Introduction To Computer Graphics

By Ahmad Elhoni

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Chapter One

- What is Computer Graphics
- History of computer graphics
- Graphics Areas
- Major Applications
- Graphics APIs
- Common Terms
- Summary

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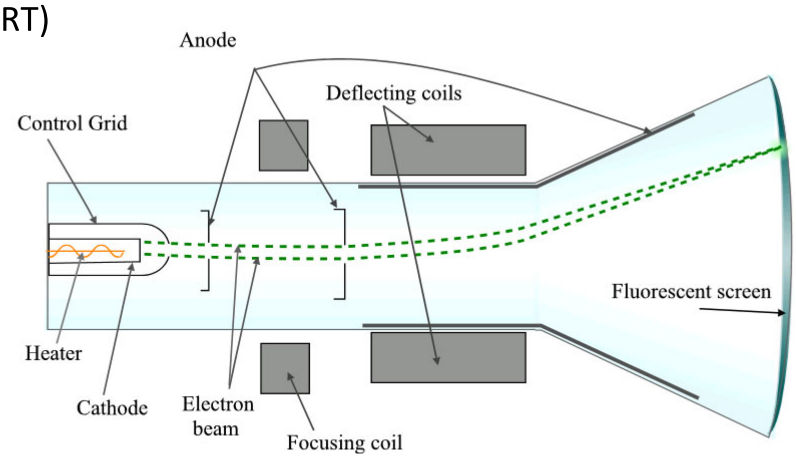
What is Computer Graphics

- **Computer graphics** is the art* of drawing pictures on computer screens with the help of computers.
- Graphics is all around us or even more!
- From captured images to fantasy games.
- Everyone uses computer graphics: children, students, engineers and scientists … etc.
- There are no limits for computer graphics.
- Almost everything on computers that is not text or sound.

History of computer graphics

- Pre-1950s (CRT)



History of computer graphics-cont.

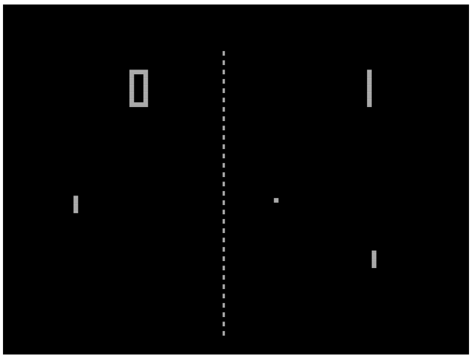
- 1950s (**SAGE** Sector Control Room)

History of computer graphics-cont.

- 1960s (**Spacewar!** running on the Computer History Museum's PDP-1)

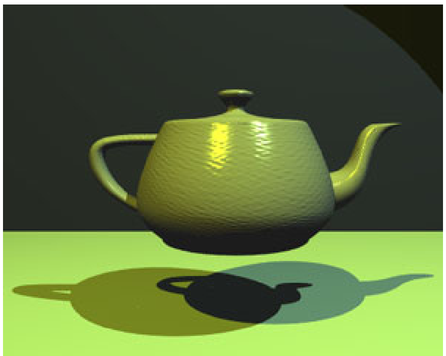
History of computer graphics-cont.

- 1960s (**Pong** arcade version)



History of computer graphics-cont.

- 1970s (The **Utah** teapot by Martin Newell and its static renders became emblematic of CGI development.)



History of computer graphics-cont.

- 1980s (Donkey Kong was one of the video games that helped to popularize computer graphics to a mass audience.

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History of computer graphics-cont.

- 1990s (Sony launched PlayStation)

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History of computer graphics-cont.

- 2000s (A screenshot from the videogame **Killing Floor**, built in **Unreal Engine** 2. Personal computers and console video games took a great graphical leap forward, becoming able to display graphics in real time computing that had previously only been possible pre-rendered and/or on business-level hardware.)

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History of computer graphics-cont.

- 2010s (A diamond plate texture rendered close-up using **physically based rendering** principles – increasingly an active area of research for computer.)

