Computergrafik 1

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Sommersemester 2013

Chapter 1 - Introduction, Motivation, Basics

- About this Class: Organization
- Tutorials
- Why Should I Learn about Computer Graphics?
- Very Brief History of Computer Graphics
- Computer Graphics Hardware: Basics
- Math Recap: What We Need to Survive...

About this class: Organization

- Mainly Bachelor Medieninformatik, 4th semester
- All other students, please check how course can be recognized

- Lecture: Andreas Butz
- Thursday, 2-4pm, Hauptgebäude, Room E004
  - Lecture (2 hours) + tutorials (2 hours)
  - Start c.t., break?

- PDF of the slides: night before class, print out and bring to take notes and **fill in blanks**
- Podcast: night after class

image source: mimuc.de

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About the Tutorials: Organization

- Tutorials: Henri Palleis
  - Will start on April 29th
  - Discussion of assignments

- Weekly assignments, in sync with lecture
  - http://www.medien.ifi.lmu.de/lehre/ss13/cg1/
  - Submission **voluntarily** (means: No bonus points!)
  - students who did the exercises statistically got better grades!

- Purpose:
  - In-depth understanding of concepts from lecture
  - Gaining some basic practical experience in low-level graphics programming
  - Preparation for written test (best preparation strategy: do the assignments)
  - Please note: Tutorials and assignments are a ***service*** for the students

image source: mimuc.de

Schedule I

- Tutorial dates:
  - Monday, 12 – 14 (Amalienstraße 73A, Raum 114)
  - Monday, 14 – 16 (Theresienstraße 41, C112)
  - Tuesday, 10 – 12 (Geschwister-Scholl-Platz 1, M101)
  - Wednesday 16 – 18 (Amalienstraße 73A, Raum 114)
  - Wednesday 18 – 20 (Amalienstraße 73A, Raum 114)

Schedule II

- Registration for the tutorials will open **tonight at 8pm**

- Register via UniWorX:
  https://uniworx.ifi.lmu.de/

- First assignment will be published today
- First tutorial on Monday April 29th

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Why should I learn about Computer Graphics?

- Basis for graphical digital media
  - –in the heart of your study and many future jobs!

- Basis for recent CG movies and SFX
  - –practically no more movies without it!

- Basis for many computer games
  - –market bigger than the film industry

source: http://sketchup.google.com

2D vs. 3D graphics vs. Pixels (see „Digitale Medien“)

- Pixel-based graphics
  - given resolution, describe color at each pixel
  - basis for digital photography
  - whole research area of image processing

- 2D graphics (aka vector graphics)
  - uses 2D lines and areas to describe an image
  - 2D drawing programs: Inkscape, Illustrator, Corel Draw, ...

- 3D graphics
  - describe 3D objects of a scene
  - compute what light would do to these objects
  - compute pixel image from a virtual camera

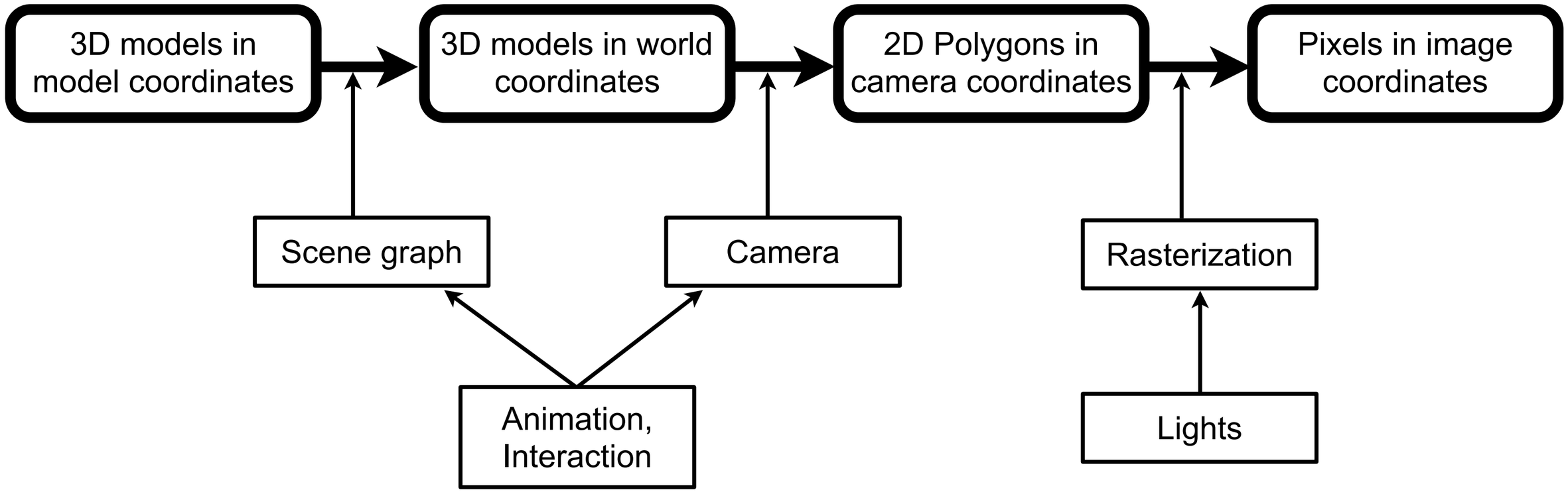
source: http://static.technorati.com/10/01/20/3467/Avatar-movie-Wallpapers.jpg

...so: 3D content on a 2D screen, huh?

