

# Computer Graphics

## Lecture 01 – Introduction

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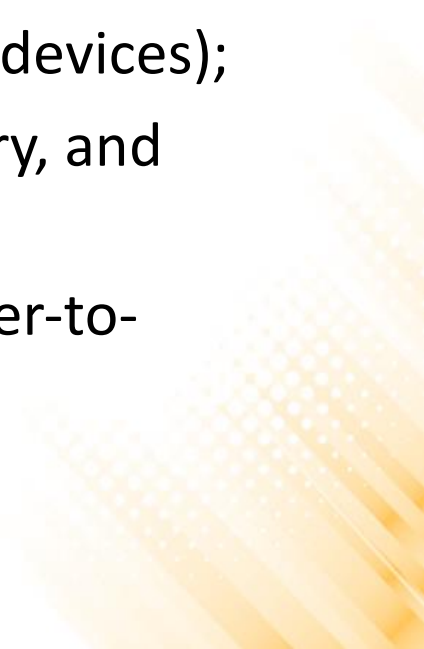


# What is Computer Graphics?

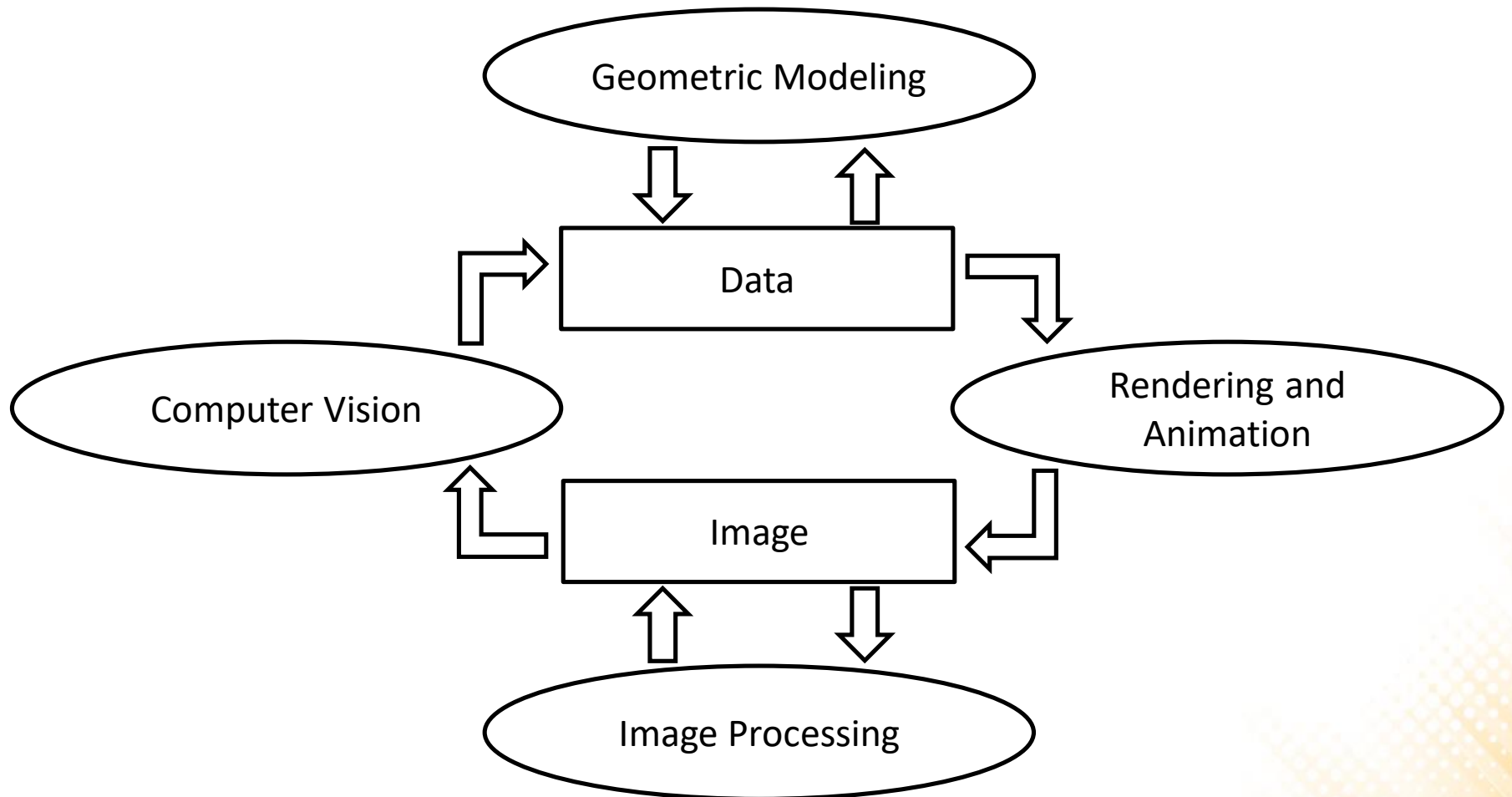
- The term computer graphics describes any use of computers to create and manipulate images [Marschner, S., et al., 2015].
- Computer graphics is the science and art of communicating visually via a computer's display and its interaction devices. [Hughes, J. F., et al., 2013]