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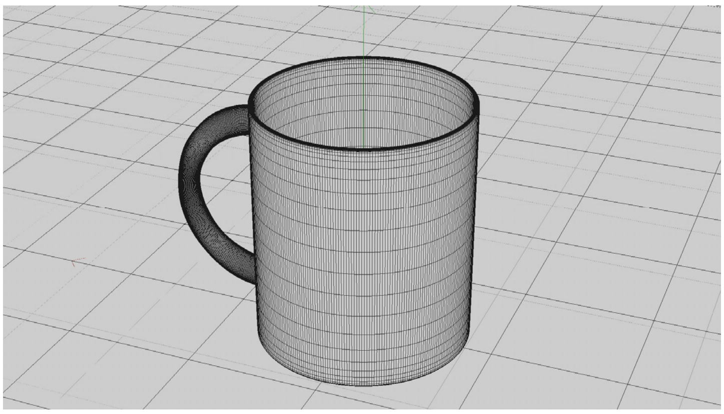
History of computer graphics-cont.

- 2020s (the future of CG!)

Graphics Areas

- **Modeling** deals with the mathematical specification of shape and appearance properties in a way that can be stored on the computer.



Graphics Areas-cont.

- **Rendering** is a term inherited from art and deals with the creation of shaded images from 3D computer models.

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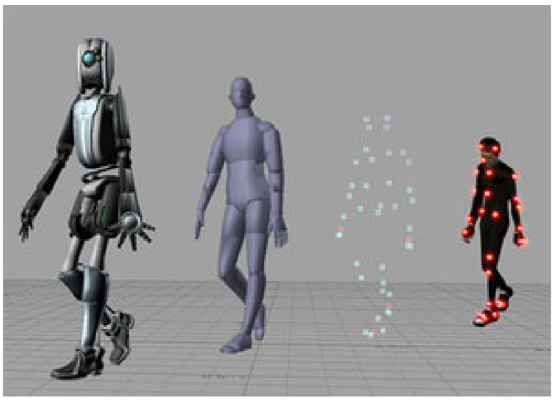
Graphics Areas-cont.

- **Animation** uses modeling and rendering but adds the key issue of movement over time.



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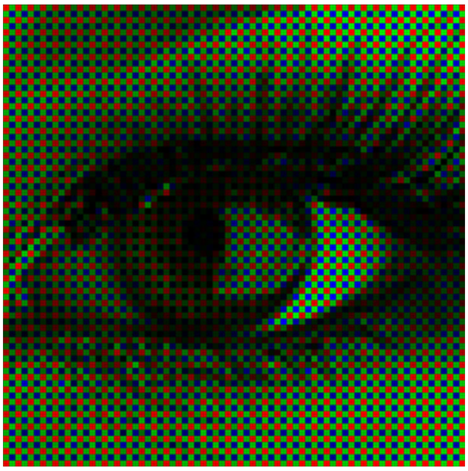
Other Areas

- User interaction
- Virtual reality
- Visualization
- Image processing
- 3D scanning
- Computational photography



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Major Applications

- Video games

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Major Applications-cont.

- Cartoons

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Major Applications-cont.

- Visual Effects

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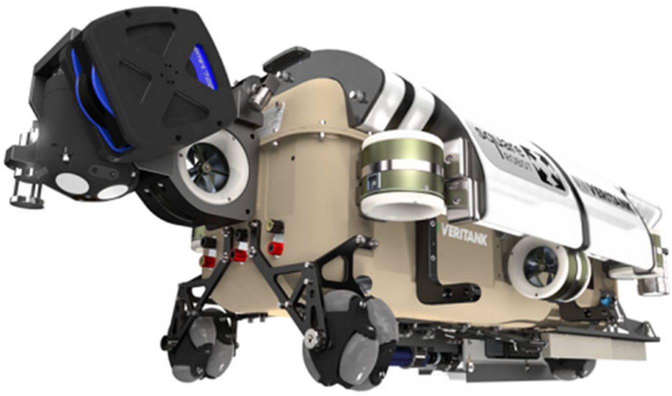
Major Applications-cont.

- Animated films

Major Applications-cont.

- CAD/CAM



Major Applications-cont.

- Simulation

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Major Applications-cont.

