Augmented reality (**AR**) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory. AR can be defined as a system that fulfils three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects.

The overlaid sensory information can be constructive (i.e. additive to the natural environment), or destructive (i.e. masking of the natural environment). This experience is seamlessly interwoven with the physical world such that it is perceived as an immersive aspect of the real environment. In this way, augmented reality alters one's ongoing perception of a real-world environment, whereas virtual reality completely replaces the user's real-world environment with a simulated one. Augmented reality is related to two largely synonymous terms: mixed reality and computer-mediated reality.

The difference between virtual, augmented, and mixed reality technologies:

•**Virtual reality (VR)** immerses users in a fully artificial digital environment.

•**Augmented reality (AR)** overlays virtual objects on the real-world environment.

•**Mixed reality (MR)** not just overlays but anchors virtual objects to the real world.

Virtual Reality

This technology immerses users in a completely virtual environment that is generated by a computer. The most advanced VR experiences even provide freedom of movement – users can move in a digital environment and hear sounds. Moreover, special hand controllers can be used to enhance VR experiences.

You need to wear a special VR headset to experience virtual reality. Most VR headsets are connected to a computer (Oculus Rift) or a gaming console (PlayStation VR) but there are standalone devices (Google Cardboard is among the most popular) as well. Most standalone VR headsets work in combination with smartphones – you insert a smartphone, wear a headset, and immerse in the virtual reality.

Immersive videos

Have you ever noticed a small cardboard icon when watching videos on YouTube? It enables the 360-degree mode that means you can wear a VR headset and experiences fully immersive videos. 360-degree videos are considered a form of VR.

Augmented Reality

In augmented reality, users see and interact with the real world while digital content is added to it. If this sounds unclear think of Pokemon Go – millions of people all over the world have been rushing with their smartphones in search for small virtual creatures. That's the most vivid example of augmented reality.

If you own a modern smartphone, you can easily download an AR app and try this technology. There's a different way to experience augmented reality, though – with special AR headsets, such as Google Glass, where digital content is displayed on a tiny screen in front of a user's eye.
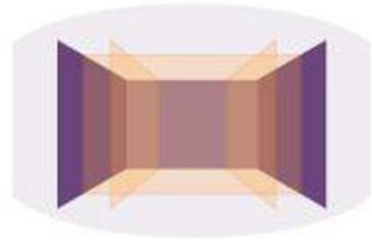
Mixed Reality

This is the most recent development in reality technologies that sometimes causes confusion, primarily because different experiences are called so. Without going too deep into science, let's look at two forms of reality technologies that are referred to as mixed reality (we've mentioned just one of them at the very beginning):

•*Mixed reality that starts with the real world* – virtual objects are not just overlaid on the real world but can interact with it. In this case, a user remains in the real-world environment while digital content is added to it; moreover, a user can interact with virtual objects. This form of mixed reality can be considered an advanced form of AR.

•*Mixed reality that starts with the virtual world* – the digital environment is anchored to and replaces the real world. In this case, a user is fully immersed in the virtual environment while the real world is blocked out. Sounds like virtual reality, right? In fact it does, but the digital objects overlap the real ones whereas in conventional VR the virtual environment isn't connected to the real world around a user. To experience this form of mixed reality, you can wear Windows mixed reality headsets

VIRTUAL REALITY (VR)

Fully artificial environment

Full immersion in virtual environment

AUGMENTED REALITY (AR)

Virtual objects overlaid on real-world environment

The real world enhanced with digital objects

MIXED REALITY (MR)

Virtual environment combined with real world

Interact with both the real world and the virtual environment

History of Augmented Reality

THE HISTORY OF AUGMENTED REALITY

1968
Ivan Sutherland created the first head mounted display, called The Sword of Damocles. It paved the way for the AR we use today.

1990
The term "augmented reality" was coined by Boeing researcher Tom Caudell.

1992
Louis Rosenberg created the first fully immersive AR system at the U.S Air Force Research Laboratory.

1998
Augmented reality was first used for navigation, in NASA's X-38 spacecraft.

2000
AR Quake launched - the first augmented reality game. As well as a head-mounted display, players had to wear a backpack containing a computer & gyroscopes!

2005
The early 2000s saw the debut of AR apps for smartphones. One of the first was AR Tennis - a two-player game developed for Nokia phones.

2008
BMW was the first brand to make use of AR for commercial purposes, with its AR enhanced print ads.

2009
Esquire published the first AR enabled magazine which let readers scan the cover to make Robert Downey Jr come to life on the page.

2012
Blippar launched the first cloud-based AR app.

2014
Blippar developed the first AR game for Google Glass, which was demoed at the Mobile World Congress.

2016
Niantic and Nintendo launched Pokemon Go - the hugely popular location-based AR game that put AR on the mainstream map.

2017
The number of AR users in the U.S hit 37 million. This is expected to grow to 67 million by 2020!

blippar

History of Augmented Reality

| First head-mounted AR display | Dedicated AR laboratory | 'Augmented reality' term is created | Virtual Fixtures, an advanced AR system | AR in theater & entertainment |
| 1968 | 1974 | 1990 | 1992 | 1994 |

| AR in print media | AR tech added to sports aerial camera | ARToolKit, open-source library | NASA hybrid synthetic vision system | NFL 1st &Ten line powered by AR |
| 2003 | 2000 | 1999 | 1998 |

| 2009 | Automotive industry leverages AR | Google Glass wearable AR tech | Microsoft HoloLens AR headset | AR applications in retail |
| 2013 | 2014 | 2016 | 2017 |

Augmented reality in the 60s & 70s

Let's take a look back to see how AR technology was created in the first place.

1968: Ivan Sutherland, a Harvard professor and computer scientist, created the first head-mounted display called 'The Sword of Damocles'.

1974: Myron Kruger, a computer researcher and artist, built a laboratory at the University of Connecticut called 'Videoplace' that was entirely dedicated to artificial reality.

Augmented reality in the 80s & 90s

Now, let's learn how AR transitioned out of the lab and into various industries and business applications.

1990: Tom Caudell, a Boeing researcher, coined the term 'augmented reality'.

1992: Louis Rosenburg, a researcher in the USAF Armstrong's Research Lab, created 'Virtual Fixtures', which was one of the first fully functional augmented reality systems.

1994: Julie Martin, a writer and producer, brought augmented reality to the entertainment industry for the first time with the theater production titled *Dancing in Cyberspace.*

1998: Sportsvision broadcasts the first live NFL game with the virtual 1st & Ten graphic system – aka the yellow yard marker. The technology displays a yellow line overlayed on top of the feed to that views can quickly see where the team just advance to to get a first down.