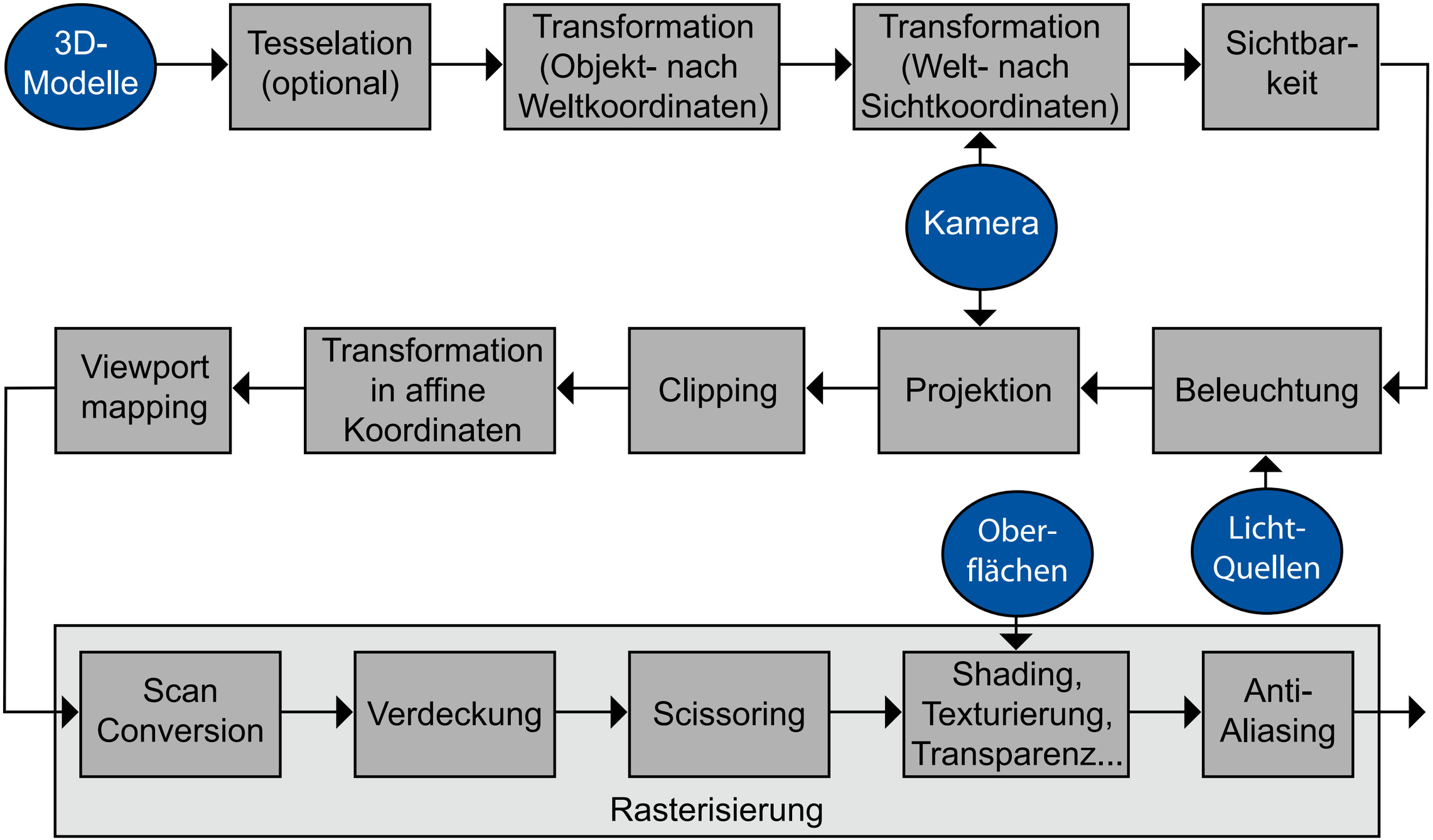
- General problem: current screens are 2D
  - for true 3D perception, we need 2 images for the 2 eyes (stereo)
  - this is technically still difficult (need glasses)
  - research area of volumetric or (auto)stereoscopic displays

- Content is 3D, display is 2D: what problems does this bring?

The 3D rendering pipeline (our version for this class)



...this was not the only way to draw this pipeline...



Lecture Content & Schedule

18 April	1. Organization, Motivation, Basics
25 April	*no lecture!*
02 May	*no lecture!*
09 May	*no lecture!*
16 May	3. Mathematical Concepts for Computer Graphics
23 May	4. 3D Modeling
30 May	*no lecture!*
06 June	5. 3D Camera, Culling, Rasterization
13 June	6. Scene Graph
20 June	7. Light, Materials, Appearance
27 June	8. Shading and Rendering
04 July	9. Basics of 3D Animation
11 July	10. Interactive 3D Graphics
23 July	Klausur

Literature Recommendations and links

- Malaka, Butz, Hussmann: Medieninformatik, Pearson Studium 2009
  - v.a. Kapitel 8: 3D-Grafik
- Bungartz, Griebel, Zenger: Einführung in die Computergraphik, 2. Auflage, Vieweg, 2002
- Hearn, Baker, Carithers: Computer Graphics with OpenGL, 4th edition, Pearson 2011
- Foley, Van Dam, Feiner: Computer Graphics – Principles and Practice, 2nd edition, Addison-Wesley, 1996
- Watt, A. et al.: Advanced Animation and Rendering Techniques.: Theory and Practice, Addison Wesley, 1992
- OpenGL: www.opengl.org
- Three.js: http://threejs.org/

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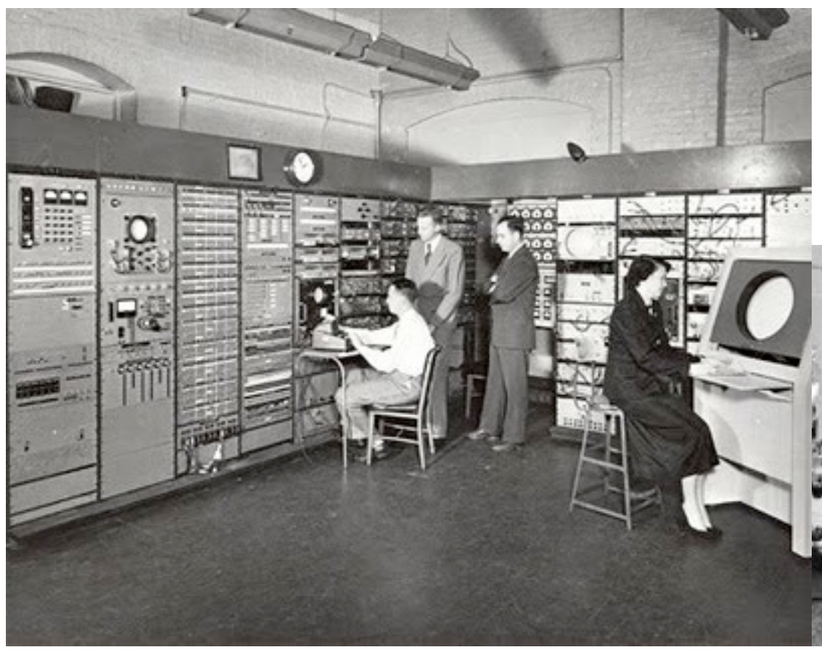
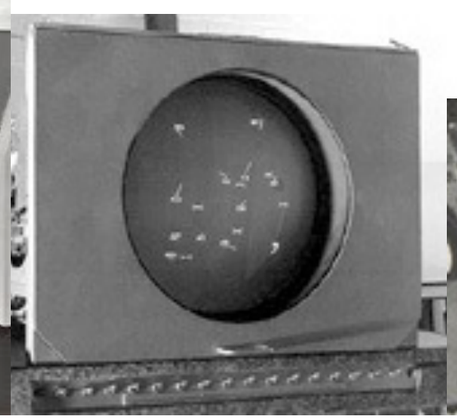
Based on lecture material by Regina Pohle-Fröhlich