- Medical imaging

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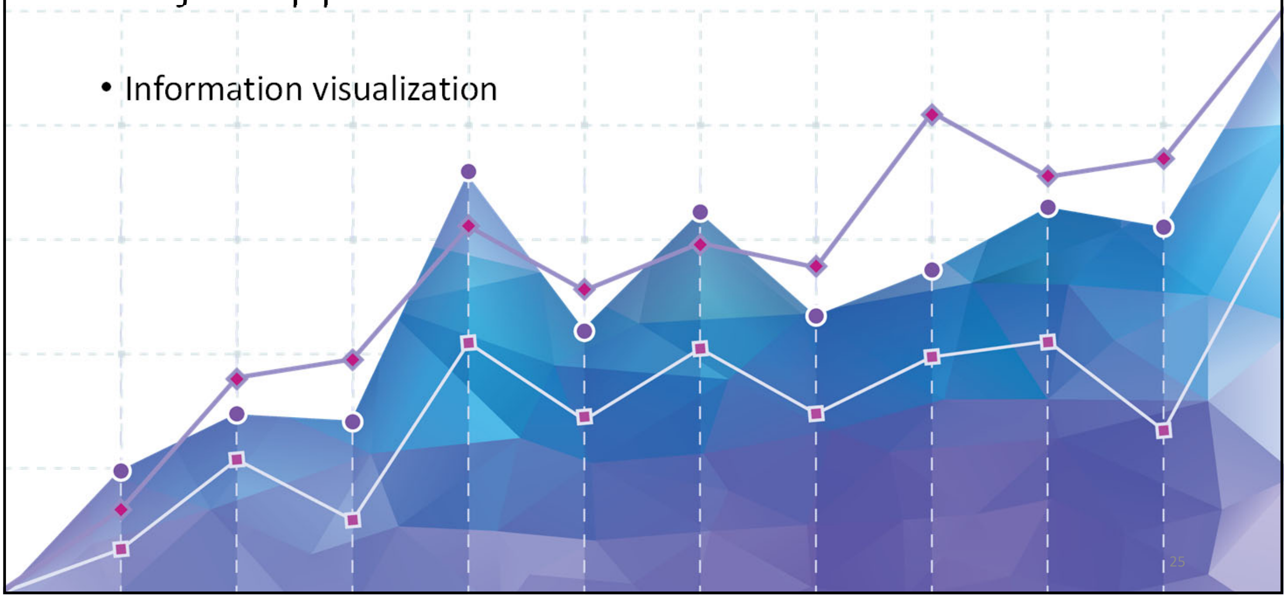
Major Applications-cont.

- Information visualization



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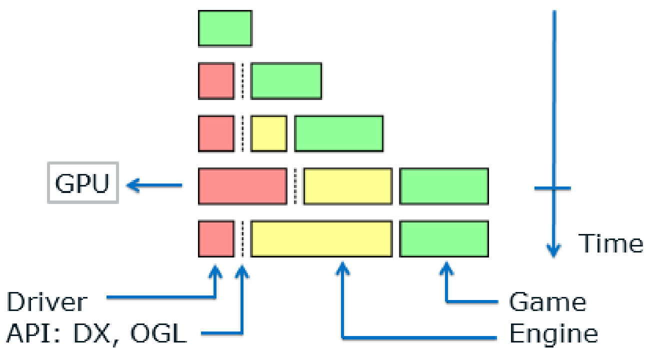
Graphics APIs

- CG requires knowing about specific hardware, file formats, and usually a graphics API.
  - Vulkan
  - Metal
  - WebGPU
  - OpenGL
  - DirectX 12.x
  - DirectX 11.x



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Common Terms

- **Pixel**: Picture Element.
- **Voxel**: Volume Element.
- **GPU**: Graphics Processing Unit.
- **API**: Application Programming Interface
- **CAD**: Computer Aided Design
- **CAM**: Computer Aided Manufacturing
- **VR**: Virtual Realty
- **AR**: Augmented Realty
- **CGI**: Computer-generated imagery

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Common Terms-cont.