# What is Computer Graphics?

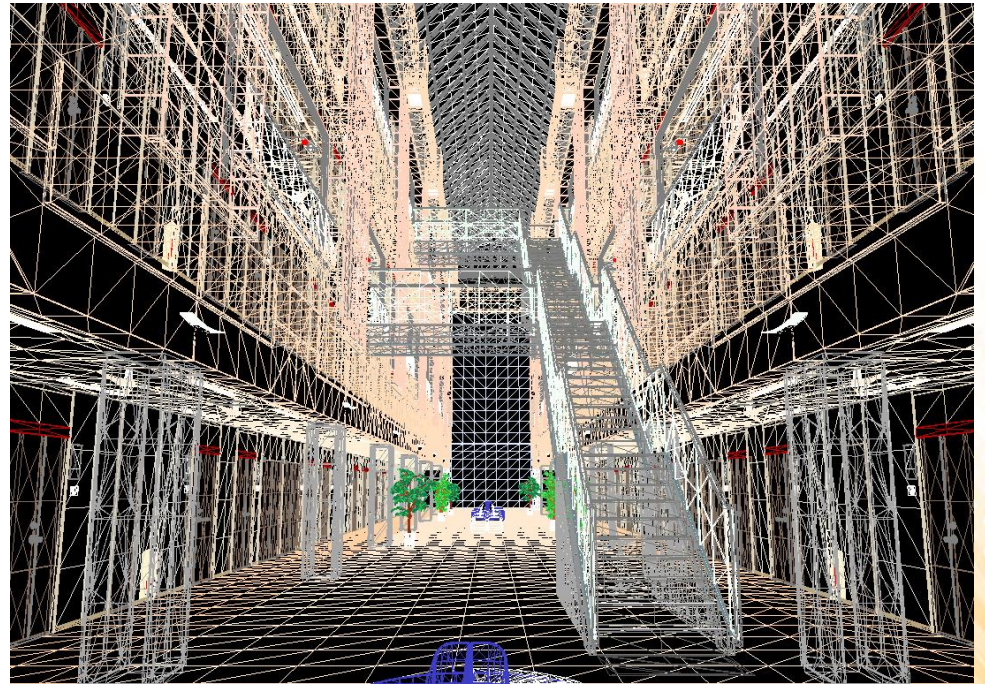
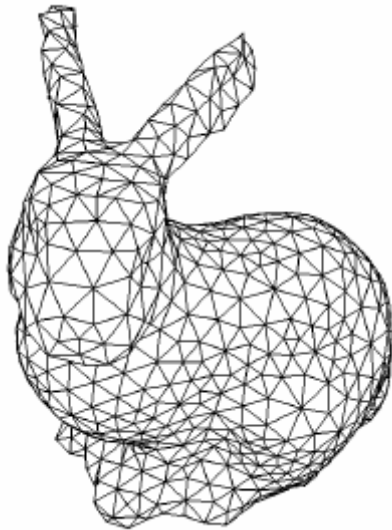
- **Computer graphics is a cross-disciplinary field:**
    - Physics (e.g.: model light behavior);
    - Mathematics (e.g.: describe shapes);
    - Human Perception (e.g.: only render things that will be noticed);
    - Human-Computer Interaction (e.g.: interaction devices);
    - Engineering (e.g.: optimize allocation of memory, and processor time);
    - Graphic Design and Art (e.g.: make the computer-to-human communication more effective);
- 

