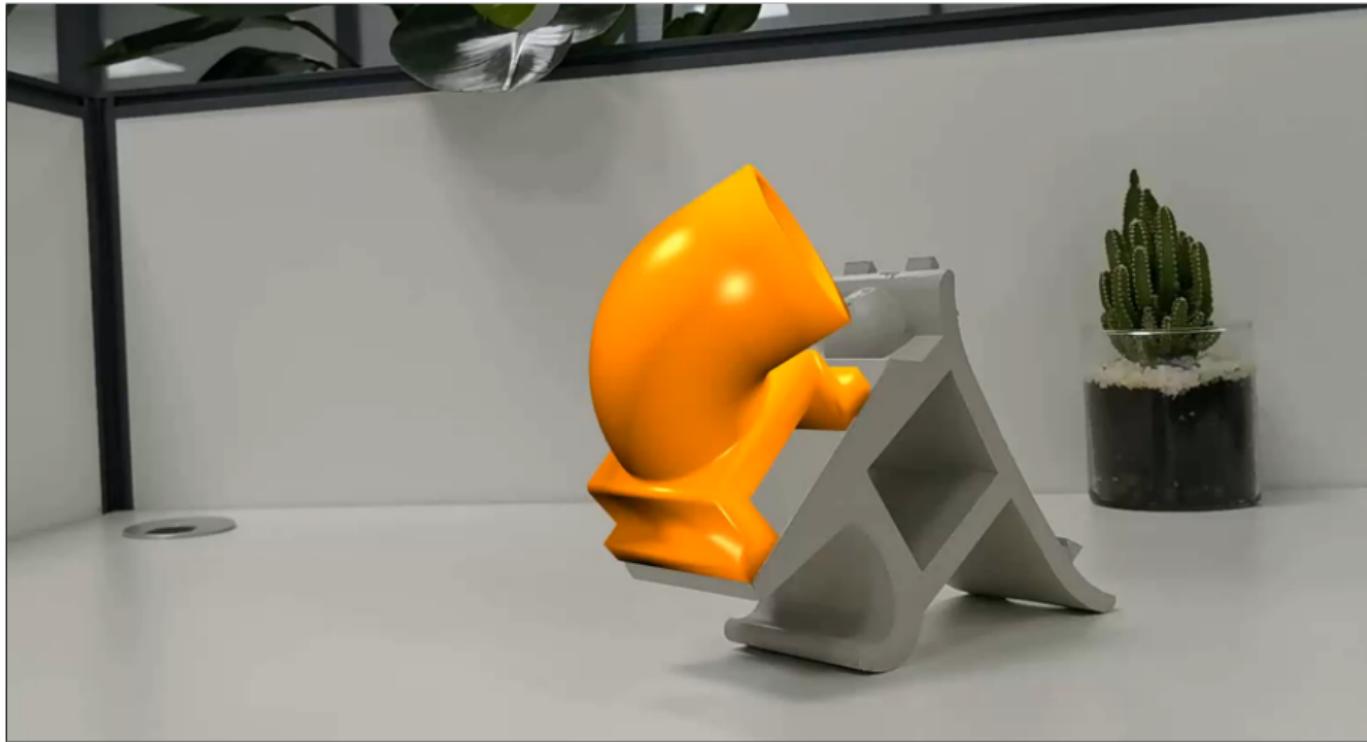
Volume Rendering

# Virtual Reality



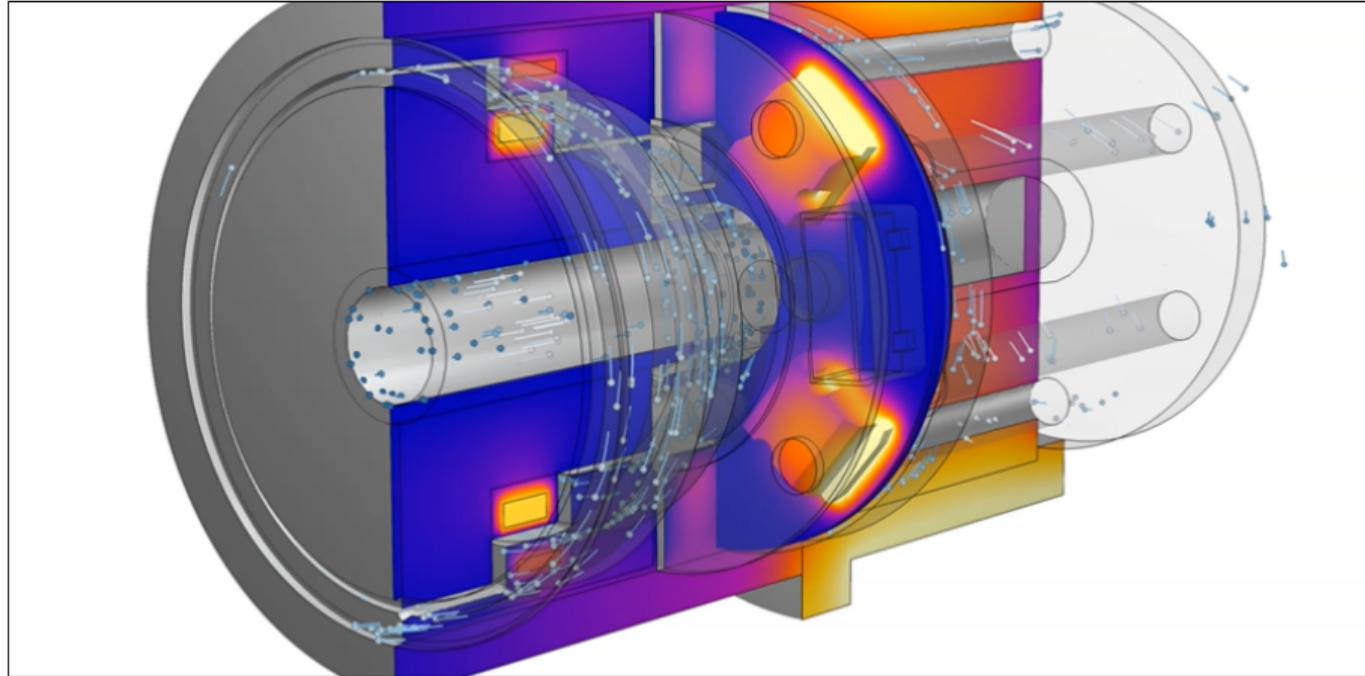