First Steps Towards Computer Graphics 1945 – 1963



wired.com

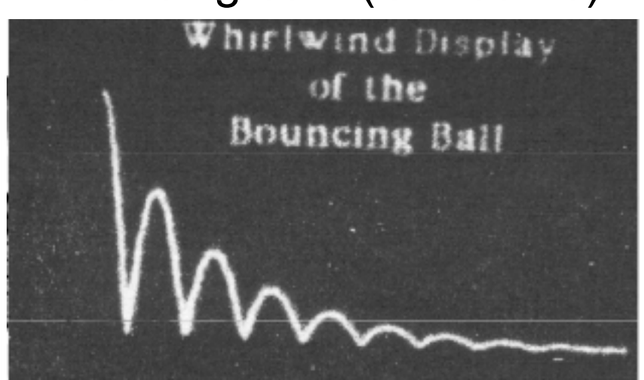
1945-1952: “Whirlwind” computer (Jay Forrester, MIT)
Digital computer using oscilloscope screen displaying real-time aircraft data, later “SAGE” system



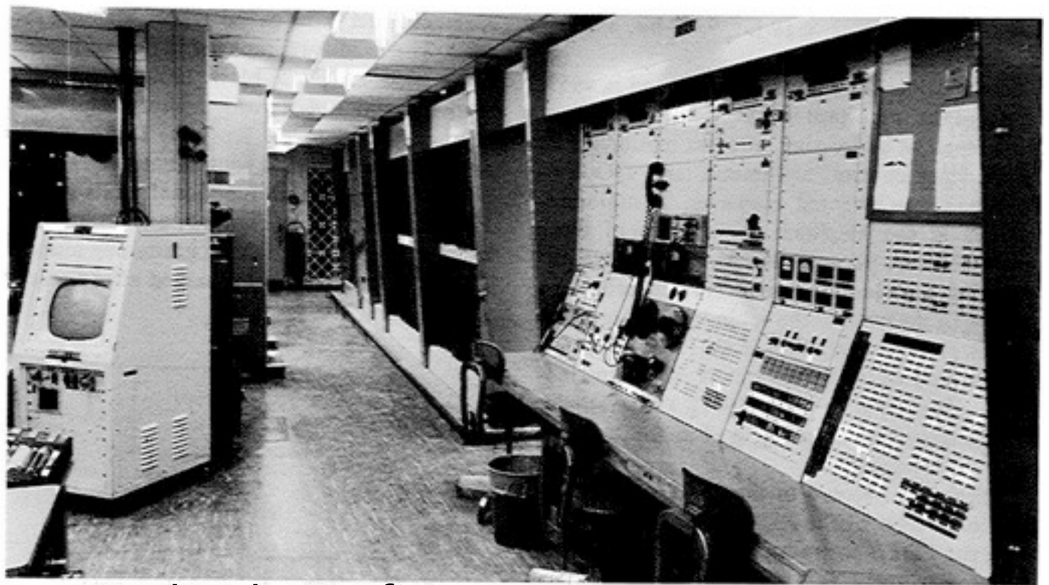
design.osu.edu/carlson/history

Using “light pen” for input

“Bouncing ball” (C. Adams)



www.rendering.ovgu.de



research.microsoft.com

1957-1969: “TX-2” computer at MIT Lincoln Lab
Transistor-based computer providing interactive graphic displays
L.G. Roberts, 1962: 3D Graphics
Ivan Sutherland, 1963: Sketchpad

computerhistory.org

Theory Development in the 1970s

- 1971: Raster Scan Principle (M. Noll, Bell Labs)
  - Connecting a TV-like display with computer memory
- 1973: First ACM “SIGGRAPH” Conference
- 1971-1975: Shading algorithms (Gouraud 1971, Phong 1975)
- 1977-1978: Shadow computation (Crow, Williams)
- 1975: 3D Model “Utah Teapot” (M. Nevell, U. Utah)
- 1979: Raytracing (mirror reflection, transparency) (Kay, Whitted)
- 1984: Global illumination model “radiosity” (Goral et al., Nishita)

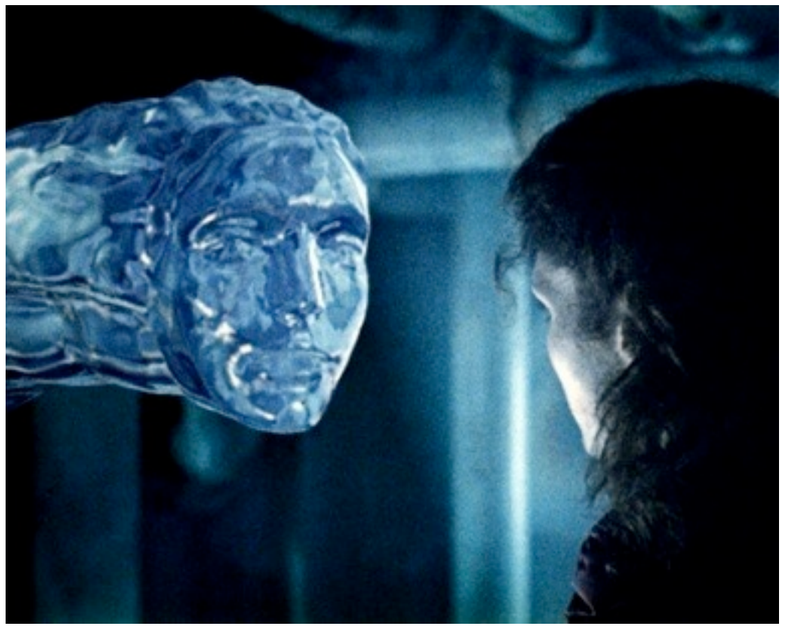
Utah Teapot
at Computer History Museum, Boston