# What is Computer Graphics?



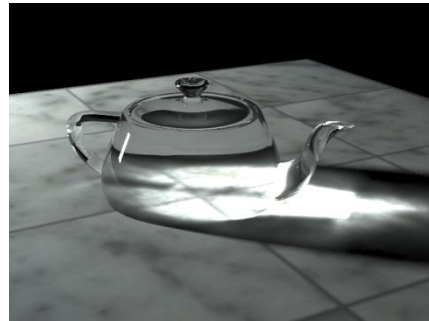
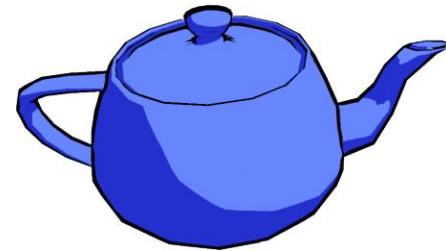
# Computer Graphics Areas

- **Modeling**: Deals with the mathematical specification of shape and appearance.
  - Definition of surface, interpolation rules, reflection models.



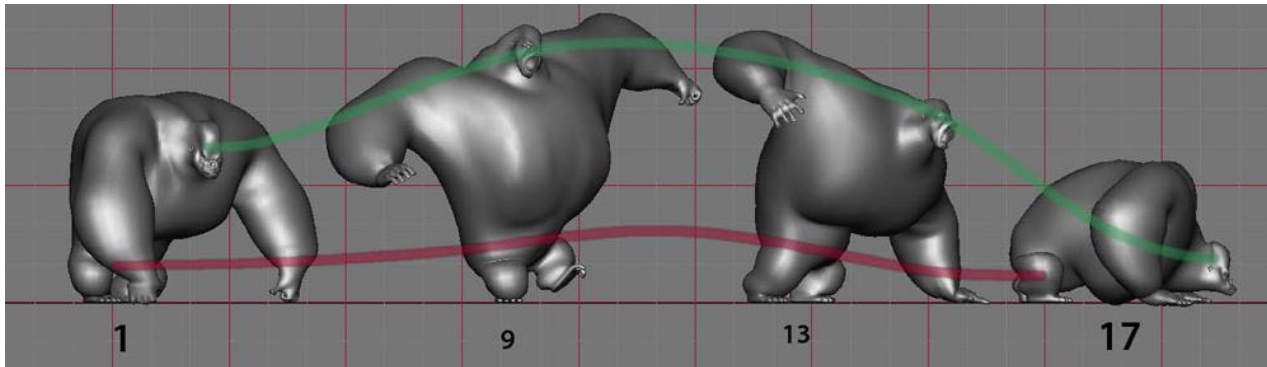
# Computer Graphics Areas

- **Rendering**: Term inherited from art – create shaded images from 3D computer models.
  - Many techniques and styles of rendering.



# Computer Graphics Areas

- **Animation**: technique to create an illusion of motion through sequences of images.
  - Time is a key issue, not usually dealt with in basic modeling and rendering.



Actor



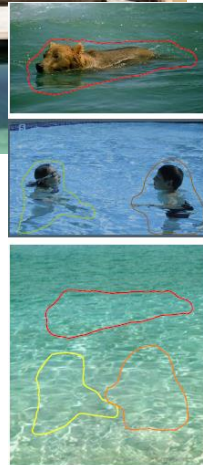
Cappellini



Oliver

# Computer Graphics Areas

- **Image processing**: deals with the manipulation of 2D images and is used in both the fields of graphics and vision.



sources/destinations



cloning



seamless cloning



# Computer Graphics Areas

- **Virtual reality**: attempts to immerse the user into a 3D virtual world.
  - Typically requires at least stereo graphics and response to head motion.