1999: NASA created a hybrid synthetic vision system of their X-38 spacecraft. The system leveraged AR technology to assist in providing better navigation during their test flights.

Augmented reality in the 2000s

By now, AR has a foothold in the fast-paced tech landscape. Let's see how its eventually rolled out to everyday consumers.

2000: Hirokazu Kato developed an open-source software library called the **ARToolKit**. This package helps other developers build augmented reality software programs. The library uses video tracking to overlay virtual graphics on top of the real world.

2003: Sportvision enhanced the 1st & Ten graphic to include the feature on the new Skycam system – providing viewers with an aerial shot of the field with graphics overlaid on top of it.

2009: *Esquire Magazine* used augmented reality in print media for the first time in an attempt to make the pages come alive.

2013: Volkswagen debuted the MARTA app (Mobile Augmented Reality Technical Assistance) which primarily gave technicians step-by-step repair instructions within the service manual.

2014: Google unveiled its Google Glass devices, a pair of augmented reality glasses that users could wear for immersive experiences.

2016: Microsoft starts shipping its version of wearable AR technology called the HoloLens, which is more advanced than the Google Glass, but came with a hefty price tag. It's definitely not an everyday type of accessory.

2017: IKEA released its augmented reality app called IKEA Place that changed the retail industry forever.

The future of augmented reality

As we become increasingly dependent on our mobile devices, the adoption of augmented reality technology will begin to rise. **AR software** advances will be the way forward as the overwhelming majority of consumers have a smartphone and already take it everywhere with them, making it a convenient medium to bring AR to nearly every consumer.

The truth is, augmented reality is already used by everyday consumers – they just don't know it. AR still seems to be misconstrued as too 'high tech' for your average Joe. But, the Snapchat dog filter and others are powered by AR. The biggest shift in augmented reality will have to be how its delivered to change the perception.
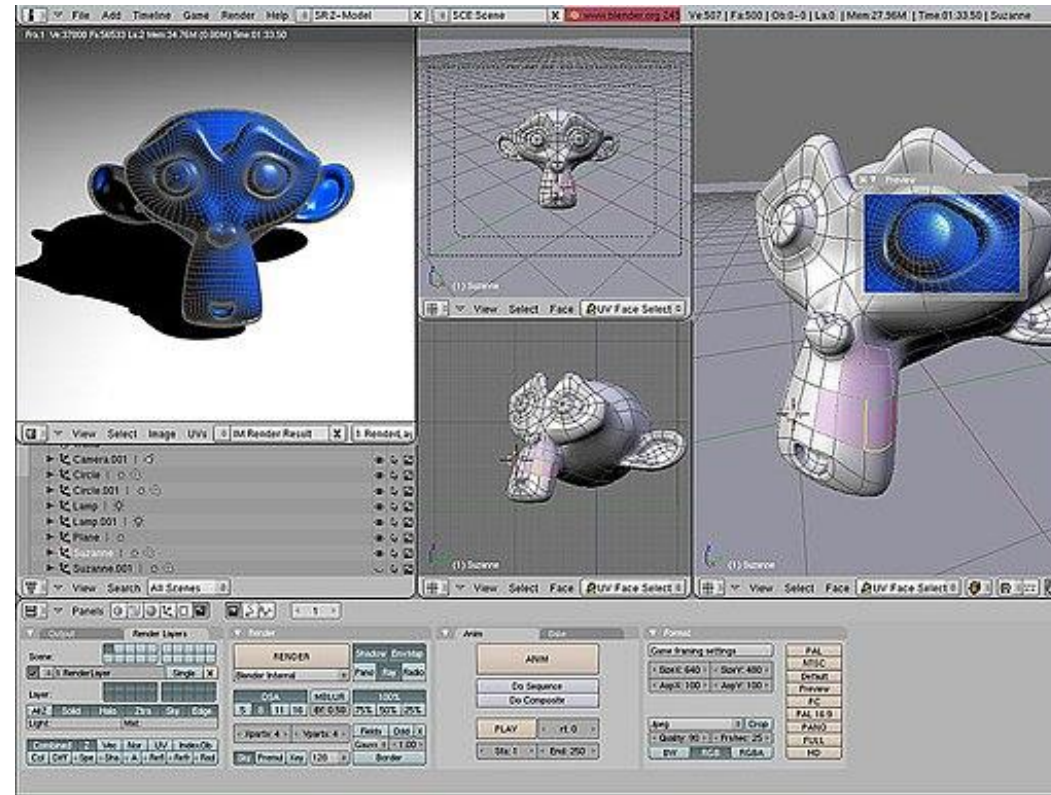
Computer Graphics

Computer graphics is branch of <u>computer science</u> that deals with generating images with the aid of computers. Today, computer graphics is a core technology in digital photography, film, video games, cell phone and computer displays, and many specialized applications. A great deal of specialized hardware and software has been developed, with the displays of most devices being driven by <u>computer graphics hardware</u>. It is a vast and recently developed area of computer science. The phrase was coined in 1960 by computer graphics researchers Verne Hudson and William Fetter of Boeing. It is often abbreviated as CG, or typically in the context of film as <u>computer generated imagery</u> (CGI).

Some topics in computer graphics include <u>user interface design</u>, <u>sprite graphics</u>, <u>rendering</u>, <u>ray tracing</u>, <u>geometry processing</u>, <u>computer animation</u>, <u>vector graphics</u>, <u>3D modeling</u>, <u>shaders</u>, <u>GPU</u> design, <u>implicit surface</u> visualization, <u>image processing</u>, <u>computational photography</u>, <u>scientific visualization</u>, <u>computational geometry</u> and <u>computer vision</u>, among others. The overall methodology depends heavily on the underlying sciences of <u>geometry</u>, <u>optics</u>, <u>physics</u>, and <u>perception</u>.

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Computer Graphics involves technology to access. The Process transforms and presents information in a visual form. The role of computer graphics insensible. In today life, computer graphics has now become a common element in user interfaces, T.V. commercial motion pictures.

Computer Graphics is the creation of pictures with the help of a computer. The end product of the computer graphics is a picture it may be a business graph, drawing, and engineering.

In computer graphics, two or three-dimensional pictures can be created that are used for research. Many hardware devices algorithm has been developing for improving the speed of picture generation with the passes of time. It includes the creation storage of models and image of objects. These models for various fields like engineering, mathematical and so on.