- **VGA**: Video Graphics Array
- **SVGA**: Super Video Graphics Array
- **HDR**: High dynamic range
- **Texel**: Texture Element
- **HDMI**: High-Definition Multimedia Interface
- **DVI**: Digital Visual Interface
- **LCD**: Liquid Crystal Display
- **LED**: Light Emitting Diodes
- **OLED**: Organic Light Emitting Diodes

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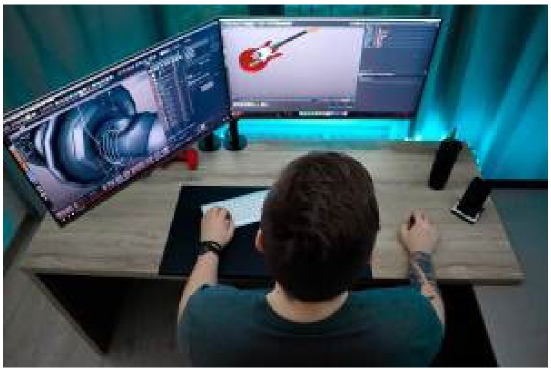
Famous 3D packages

- 3ds Max
- Maya
- Houdini
- Blender
- Cinema 4D
- Softimage
- SketchUp



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Summary

- Computer Graphics is around us all
- Any thing can be done using proper CG tools and techniques
- Computer graphics has evolved rapidly
- We have studied the main areas of computer graphics
- Computer graphics involve many applications
- There are many 3D Graphics APIs and packages.

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Chapter Two

- Sets and Mappings
- Solving Quadratic Equations
- Trigonometry
- Vectors
- Curves and Surfaces
- Linear Interpolation
- Summary

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Sets and Mappings

- Mappings, also called functions,
- Like a function in programs a map takes an argument and return an object of a particular type.
- In a program we say “type”; in math we would identify the set.
- When we have an object that is a member of a set, we use the ∈ symbol. For example,

$$a \in \boldsymbol{S}$$

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Sets and Mappings-cont.

- Given **A** and **B** sets, we can create a third set by

$$\mathbf{A} \times \mathbf{B}$$

is composed of all possible ordered pairs (a, b)
where $a \in \mathbf{A}$ and $b \in \mathbf{B}$

- Common sets of interest include
  - $\mathbb{R}$ - real numbers
  - $\mathbb{R}^2$ - ordered pairs in the real 2D plane;
  - $\mathbb{R}^+$ - nonnegative real numbers (includes zero);
  - $\mathbb{R}^n$ - points in n-dimensional Cartesian space;
  - $\mathbb{Z}$ - integers;

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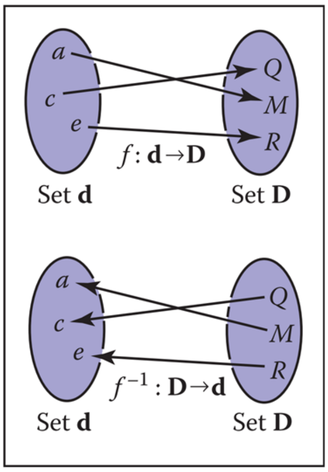
Sets and Mappings-cont.

- A function called f that takes a real number input and maps it to an integer

$$f : \mathbb{R} \mapsto \mathbb{Z}$$

- The point $f(a)$ is called the image of a,
- A **bijection** f and the inverse function f^{-1}. Note that f^{-1} is also a bijection.



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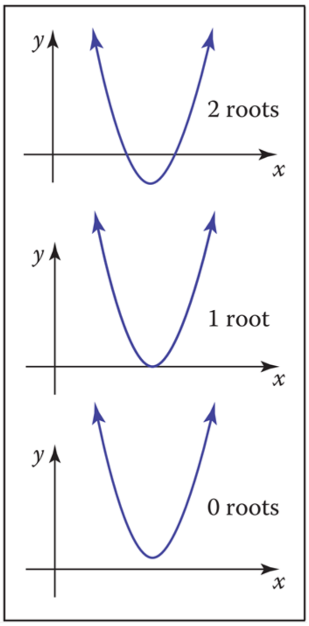
Solving Quadratic Equations

- A quadratic equation has the form

$$Ax^2 + Bx + C = 0$$

- The solution are one of the following

$$x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$



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Trigonometry history

- **Trigonometry** is a branch of mathematics that studies relationships between side lengths and angles of triangles.
- The field emerged in the Hellenistic world during the 3rd century BC from applications of geometry to astronomical studies.
- **Hipparchus** "the father of trigonometry".