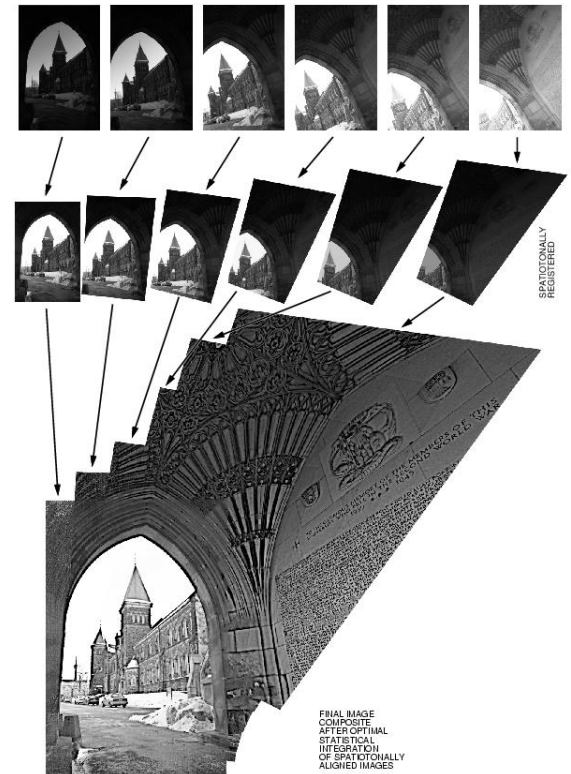
# Computer Graphics Areas

- **3D scanning**: uses range-finding technology to create measured 3D models.



# Computer Graphics Areas

- **Computational photography**: explores the use of computer graphics, computer vision, and image processing methods to enable new ways of photographically capturing objects, scenes, and environments.



# Applications – Video Games

- Video games increasingly use sophisticated 3D models and rendering algorithms.



# Applications – Cartoons

- Cartoons are often rendered directly from 3D models.
  - Many traditional 2D cartoons use backgrounds rendered from 3D models.



# Applications – Visual Effects

- Visual effects use almost all types of computer graphics technology.
  - Superimpose backgrounds with separately filmed foregrounds.
  - Synthetic environments, objects, and even characters.