Today computer graphics is entirely different from the earlier one. It is not possible. It is an interactive user can control the structure of an object of various input devices.
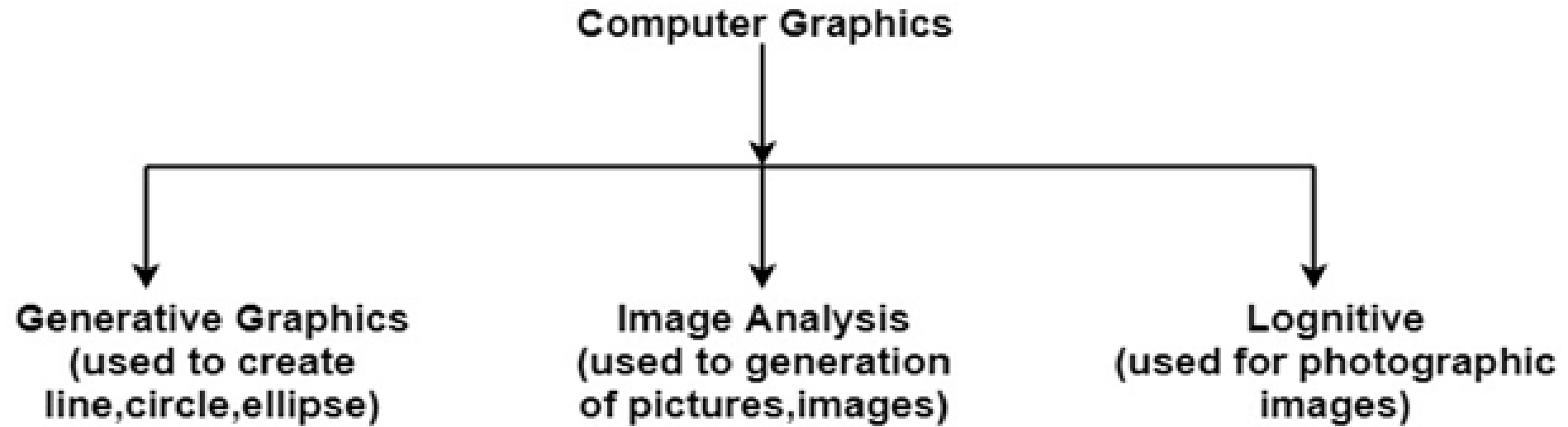
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Why computer graphics used?

Suppose a shoe manufacturing company want to show the sale of shoes for five years. For this vast amount of information is to store. So a lot of time and memory will be needed. This method will be tough to understand by a common man. In this situation graphics is a better alternative. Graphics tools are charts and graphs. Using graphs, data can be represented in pictorial form. A picture can be understood easily just with a single look.

Interactive computer graphics work using the concept of two-way communication between computer users. The computer will receive signals from the input device, and the picture is modified accordingly. Picture will be changed quickly when we apply command.

Computer Graphics

Generative Graphics
(used to create
line,circle,ellipse)

Image Analysis
(used to generation
of pictures,images)

Lognitive
(used for photographic
images)

Real-time computer graphics

Real-time computer graphics or **real-time rendering** is the sub-field of <u>computer graphics</u> focused on producing and analyzing images in <u>real time</u>. The term can refer to anything from rendering an application's graphical user interface (<u>GUI</u>) to real-time <u>image analysis</u>, but is most often used in reference to interactive <u>3D computer graphics</u>, typically using a <u>graphics processing unit</u> (GPU). One example of this concept is a <u>video game</u> that rapidly renders changing 3D environments to produce an illusion of motion.

Computers have been capable of generating 2D images such as simple lines, images and <u>polygons</u> in real time since their invention. However, quickly rendering detailed 3D objects is a daunting task for traditional <u>Von Neumann architecture</u>-based systems. An early workaround to this problem was the use of <u>sprites</u>, <u>2D images</u> that could imitate 3D graphics.

Different techniques for <u>rendering</u> now exist, such as <u>ray-tracing</u> and <u>rasterization</u>. Using these techniques and advanced hardware, computers can now render images quickly enough to create the illusion of motion while simultaneously accepting user input. This means that the user can respond to rendered images in real time, producing an interactive experience.
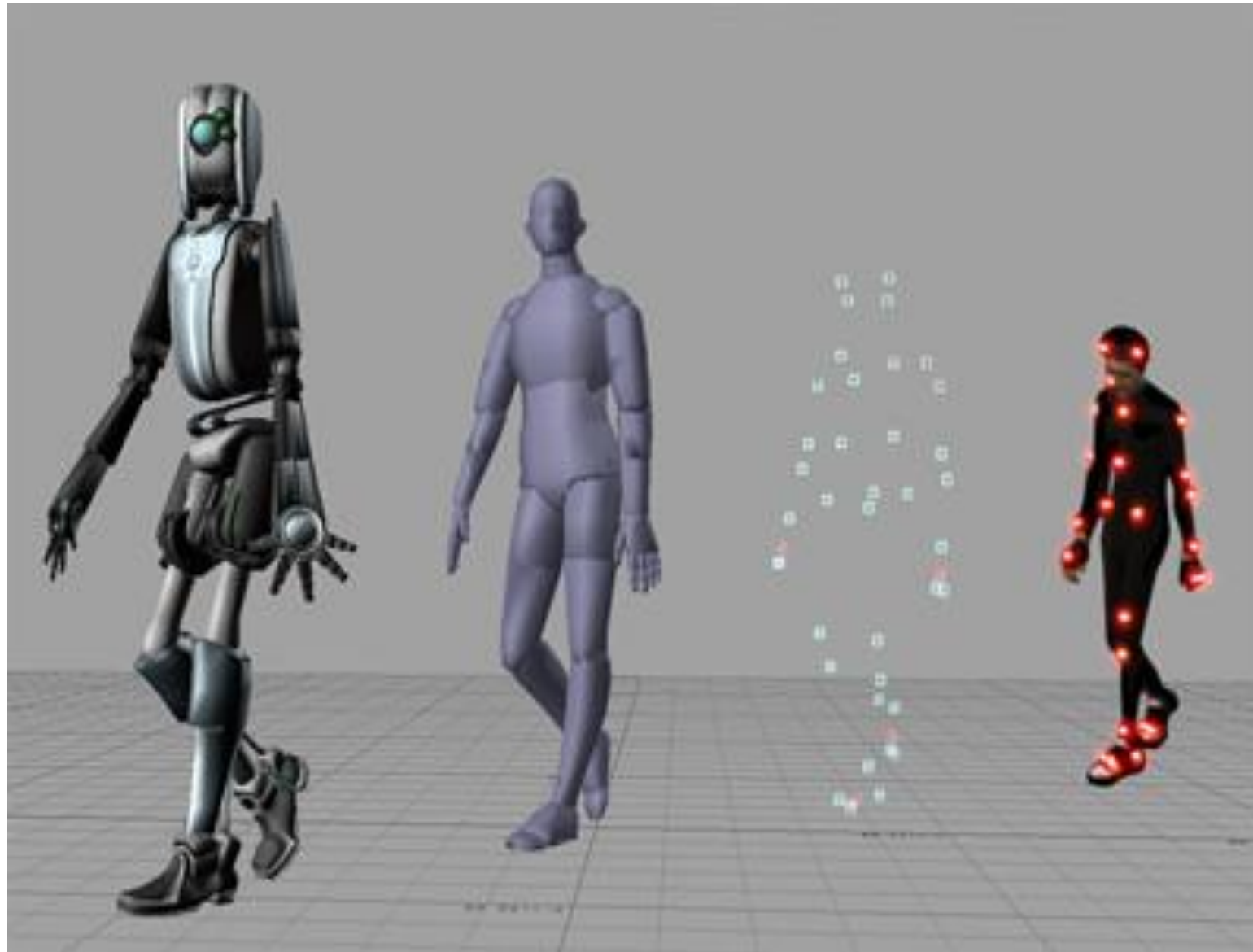
Flight simulator