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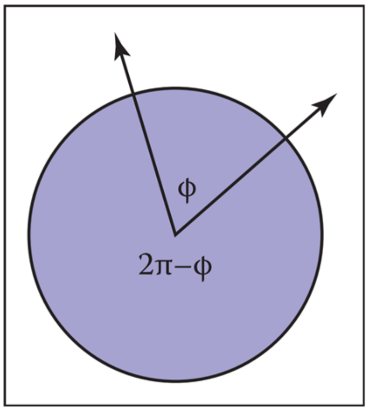
Angles

- An angle is the length of the arc of the unit circle that is “cut” by the two directions.

$$\text{degrees} = \frac{180}{\pi}\ \text{radians};$$

$$\text{radians} = \frac{\pi}{180}\ \text{degrees}.$$



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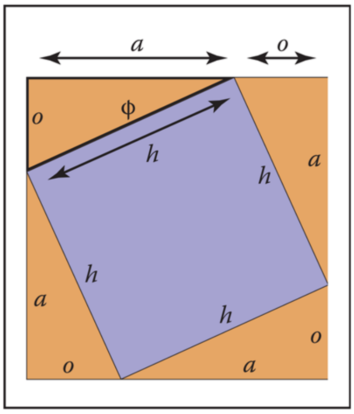
Trigonometric Functions

- Pythagorean theorem:

$$a^2 + o^2 = h^2$$

- Mathematical prof

$$2ao + h^2 = (a + o)^2$$



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Trigonometry

- We define **sine** and **cosine** of ϕ, as well as the other ratio-based trigonometric expressions:

$$\sin\phi \equiv o/h;$$
$$\csc\phi \equiv h/o;$$
$$\cos\phi \equiv a/h;$$
$$\sec\phi \equiv h/a;$$
$$\tan\phi \equiv o/a;$$
$$\cot\phi \equiv a/o.$$

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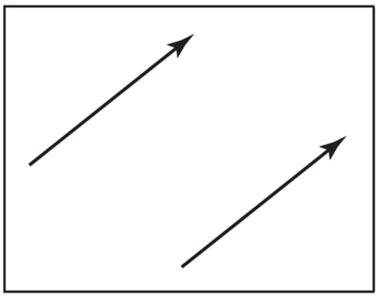
Vectors

- A **vector** describes a length and a direction.
- It can be usefully represented by an arrow.
- Two vectors are equal if they have the same length and direction even if we think of them as being located in different places
- The **zero** vector is the vector of **zero** length. The direction of the zero vector is undefined.



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Vector Operations

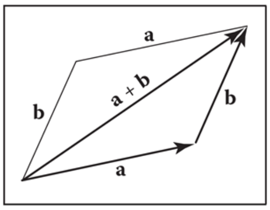
- Two vectors are added according to the **parallelogram** rule.

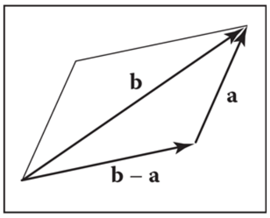
$$a + b = b + a$$

- You can visualize vector subtraction with a parallelogram

$$a + (b - a) = b$$

- Vectors can be multiplied.

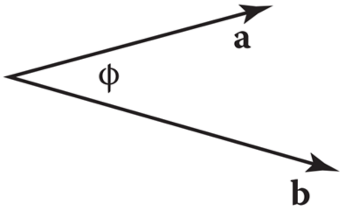




Dot Product

- The **dot** product of a and b is denoted a · b and is often called the **scalar** product

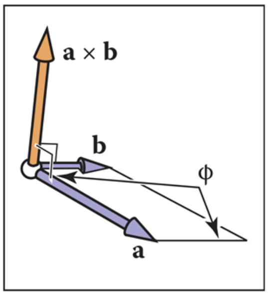
$$\mathrm{a} \,.\, \mathrm{b} = \|\mathrm{a}\| \|\mathrm{b}\| \cos \phi$$



Cross Product

- The **cross** product returns a 3D vector that is perpendicular to the two arguments of the cross product.

$$\|a \times b\| = \|a\|\|b\| \sin \phi$$



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Curves and Surfaces

- Objects are **not flat** all the time and we need to draw **curves** many times to draw an object
- A curve is an infinitely large set of points. Each point has two neighbors except endpoints.
- Curves can be broadly classified into three categories −
  - **explicit**,
  - **implicit**, and
  - **parametric curves**

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Curves and Surfaces-cont.