wikipedia.org

Computer Graphics Goes to Cinema: 1980s

- 1979: Computer Graphics department of Lucas Film founded (ILM)
- 1980: Demonstration of video “Vol Libre” (L. Carpenter) at SIGGRAPH
- 1980: Computer Animations in movie “Tron”
- 1981: Predecessor of “Renderman” (REYES) by L. Carpenter at Lucas Film
- 1986: “Pixar” founded (Catmull, Smith), split off Lucas Film
- 1988: Movie “The Abyss” (Water creature by Lucas Film ILM)
- 1989: Motion Capturing (Jim Henson)
- 1995: Movie “Toy Story” (Pixar, fully computer-generated)

Vol Libre atariarchives.org



Abyss empireonline.com

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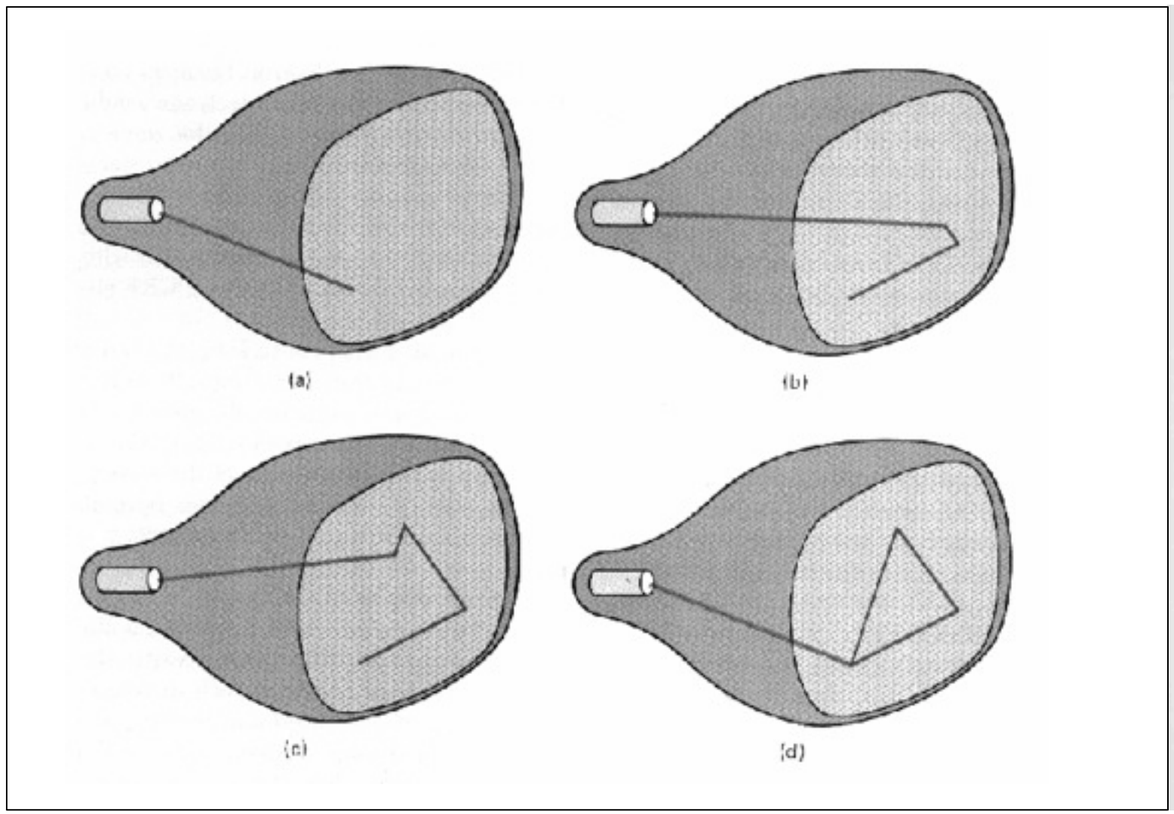
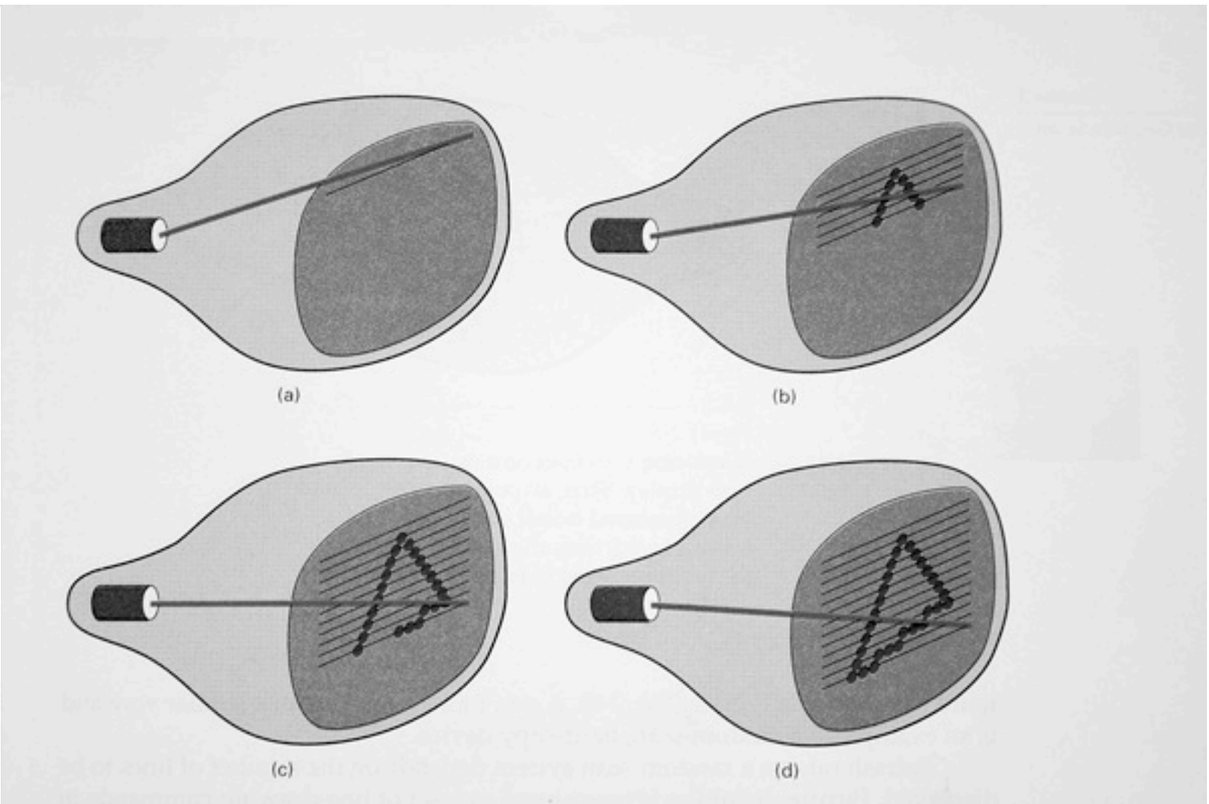
Types of Screens