A Virtual Conference (from Meta)

# Augment Reality



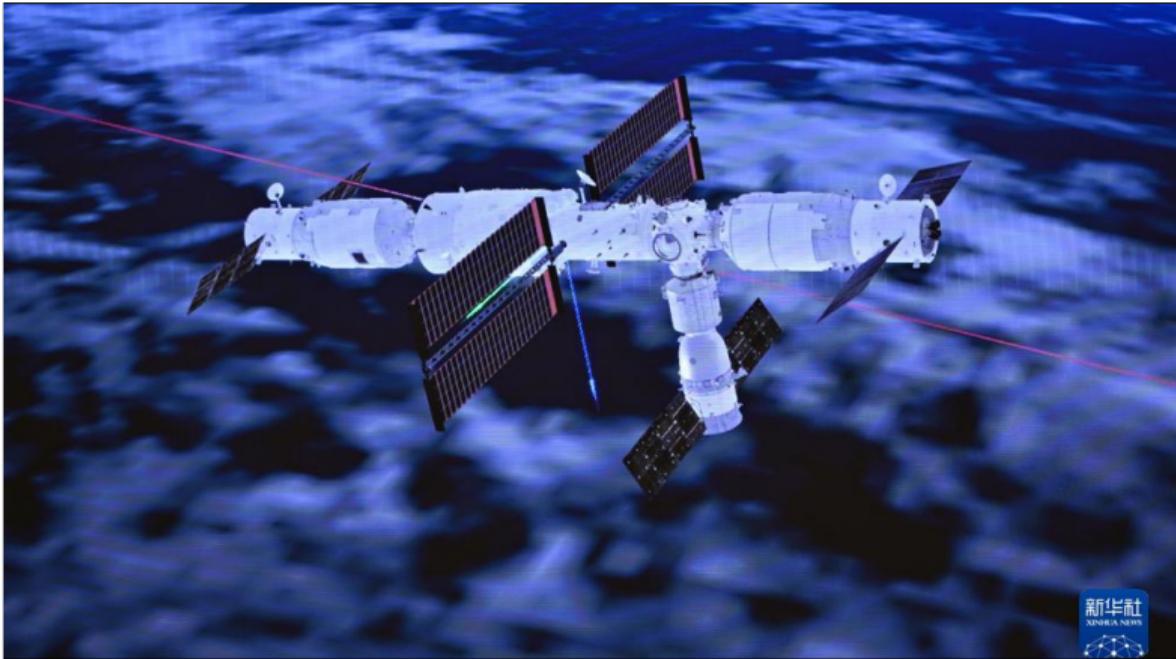
A virtual part on a real part (from Zhejiang University)