- **Implicit Curves**
  - Implicit curve representations define the set of points on a curve by employing a procedure that can test to see if a point in on the curve.
  - Usually, an implicit curve is defined by an implicit function of the form

$$f(x, y) = 0$$

Curves and Surfaces-cont.

- **Explicit Curves**
  - A mathematical function can be plotted as a curve. Such a function is the explicit representation of the curve.

$$y = f(x)$$

  - The explicit representation **is not general**, since it cannot represent **vertical lines** and is also single-valued. For each value of x, only a single value of y is normally computed by the function.

Curves and Surfaces-cont.

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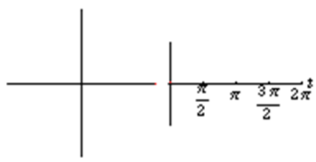
Curves and Surfaces-cont.

- **Parametric Curves**
  - Curves having parametric form are called **parametric curves**. The explicit and implicit curve representations can be used only when the function is known. In practice the parametric curves are used. A two-dimensional parametric curve has the following form −

$$P(t) = f(t), g(t)$$

or

$$P(t) = x(t), y(t)$$



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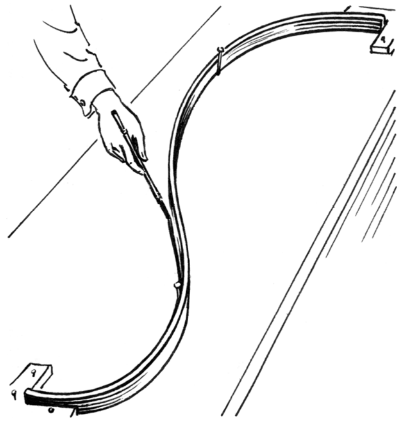
Curves and Surfaces-cont.

- A **spline**, or the more modern term **flexible curve**, consists of a long strip fixed in position at a number of points whose tension creates a smooth curve passing through those points, for the purpose of transferring that curve to another material.
- Examples:
  - **Bezier Curves**
  - **B-spline** or **basis spline**
  - **Non-uniform rational basis spline** (**NURBS**)



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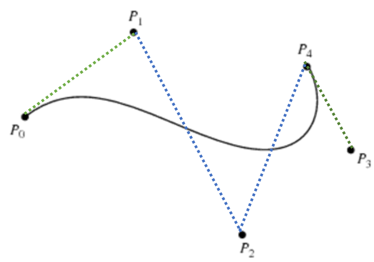
Curves and Surfaces-cont.

- **Bezier Curves**
  - Bezier curve is discovered by the French engineer **Pierre Bézier**. These curves can be generated under the control of other points.
  - Approximate tangents by using control points are used to generate curve. The Bezier curve can be represented mathematically as −

$$\sum_{k=0}^{n} P_i B_i^n(t)$$

where $B_i^n(t)$ is **Bernstein polynomial**…



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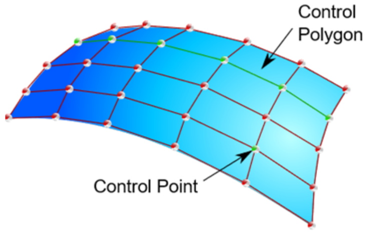
Curves and Surfaces-cont.

- In mathematics, a surface is a **generalization of a plane,** which is not necessarily flat – that is, the curvature is not necessarily zero. This is analogous to a curve generalizing a straight line.
- The mathematical concept of a surface is an idealization of what is meant by surface in science, **computer graphics**, and common language.



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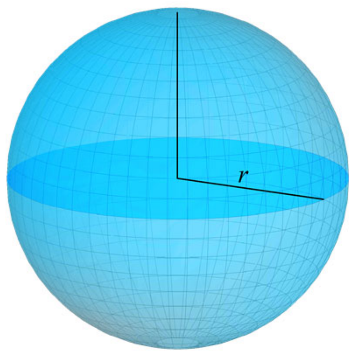
Curves and Surfaces-cont.