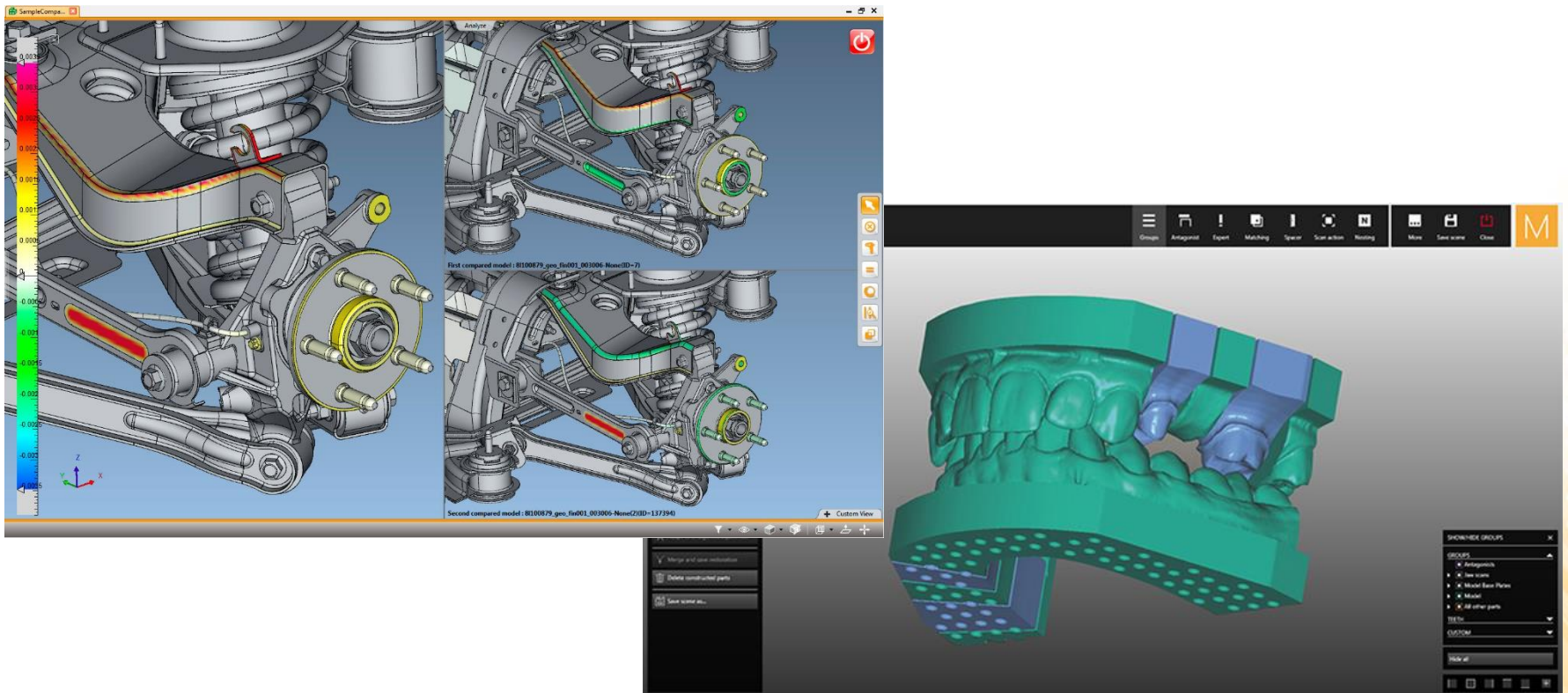
# Applications – Animated Films

- Animated films use many of the same techniques that are used for visual effects, but without necessarily aiming for images that look real.



# Applications – CAD/CAM

- Computer-Aided Design and Computer-Aided Manufacturing use computer technology to design parts and products on the computer to guide the manufacturing process.





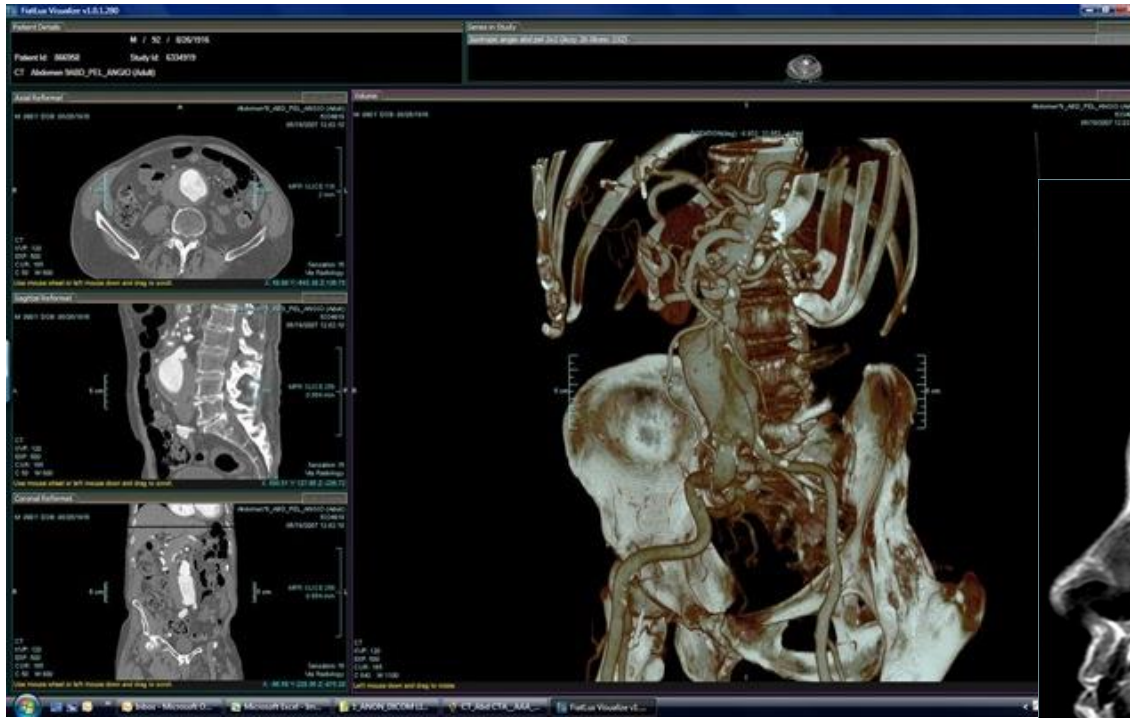
# Applications – Simulation

- Simulation can be thought of as accurate video gaming.