# Simulation



Charging Through Electric Motor Development with Simulation (from Ansys)

# Simulation and Monitoring



Docking of China's Shenzhou 14 spaceship with China's Tiangong space station on 5th of June, 2022

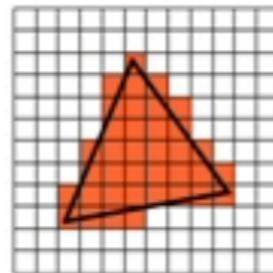


Prof. Zhengxu Zhao,  
Professor of University of  
Derby from 1997 to 2008

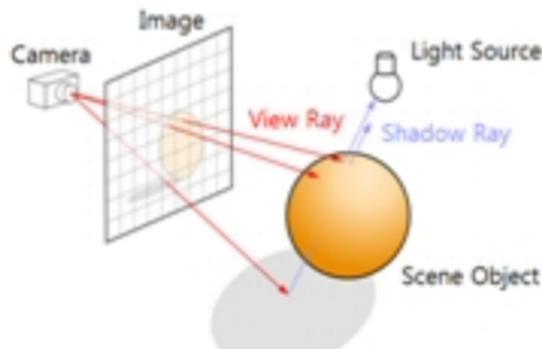
# Rendering Pipelines

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## Rasterization

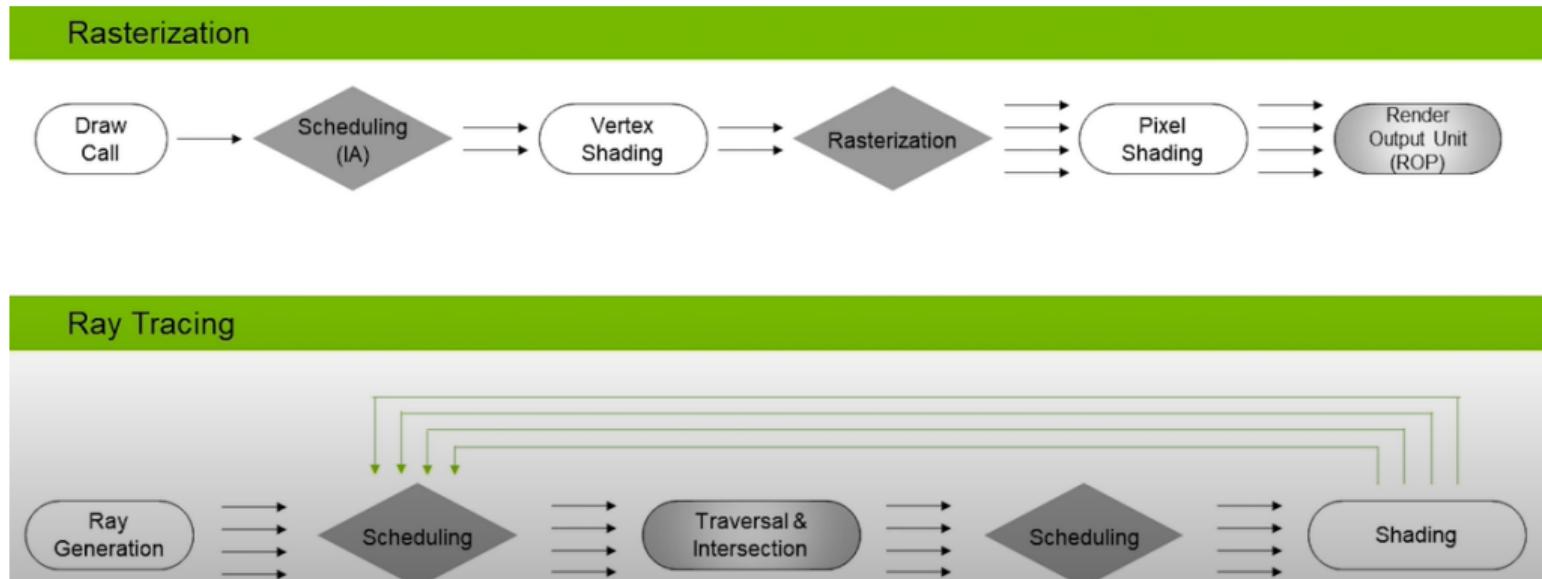


## Ray Tracing

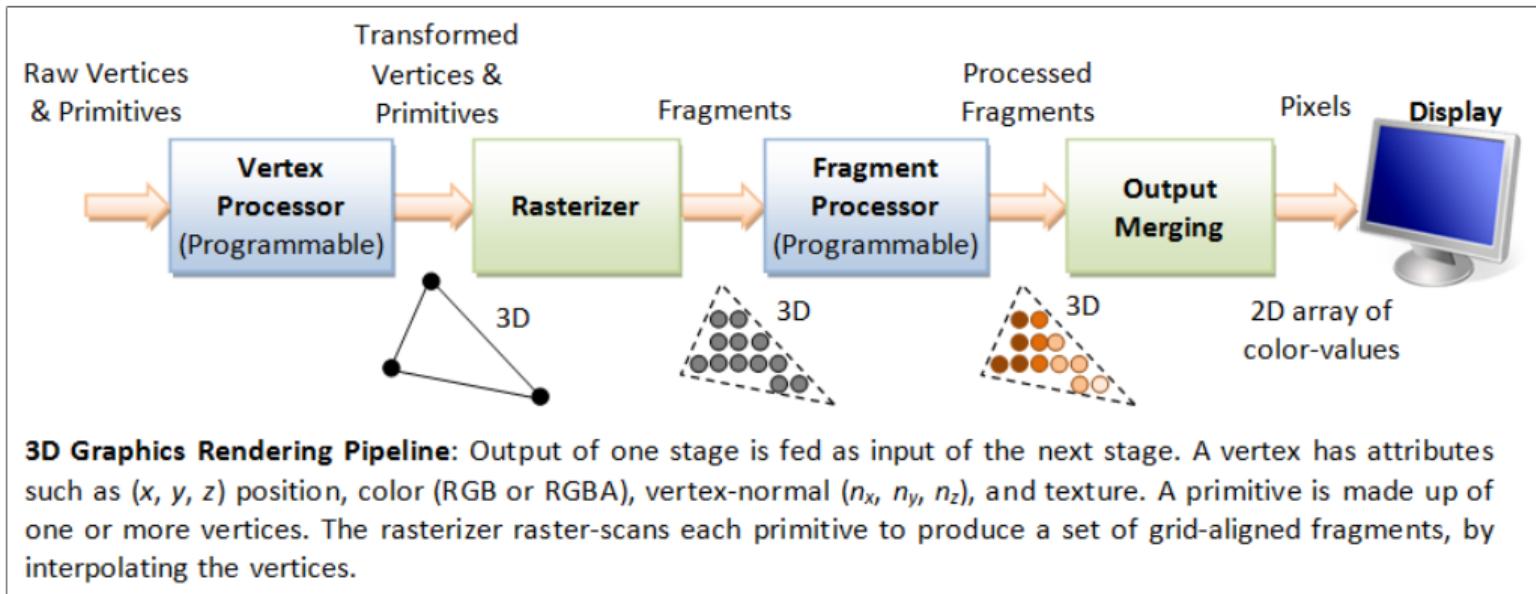


Ray traced

# Rendering Pipelines



# The Classical Rasterisation Pipeline

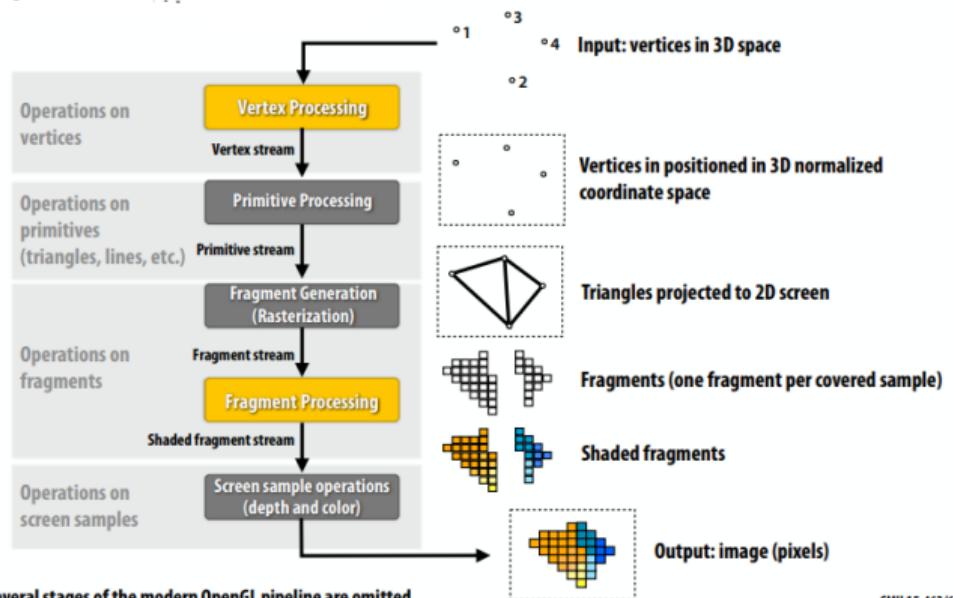


[Prof. Chua Hock Chuan, NTU]

# Module Outline (Autumn 2025)

# What you will learn this Term

- ▶ Scene and camera (Vertex shader)
  - ▶ Model and view transforms
  - ▶ Perspective Projection