A flight simulator is a device that artificially re-creates aircraft flight and the environment in which it flies, for pilot training, design, or other purposes. It includes replicating the equations that govern how aircraft fly, how they react to applications of flight controls, the effects of other aircraft systems, and how the aircraft reacts to external factors such as air density, turbulence, wind shear, cloud, precipitation, etc. Flight simulation is used for a variety of reasons, including flight training (mainly of pilots), the design and development of the aircraft itself, and research into aircraft characteristics and control handling qualities.

History of flight simulation

In 1910, on the initiative of the French commanders **Clolus and Laffont** and **Lieutenant Clavenad**, the first ground training aircraft for military aircraft were built. The "Tonneau Antoinette" (Antoinette barrel), created by the Antoinette company, seems to be the precursor of flight simulators.

The 1920s and 1930s

The best-known early flight simulation device was the Link Trainer, produced by Edwin Link in Binghamton, New York, USA, which he started building in 1927. He later patented his design, which was first available for sale in 1929. The Link Trainer was a basic metal frame flight simulator usually painted in its well-known blue color. Some of these early war era flight simulators still exist, but it is becoming increasingly difficult to find working

World War II (1939–1945)

The principal pilot trainer used during World War II was the Link Trainer. Some 10,000 were produced to train 500,000 new pilots from allied nations, many in the US and Canada because many pilots were trained in those countries before returning to Europe or the Pacific to fly combat missions. Almost all US Army Air Force pilots were trained in a Link Trainer

1945 to the 1960s

In 1954 United Airlines bought four flight simulators at a cost of $3 million from Curtiss-Wright that were similar to the earlier models, with the addition of visuals, sound and movement. This was the first of today's modern flight simulators for commercial aircraft

Today

The simulator manufacturers are consolidating and integrate vertically as training offers double-digit growth: CAE forecast 255,000 new airline pilots from 2017 to 2027 (70 a day), and 180,000 first officers evolving to captains. The largest manufacturer is Canadian CAE Inc. with a 70% market share and $2.8 billion annual revenues, manufacturing training devices for 70 years but moved into training in 2000 with multiple acquisitions. Now CAE makes more from training than from producing the simulators. Crawley-based L3 CTS entered the market in 2012 by acquiring Thales Training & Simulation's manufacturing plant near Gatwick Airport where it assembles up to 30 devices a year, then UK CTC training school in 2015, Aerosim in Sanford, Florida in 2016, and Portuguese academy G Air in October 2017

Virtual Reality environment

Virtual meaning near or proximate, virtual reality can loosely be defined as something near reality or to what we feel and experience. Basically a realm created beyond the scope of the real world via latest computer hardware and software technology is known as a virtual reality. A VR environment, on the other hand, is the overall computer-generated atmosphere created by this latest technology, amplifying characters, objects or situations to create a three-dimensional, more immersive experience.

How Virtual Reality Environment Works?

Virtual reality environments, much like video games, provide sensory stimulation in a closed sensory environment. By isolating the user from real-world sensations, it emulates the setting by duplicating not only the objects and faces that we see in everyday lives, but also audio feedback, motion, and movements as well as orientation mechanics. Moreover, it provides the illusion of a placement to another location by offering an enhanced display accompanied by other modalities.

The architecture of a VR environment consists of a high-tech computer, a human-computer interface in combination with one or more users which interact with and perceive the artificially created world.

Three basic types of hardware devices are used to create the illusion of a virtual environment for human interaction. They include a set of sensors, which help detect the user's bodily movements, a set of effectors, which provide the stimulation necessary for immersion into a virtual world, and lastly any precisely developed piece of hardware that creates a connection between the sensors and the effectors.

This, connection in turn, produces an environment that bears an uncanny resemblance to the real world. These hardware devices are in turn are connected to explicitly designed software which monitors the shape of the actors and surrounding objects, the virtual interactions based on rules of kinematic rules of behavior as well as the characterizations.

Requirements Virtual Environment

A virtual reality environment focuses on each of the human senses. Sensory feedback to the user is provided numerous output devices which work in conjunction with input sensors. Graphic workstations are responsible for providing visual feedback while MIDI output provides the audio. Some of the commonly used devices for immersive VR experiences include but are not limited to:

- Magnetic trackers

- Data Gloves

- MIDI keyboards

- Shutter Glasses

- Head-Mounted Displays

- CAVE

Types of Virtual Reality Environments

The cornerstone of Augmented as well as VR systems, virtual reality environments give the consumer a context preview of the experience they are about to have.

There are a number of different VR Environments. Tailor made with vastly different features; the various types give the users extremely diverse immersive experiences. As such, they are broadly categorized into four types. Each category is graded based on the level of immersion and perceptiveness it provides to the users. These four main categories are:

- Non-immersive
- Semi-immersive
- Completely Immersive
- Or Collaborative

Non-Immersive

Implementing the least amount of VR techniques, Non-immersive type uses the desktop system for viewing. By using a standard high-resolution monitor, along with conventional interactive tools such as keyboards, trackballs, or mice, Non Immersive systems are the most basic.

Viewed via a portal or window, non-immersive systems are perfect for casual use as they do not require any fancy hardware, nor any complex virtual reality environment in computer graphic performance. They can and are easily, and economically used on a regular high specification personal computers via a VR software.

Semi Immersive

Using slightly more complex VR technologies, a semi- immersive virtual reality environment or system is one of the latest of the lot. Providing a greater sense of immersion and presence than the non-immersive version, the perfect example of a semi-immersive type would be a flight simulator. A flight simulator with large projection screens and a great projection system and monitors allows the user to indulge partly in an immersive atmosphere but still be aware of real world surroundings.