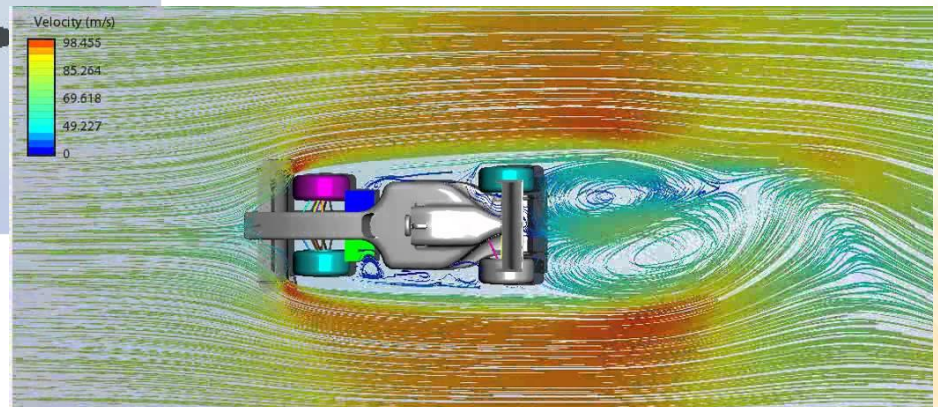
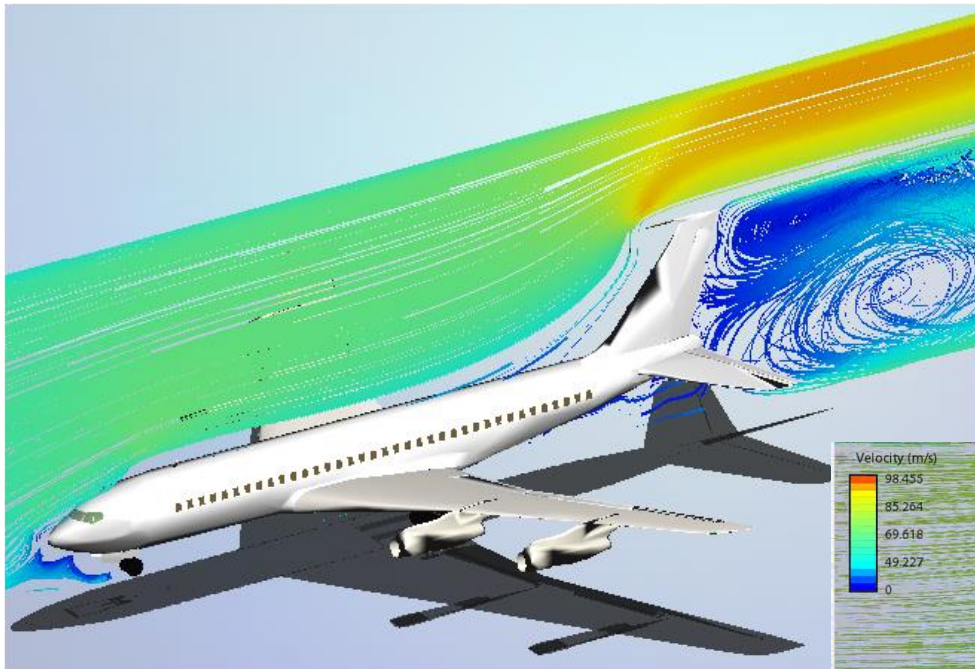
# Applications – Medical Imaging

- Medical imaging creates meaningful images of scanned patient data.



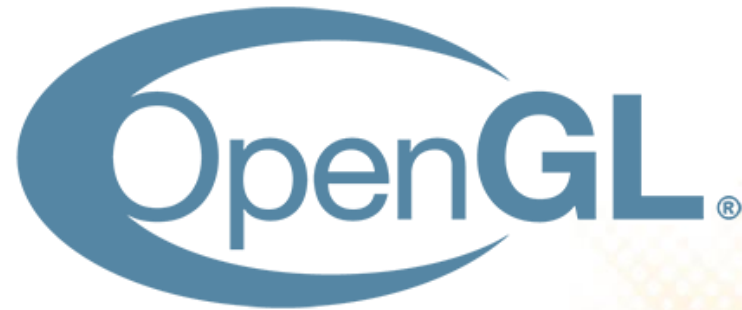
# Applications – Information Visualization

- Information visualization creates images of data that do not necessarily have a “natural” visual representation.



# Graphics APIs

- A graphics API (Application Program Interface) is a set of functions that perform basic operations such as drawing images and 3D surfaces into windows on the screen.
  - Graphics APIs vs User-Interface APIs.
- Dominant Graphics APIs: Direct3D and OpenGL.



# Graphics Hardware

- Computer hardware and software (graphics card and device driver) that generates computer graphics and allows them to be shown on a display.
- The processors on GPUs are highly parallel and support thousands of concurrent threads.
  - The hardware is designed to process larger numbers of pixels and vertices in short amounts of time.