  - ▶ Scene graph (C++)
- ▶ Pixel and image (Fragment shader)
  - ▶ Lighting and Shading
  - ▶ Texture Mapping
  - ▶ After effects
- ▶ OpenGL and OpenGL Shader Language (GLSL)



[CMU 15-462]

# Assessments@Derby



Assessment	Weighting	Submission Date	Return Date
Programming Project 1 (Autumn)	50%	19 <sup>th</sup> Jan. 2026	2 <sup>nd</sup> Feb. 2026
Programming Project 2 (Spring)	50%	18 <sup>th</sup> May 2026	1 <sup>st</sup> June 2026

Note : To avoid deadline bunching, these assessment deadlines are SUBJECT TO CHANGE if there are significant conflicts with other modules.

# Recommended books



- ▶ (Practical GLSL shader programming) D. Wolff. *OpenGL 4.0 Shading Language Cookbook, Third Edition.*  
Packt Publishing, 2018
- ▶ (Modern GPU programming) T. Akenine-Mller, E. Haines, and N. Hoffman. *Real-Time Rendering, Fourth Edition.*  
A. K. Peters, Ltd., USA, 4th edition, 2018
- ▶ (Theories) S. Marschner and P. Shirley. *Fundamentals of Computer Graphics: fifth Edition.*  
CRC Press, 2021

# Survey and feedback @Derby



- ▶ Survey on Blackboard each week
  - ▶ After-class survey on Blackboard every week;
  - ▶ You are welcome to take the survey and give feedback.
- ▶ Office hour
  - ▶ MS308, 16:10-17:00 Monday, Friday ( autumn term )
  - ▶ Teams, by email booking ([y.zhao at derby.ac.uk](mailto:y.zhao@derby.ac.uk))

Questions?

# Lab session

# LabA01 Hello OpenGL



- ▶ Set up the OpenGL framework (or directly start from the scaffold framework on blackboard)
- ▶ Create an OpenGL Window
- ▶ Draw a triangle

LabA 01 guide: <https://youbing.gitbook.io/graphics/graphics25/term1/laba01>

Github Code : <https://github.com/zhaoyoubing/proj01>

You are not expected to finish all the lab tasks in class. Try also to spend some time on labs following the lab guide.