- Note: Graphics output is generated also for other devices, like printers!
- Traditional distinction, makes sense mainly for Cathode Ray Tubes:
  - Random Scan Display (vector display)
  - Raster Scan Display



Random Scan



Raster Scan

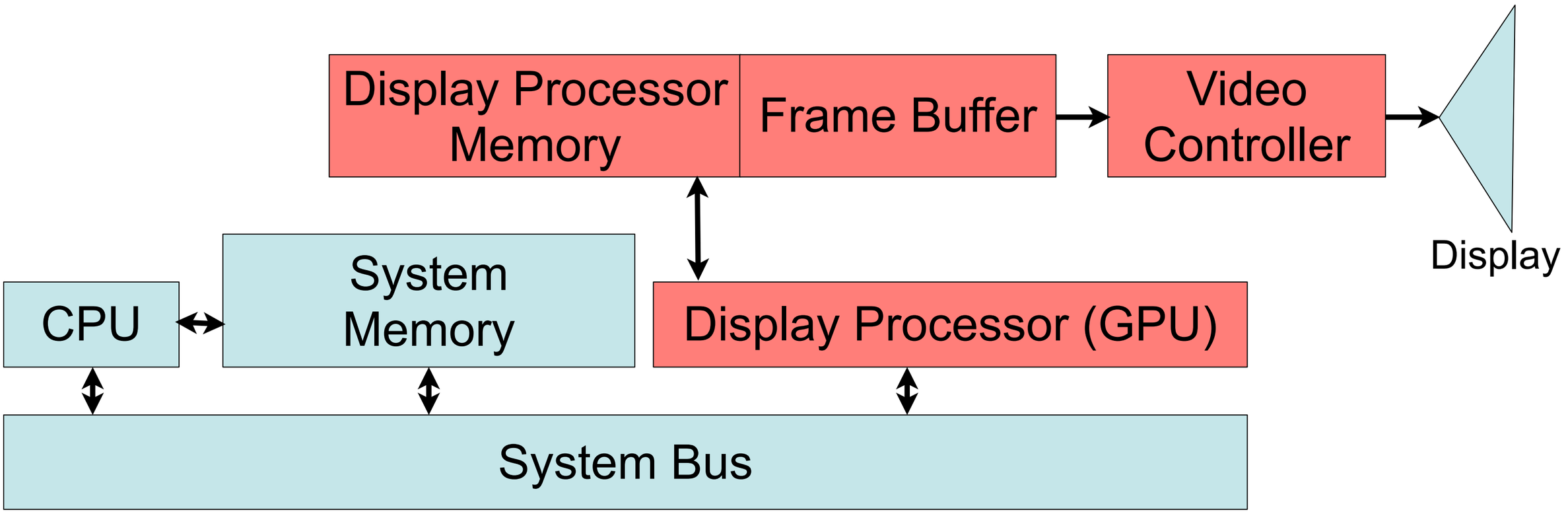
Display Technologies

- Cathode Ray Tube (CRT)
- Liquid Crystal Display (LCD)
  - in particular Thin Film Transistor (TFT) technology
- Plasma Displays

- Color created by enhanced resolution plus color filters

- Device coordinates:
  - Given by resolution of given display
  - Low level picture element (“pixel”) shows individual RGB value

Graphics Subsystems



- Memory:
  - From segment of system memory to large dedicated memory hardware
  - Stores more than just frames: E.g. Objects and texture data
- High-Performance Graphics Processing Unit (GPU)
  - Carries out specialized algorithms like texture mapping, antialiasing, rendering polygons, geometric calculations, programmable shaders
- Digital Analog Conversion (“RAMDAC”)