Completely Immersive

VR systems that provide the most direct and encompassing experience are the fully immersive virtual reality environments. They are usually provided with the help of Head-Mounted Displays (HMD) or a head-coupled display for example Binocular Omni-Orientation Monitor (BOOM).

One of the main systems to provide a fully immersive experience is CAVE (Cave Automatic Virtual Environment). A multi-user, high-resolution video, and audio virtual environment, CAVE is a full room sized VR Device. Projection setup which involves the user wearing a pair of head-mounted display, a fully immersive system is achieved by displaying two identical three dimensional images at very close range to the eye which the brain processes into one single image.

The CAVE records the user's movements via a motion capture system which is viewed by the user through the head-mounted display. CAVE allows an individual to forgo completely the real world and submerge themselves within a computer-generated atmosphere by combining total VR immersion and actual interactions. What's more, immersive systems such as CAVE also incorporate haptic interactions which is essentially adding a force feedback to the virtual experience. Various forms of movements are experienced by the user such as vibrations in a virtual reality environment accompanied by images/video and audio which work to enhance the overall immersive experience.
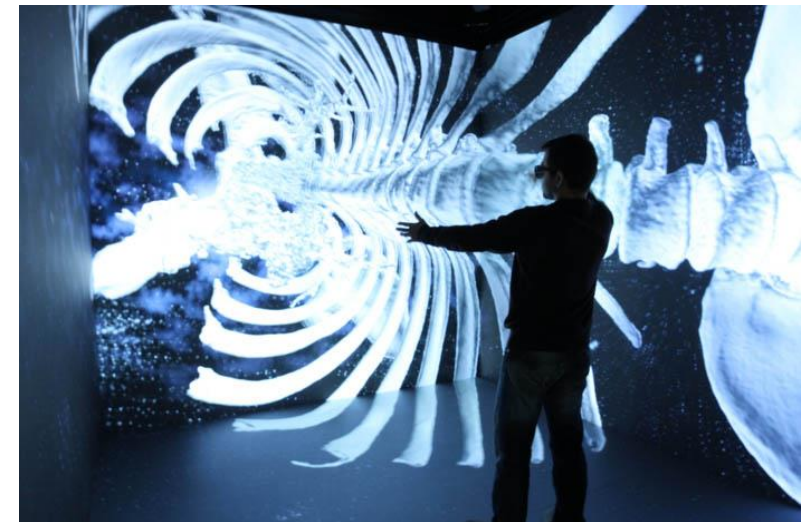
Collaborative

Another type that is becoming increasingly popular these days is a collaborative virtual environment. Allowing a number of people based at various locations to interact with one another in a similar space, collaborative system gives a group of individuals a collective experience. It is the collaborative system, which when accompanied by a mix of the real world fragments, is known as augmented reality environment.

The use of virtual reality as a training tool is well known, in particular in the field of surgery. Medical schools have adopted this technology as a way of teaching the next generation of surgeons, for example robotic surgery.

The medical uses of virtual reality are covered in more detail in our training for surgery article within this section.
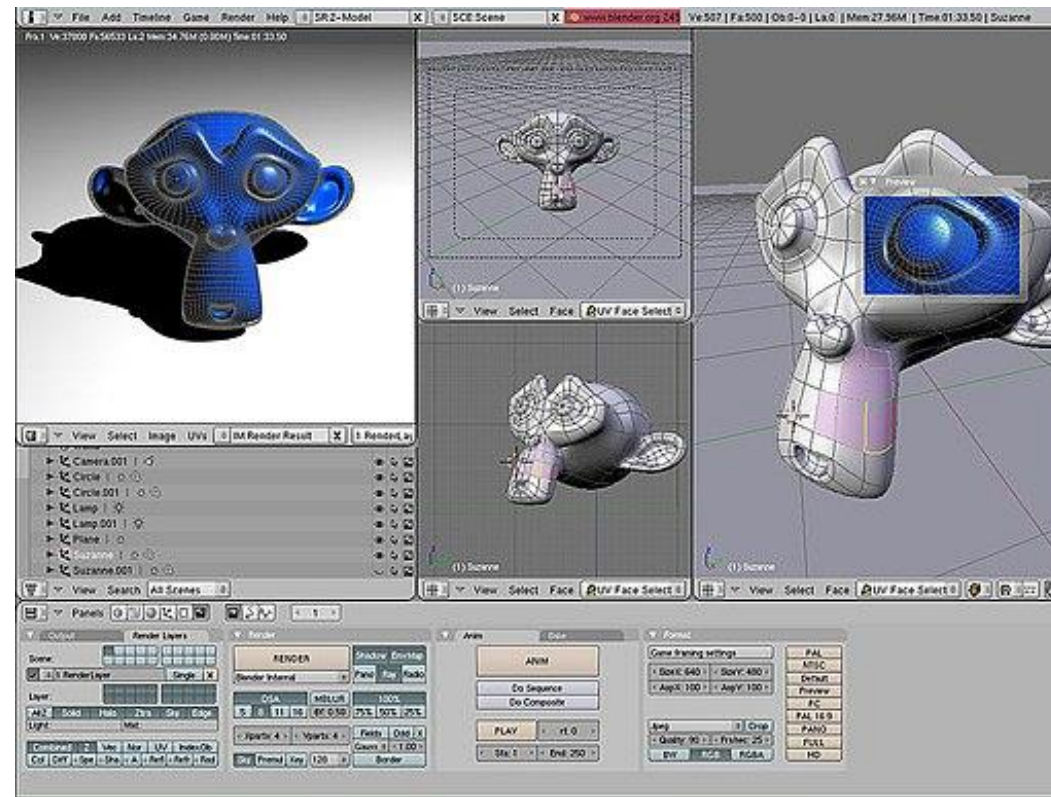
Advantages of virtual reality training

• Little/no risk.

• Safe, controlled area.

• Realistic scenarios.

• Can be done remotely saving time and **money**.

• Improves retention and recall.

• Simplifies complex problems/situations.

• Suitable for different **learning** styles.

• Innovative and enjoyable.