- If we defining **three-variate** function in a polynomial, the surface is an algebraic surface
- For example, the unit sphere is an algebraic surface, as it may be defined by the implicit equation

$$x^2 + y^2 + z^2 - 1 = 0$$

or in parametric form

$$x = \cos(u)\cos(v)$$
$$y = \sin(u)\cos(v)$$
$$z = \sin(v)\,.$$



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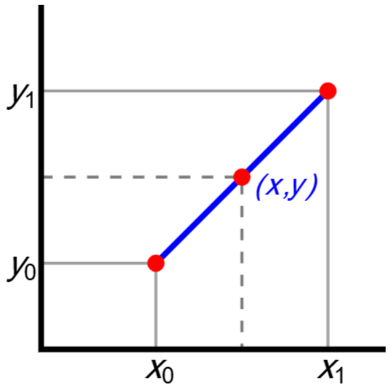
Linear interpolation

- **Interpolation**: The computation of points or values between ones that are known or tabulated using the surrounding points or values
- In mathematics, **linear interpolation** is a method of **curve fitting** using **linear polynomials** to construct new data points within the range of a discrete set of known data points.



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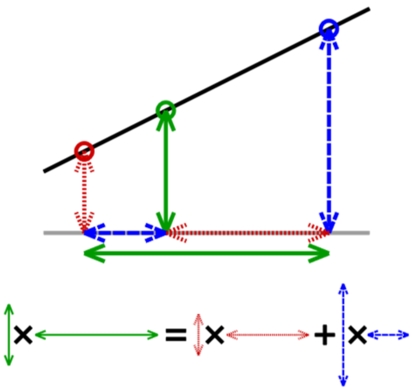
Linear interpolation-cont.

- If the two known points are given by the coordinates (x_0, y_0) and (x_1, y_1), the linear interpolant is the straight line between these points.
- For a value x in the interval (x_0, x_1) the value y along the straight line is given from the equation of slopes

$$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0},$$



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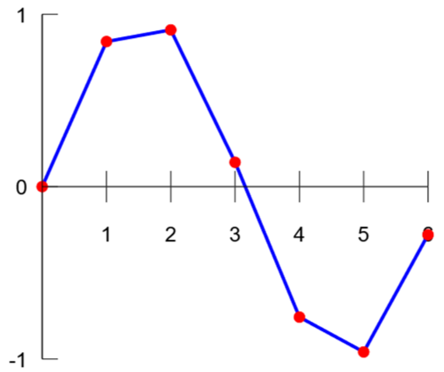
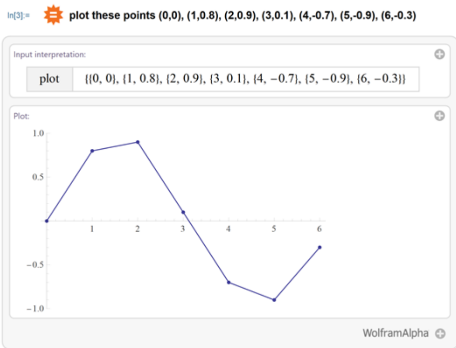
Linear interpolation-cont.

- Linear interpolation on a set of data points (x_0, y_0), (x_1, y_1), …, (x_n, y_n) is defined as the concatenation of linear interpolants between each pair of data points.





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Summary

- A **set** is unordered collection of objects of the same type, with the rule for determining if a given object(**element**) is in the set.
- A **quadratic equation** with real or complex coefficients has two solutions, called **roots**. These two solutions may or may not be distinct, and they may or may not be real
- **Trigonometry** (from Greek *trigōnon*, "**triangle**" and *metron*, "measure") is a branch of mathematics that studies relationships between side lengths and angles of triangles.
- The history of vector analysis is particularly interesting. It was largely invented by **Grassman** in the mid-1800s

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Summary-cont.

- A **curve** is an infinitely large set of points. Each point has two neighbors except endpoints. Curves can be broadly classified into three categories − **explicit**, **implicit**, and **parametric** curves.
- **Surfaces** are one way of representing objects. The other ways are wireframe (lines and curves) and solids. **Point clouds** are also sometimes used as temporary ways to represent an object
- **Linear interpolation** (**LERP**) is often used to approximate a value of some function f using two known values of that function at other points.

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