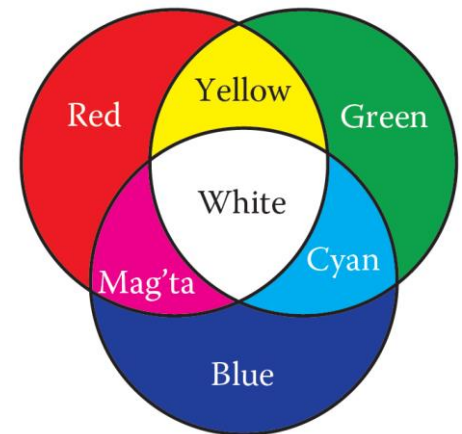
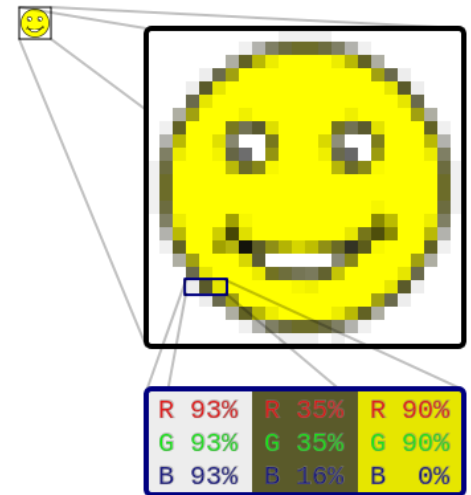


# Graphics Pipeline

- The Graphics Pipeline is a special software/hardware subsystem that efficiently draws 3D primitives on screen.
  - Is optimized for processing 3D triangles with shared vertices.
- The basic operations in the pipeline map the 3D vertex locations to 2D screen positions and shade the triangles so that they both look realistic and appear in proper back-to-front order.
  - Geometric manipulation using matrices and vectors.
- The speed at which images can be generated depends strongly on the number of triangles being drawn.

# Raster Images

- Most computer graphics images are presented to the user on some kind of raster display.
  - Raster displays show images as rectangular arrays of pixels.
  - Different colors are achieved by mixing varying intensities of red, green, and blue light.
- A raster image is simply a 2D array that stores the pixel value for each pixel—usually a color stored as three numbers, for red, green, and blue (RGB model).



# Raster Devices

- **Displays:**

- Current displays (televisions, computer displays, digital cinematic projectors) are nearly universally based on fixed arrays of pixels.
- Emissive displays directly emit controllable amounts of light (e.g. LED).
- Transmissive displays require a light source to illuminate the pixels, which vary the amount of light that they allow to pass (e.g. LCD).

- **Input Devices:**

- Digital cameras are 2D array input devices. The image sensor is a semiconductor device with a grid of light-sensitive pixels.
- The camera's lens projects an image of the scene to be photographed onto the sensor, and then each pixel measures the light energy falling on it, ultimately resulting in a number that goes into the output image.



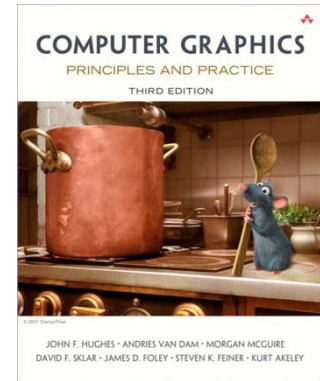
# Graphics Coding Tips

- **Class Design:** vector2, vector3, vector4, matrix4x4, transform, ...
- **Float vs. Double:** tradeoff between performance and precision.
- **Optimizations** are important, but unnecessary "optimizations" make the code harder to read without speeding things up.
- **Debugging Graphics Programs:**
  - Images as coded debugging output;
  - Traditional debugger;
  - Data visualization for debugging;

# Further Reading

- Hughes, J. F., et al. (2013). **Computer Graphics: Principles and Practice** (3rd ed.). Upper Saddle River, NJ: Addison-Wesley Professional. ISBN: 978-0-321-39952-6.

- **Chapter 1: Introduction**



- Marschner, S., et al. (2015). **Fundamentals of Computer Graphics** (4th ed.). A K Peters/CRC Press. ISBN: 978-1482229394.

- **Chapter 1: Introduction**

- **Chapter 3: Raster Images**