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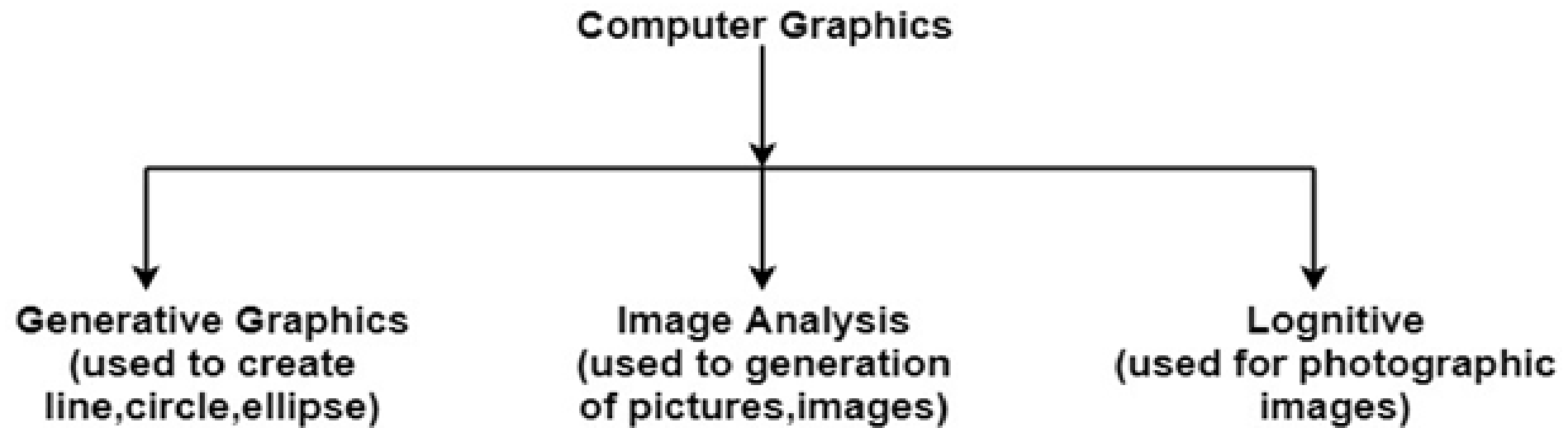
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(used to create
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A virtual world Space

A **virtual world** is a computer-simulated environment which may be populated by many users who can create a personal avatar, and simultaneously and independently explore the virtual world, participate in its activities and communicate with others. These avatars can be textual, two or graphical representations, or live video avatars with auditory and touch sensations. In general, virtual worlds allow for multiple users but single player computer games, such as Skyrim, can also be considered a type of virtual world.

The user accesses a computer-simulated world which presents perceptual stimuli to the user, who in turn can manipulate elements of the modeled world and thus experience a degree of presence. Such modeled worlds and their rules may draw from reality or fantasy worlds. Example rules are gravity, topography, locomotion, real-time actions, and communication. Communication between users can range from text, graphical icons, visual gesture, sound, and rarely, forms using touch, voice command, and balance senses.

Massively multiplayer online games depict a wide range of worlds, including those based on science fiction, the real world, super heroes, sports, horror, and historical milieus. The most common form of such games are fantasy worlds, whereas those based on the real world are relatively rare.[original research?] Most MMORPGs have real-time actions and communication. Players create a character who travels between buildings, towns, and worlds to carry out business or leisure activities. Communication is usually textual, but real-time voice communication is also possible. The form of communication used can substantially affect the experience of players in the game

Positioning the virtual observer

The VO always has a specific location within the VE and will gaze along some line of sight. The VO has two eyes which, ideally, receive two different views of the environment to create a 3D stereoscopic image
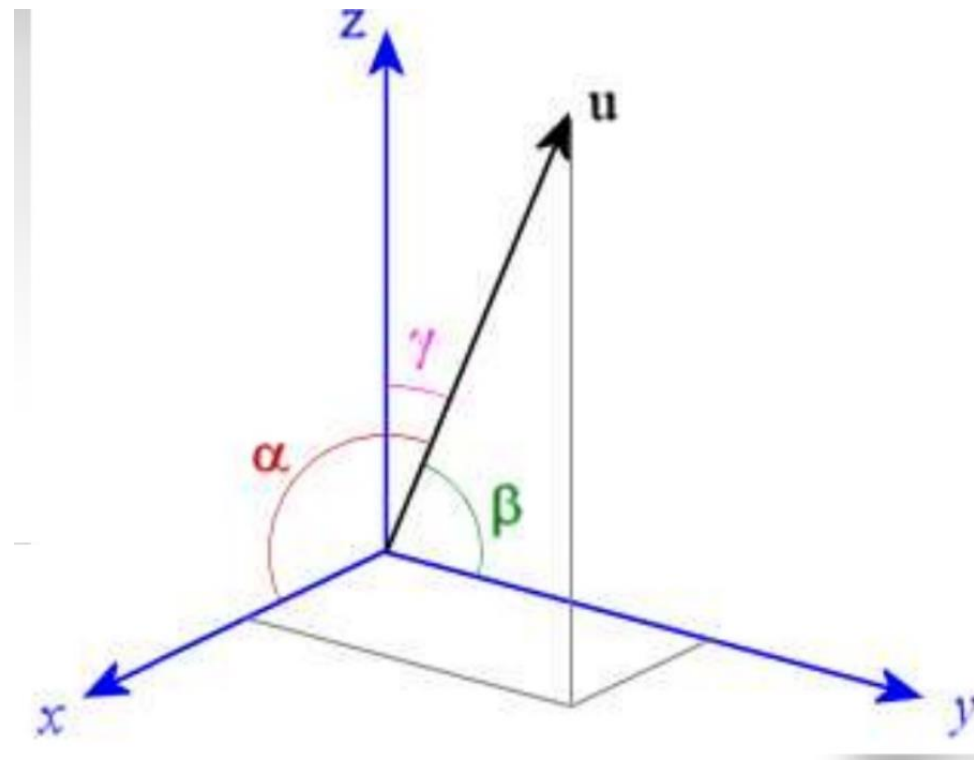
The perspective projection

A **3D** (*or*, **graphical**) **projection**, is a design technique used to display a three-dimensional (3D) object on a two-dimensional (2D) surface. These projections rely on visual perspective and aspect analysis to project a complex object for viewing capability on a simpler plane.

3D projections use the primary qualities of an object's basic shape to create a map of points, that are then connected to one another to create a visual element. The result is a graphic that contains conceptual properties to interpret that the figure or image is not actually flat (2D), but rather, is a solid object (3D) being viewed on a 2D display.