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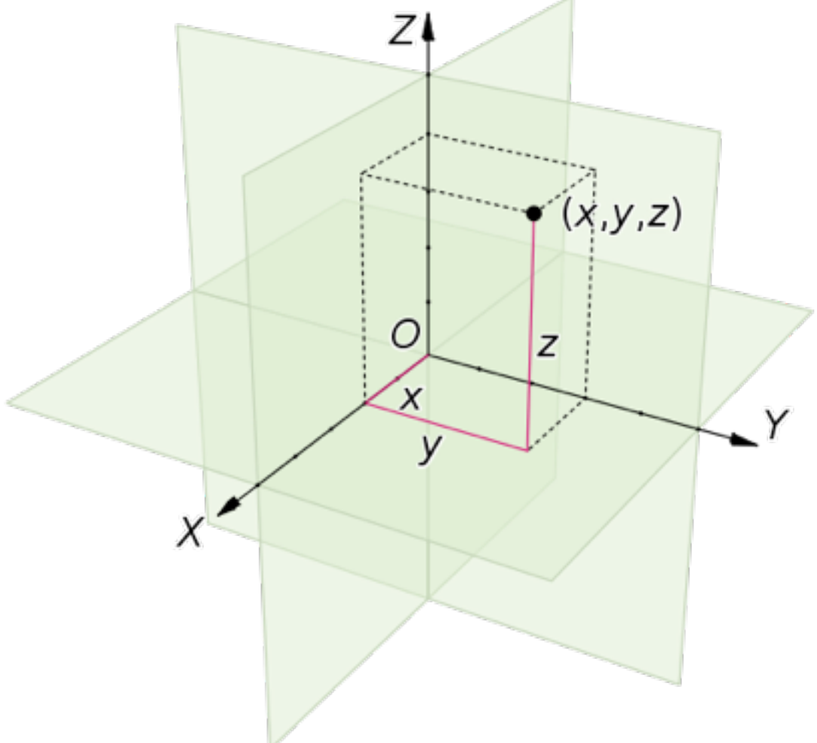
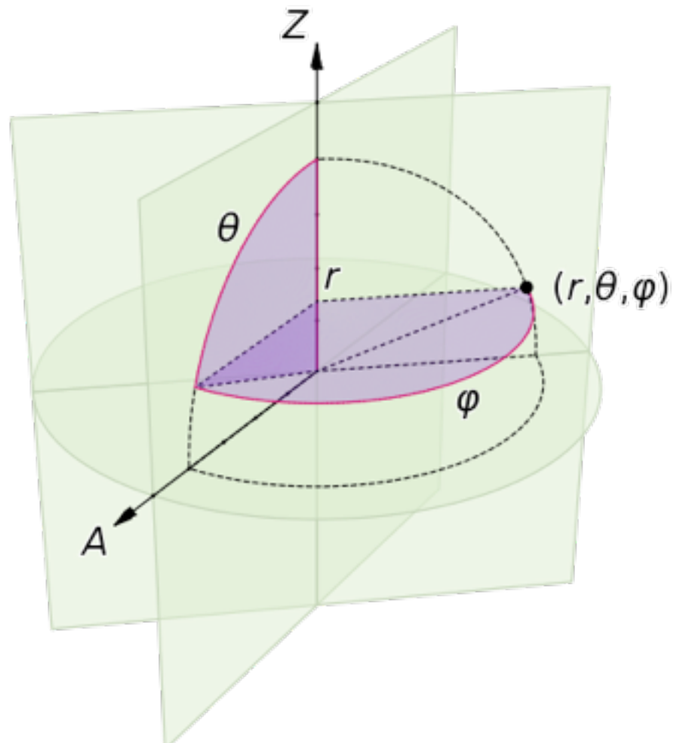
Coordinate Reference Frames

- Dimensionality
  - We will meet: 2, 3 and 4 dimensions
- Types of coordinate systems
  - Cartesian (rectilinear): Pairwise orthogonal axes with (identical) linear scale
  - Non-cartesian (curvilinear): Many other systems
    - e.g. polar/spherical coordinates: angle plus distance

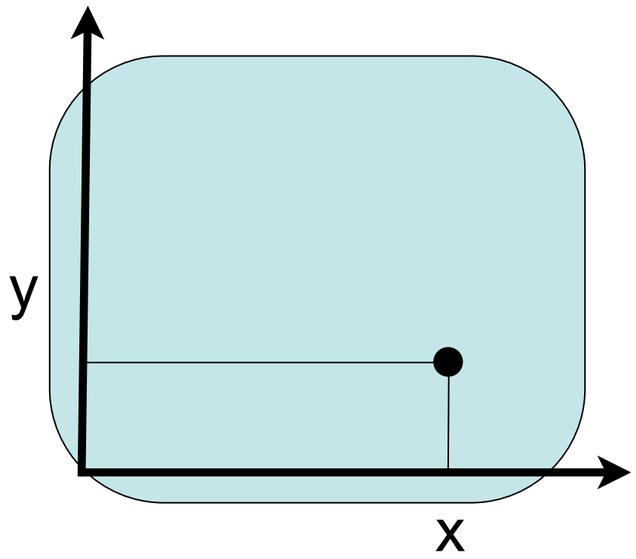


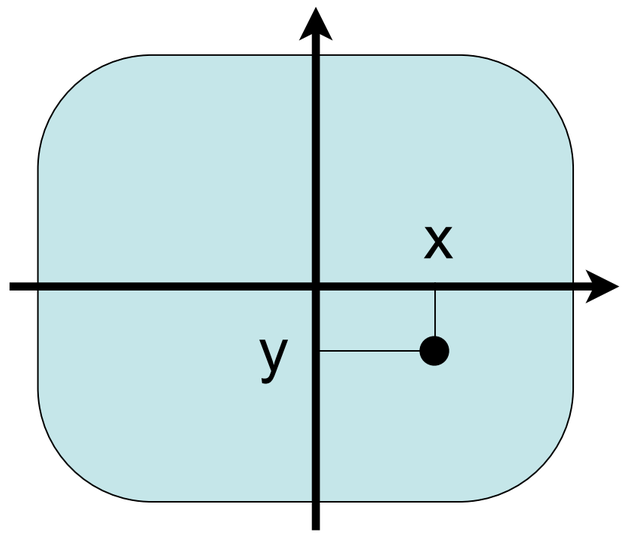


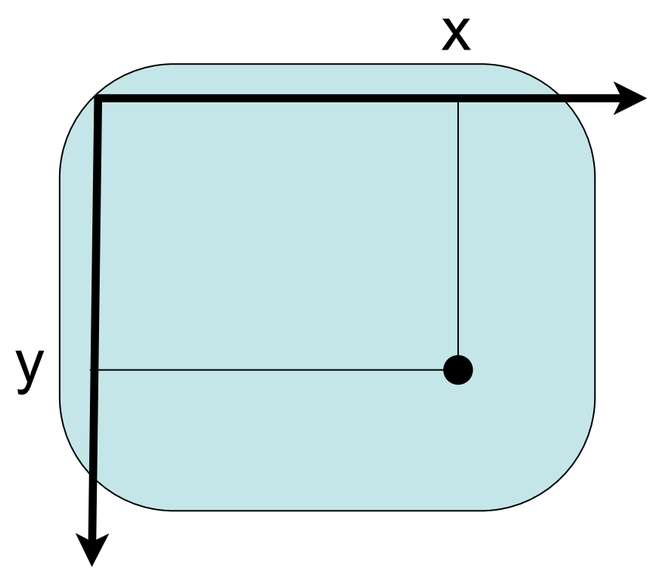
Images: Wikipedia

2D Cartesian Coordinate Reference Frames

Device-independent commands of graphics packages:
Varying schemata: origin may be in lower-left corner, center, upper-left corner