3D objects are largely displayed on two-dimensional mediums (i.e. paper and computer monitors). As such, graphical projections are a commonly used design element; notably, in engineering drawing, drafting, and computer graphics. Projections can be calculated through employment of mathematical analysis and formulae, or by using various geometric and optical techniques.
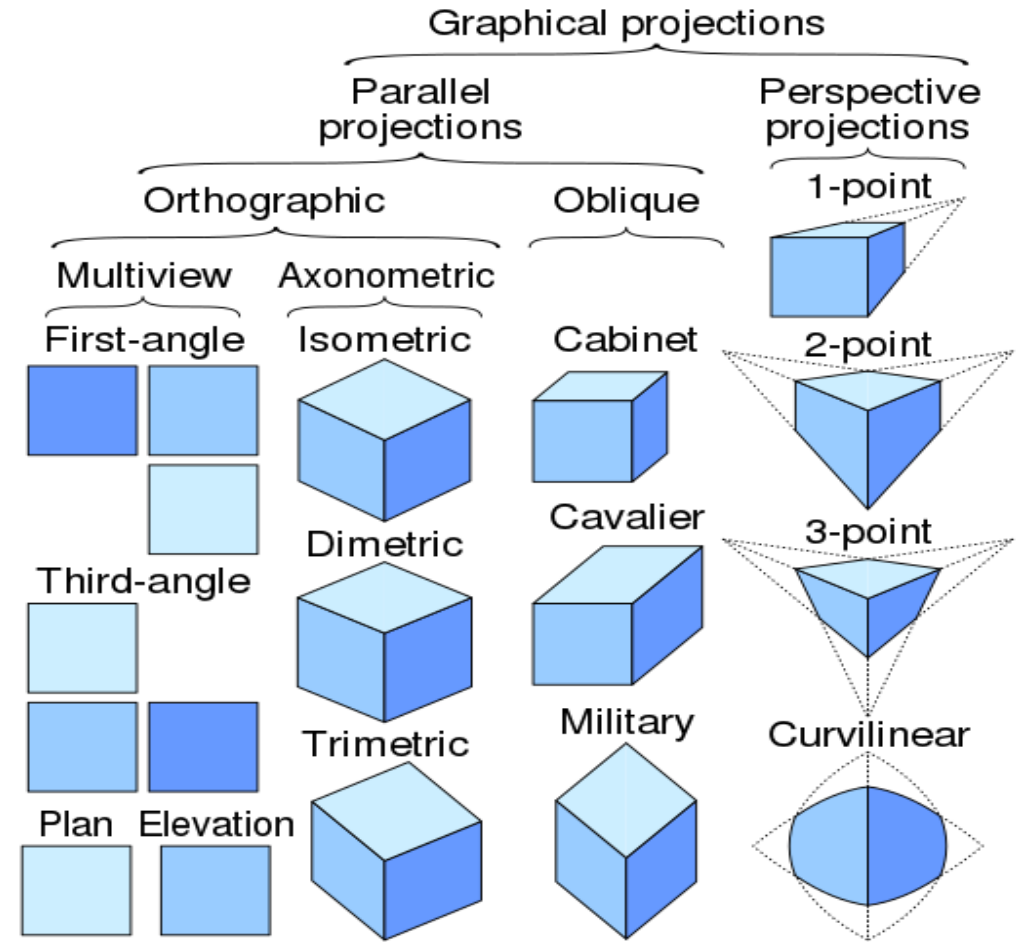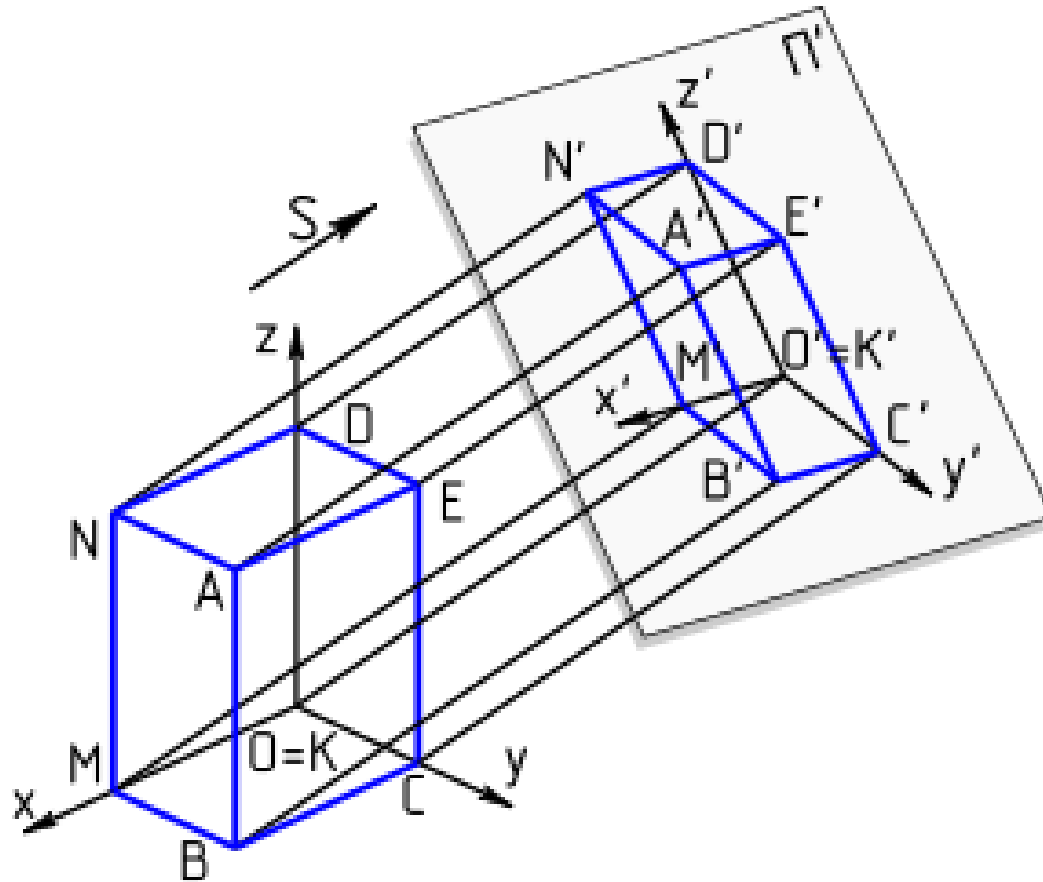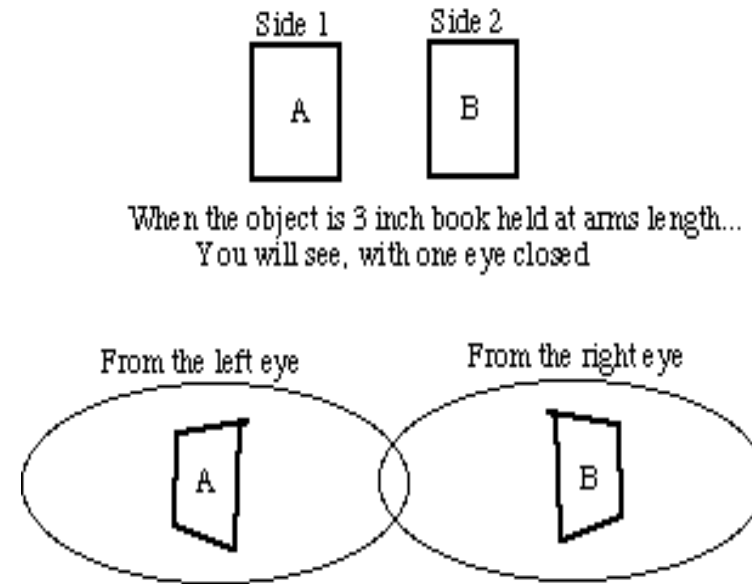
Human Vision

We are 3D creatures, living in a 3D world but our eyes can show us only two dimensions. The depth that we all think we can see is merely a trick that our brains have learned; a by product of evolution putting our eyes on the front of our faces. To prove this, close one eye and try to play tennis.