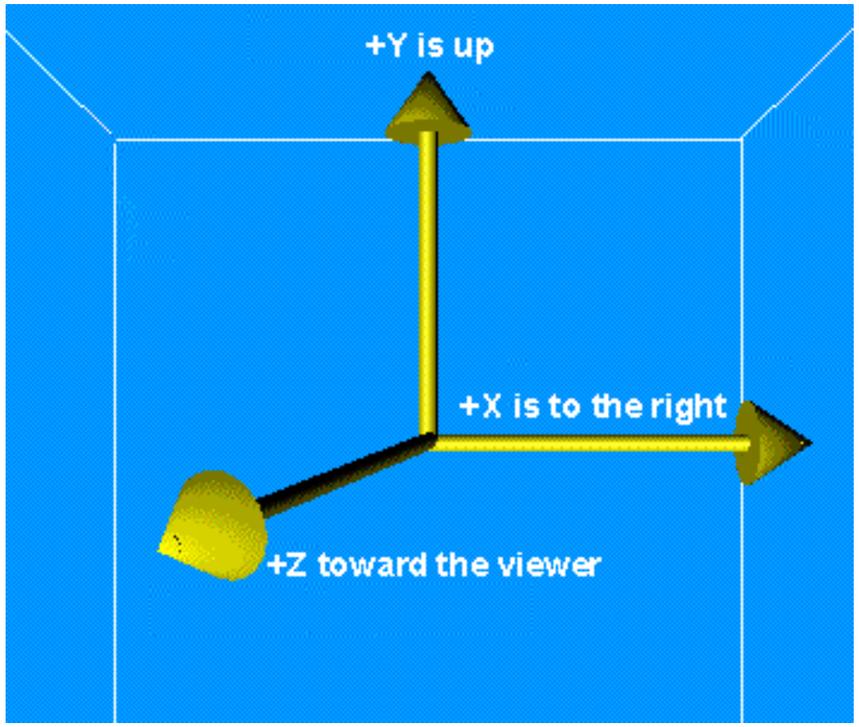


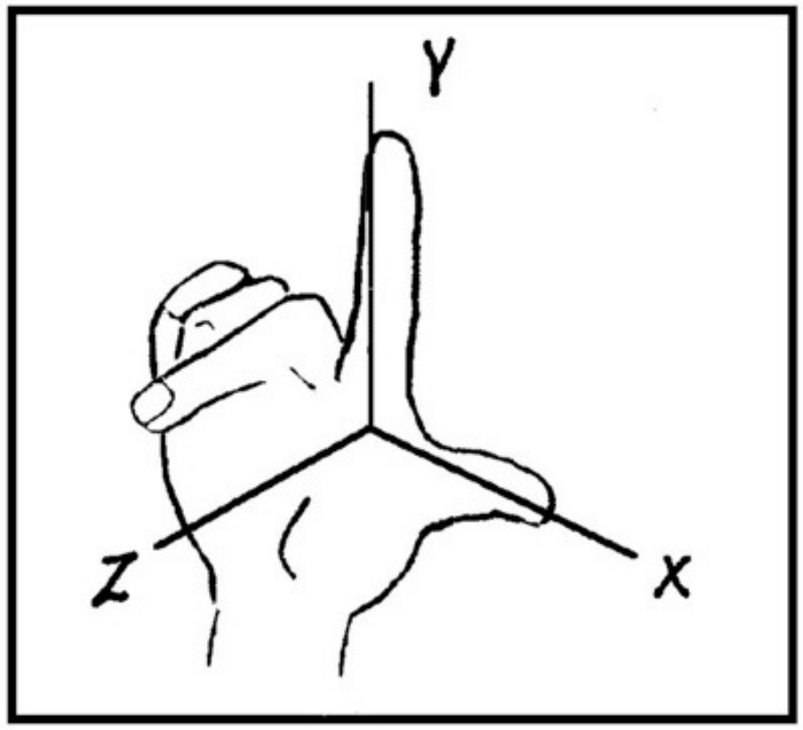
Device coordinates:
- Scan lines on cathode ray tubes, printers:
  origin in upper left corner, y axis points downwards
- Other devices: Origin in lower-left corner

Normalized device coordinates: Range from 0.0 to 1.0 (real number)
Physical device coordinates: Integers (pixel address)

Standard 3D Cartesian Coordinate Reference Frames

- Most frequently used “world coordinates” (e.g. in OpenGL):
  “Right handed” system, often depicted as looking from z axis





Pictures:
euclidianspace.com,
cornell.edu

- “Left handed” system used in special cases
  (e.g. 2D screen positions with additional depth information)

Points and Vectors

- *Point*
  - Position specified with coordinate values in some reference frame
  - e.g. in 3D Cartesian coordinates: (p_x, p_y, p_z)
- *Vector*
  - Tuple of real numbers, considered as element of a vector space
  - Often written vertically (column vector)

$$\begin{pmatrix} p_x \\ p_y \\ p_y \end{pmatrix}$$

  - In CG, people are sloppy about the diference between row and column vectors!
- Difference between two positions gives a vector
- Position can be specified by vector from origin in Cartesian system
- Vectors can be multiplied with a real number pointwise
- Two vectors of same length can be added pointwise

Properties of Vectors

- Magnitude (length)

$$a = \left(a_x, a_y, a_z\right) \qquad ||a|| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

- Direction angles

$$\cos\delta_x = \frac{a_x}{||a||} \qquad \cos\delta_y = \frac{a_y}{||a||} \qquad \cos\delta_z = \frac{a_z}{||a||}$$

Scalar Product (Dot Product)

- The *scalar product* computes a real (scalar) value from two coordinate vectors of equal length

$$\begin{pmatrix} a_x \\ a_y \\ a_z \end{pmatrix} \bullet \begin{pmatrix} b_x \\ b_y \\ b_z \end{pmatrix} = a_x b_x + a_y b_y + a_z b_z$$

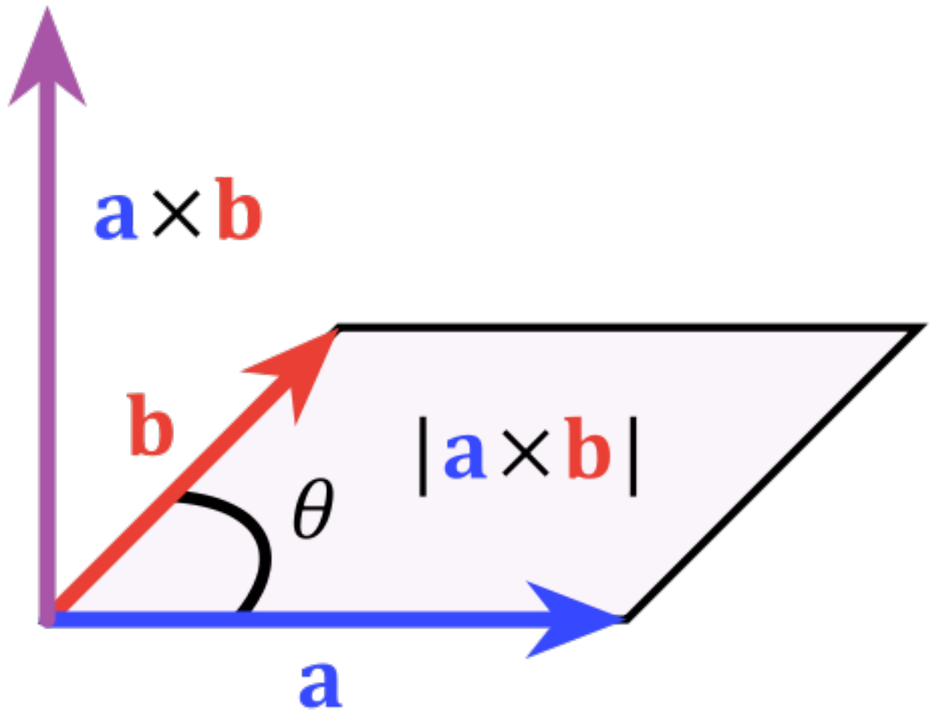
- Application: Computation of angle between two coordinate vectors

$$a \bullet b = \|a\| \cdot \|b\| \cdot \cos\alpha$$

Cross Product (Vector Product)

- The *cross product* of two coordinate vectors is a vector which is perpendicular to both given vectors
  - Direction: Right-hand rule
  - Magnitude: Equals spanned parallelogram

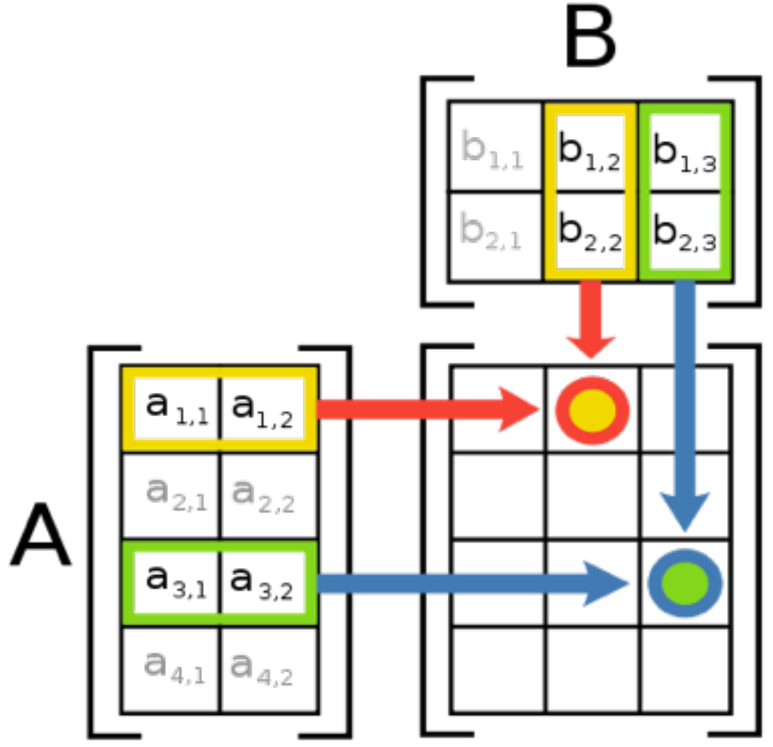
$$\begin{pmatrix} a_x \\ a_y \\ a_z \end{pmatrix} \times \begin{pmatrix} b_x \\ b_y \\ b_z \end{pmatrix} = \begin{pmatrix} a_y b_z - a_z b_y \\ a_z b_x - a_x b_z \\ a_x b_y - a_y b_x \end{pmatrix}$$



Matrices

- A *matrix* is an (*m*×*n*) arrangement of real numbers (*m* rows, *n* columns)
- Used in CG for expressing computations on coordinate vectors
- A matrix can be multiplied with a real number pointwise
- Two matrices of identical dimensions can be added pointwise
- Multiplying matrices:
  (*m*×*p*)-matrix *A* multiplied by (*p*×*n*)-matrix *B* gives (*m*×*n*)-matrix *C*

$$C_{i,j} = \sum_{k=1}^{p} A_{ik} \cdot B_{kj} \qquad \begin{aligned} 1 \le i \le m, \\ 1 \le j \le n \end{aligned}$$



Multiplying a Matrix and a Vector

- Special case of matrix multiplication
- (*m*×*p*)-matrix *A* multiplied with vector *v* of length *p* gives vector *w* of length *m*

$$w_j = \sum_{k=1}^{p} A_{ik} \cdot v_k$$