The miracle of our depth perception comes from our brain's ability to put together two 2D images in such a way as to extrapolate depth. This is called stereoscopic vision.

Something to think about: Most predators have stereoscopic vision in order to gauge distance to their prey as they hunt. Most herbivores' eyes are on the sides of their heads so that they can see as much of their environment as possible. They don't see depth the way we do.

It works like this. Because your eyes are separated on your face, each retina produces a slightly different image. That difference in images is a direct result of the depth of the objects that we are looking at.

Side 1   Side 2

A   B

When the object is 3 inch book held at arms length...
You will see, with one eye closed

From the left eye   From the right eye

A   B

When those two images are assembled in your brain, they are interpreted as depth.

Stereoscopic vision works most effectively for distances up to 18 feet. Beyond this distance, your brain starts using relative size and motion to determine depth.

3D stereoscopic imaging is as simple as producing two slightly different images - the same as your eyes would produce - and then showing each eye only one of those images. This can be done with light-refraction, color-filtering, or light polarization.
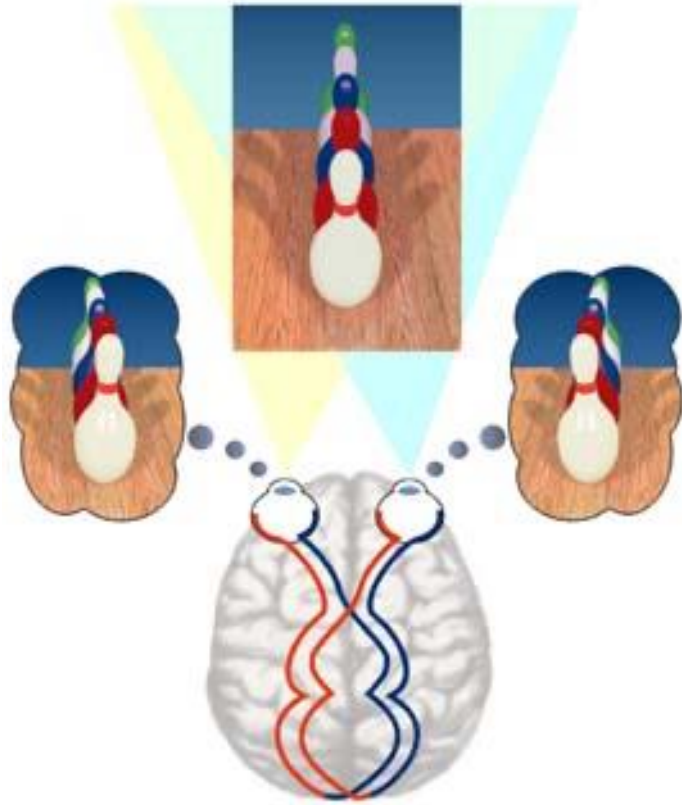
Stereo perspective projection

A **stereo perspective projection** is approximated from two parallel **projections** that are subsequently rendered onto an image plane by **perspective projection**.
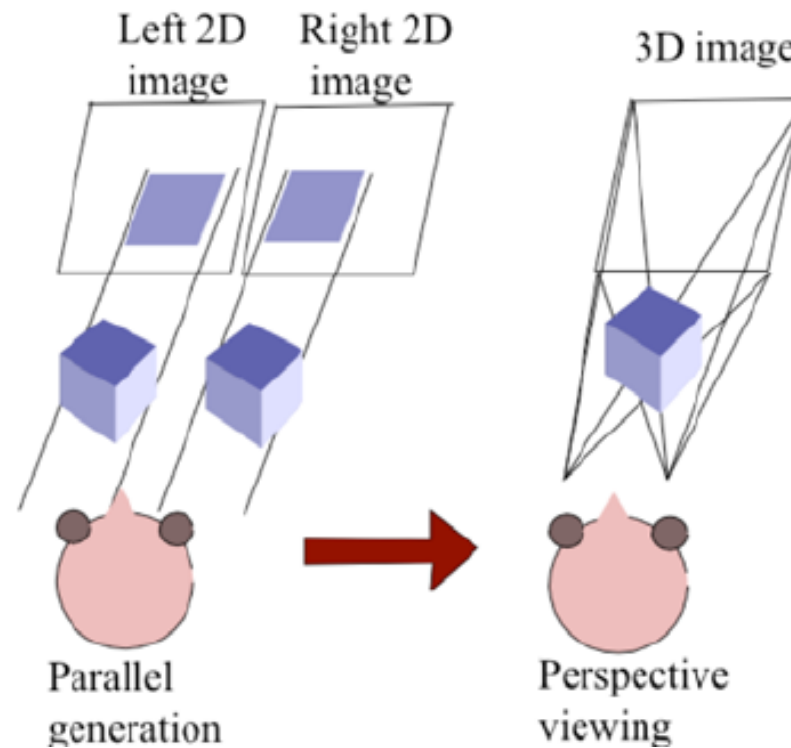
3D clipping

3D clipping is required when displaying **3D** objects that can have negative z values when transformed to world space. ... **3D clipping** solves this problem by **clipping** a polygon's world space points against a specified z plane, called the near **clipping** plane.

3D clipping is required when displaying 3D objects that can have negative z values when transformed to world space. Consider again our 40x40x40 cube. If we assume the cube vertices are defined in world space instead of object space, the cube will be drawn centered at the world space origin. This means the front half of the cube will extend through z=0 and into negative z space. This will cause major problems when we project the world space points to screen space when displaying the cube.

3D clipping

3D clipping solves this problem by clipping a polygon's world space points against a specified z plane, called the near clipping plane. Any z coordinates that extend into this plane are set to the near clipping value, and their x and y coordinates are adjusted accordingly. Besides the near clipping plane, Fastgraph's 3D clipping also supports a far clipping plane. Objects that are completely behind the far clipping plane are not drawn, as we assume these are too far away for the viewer to see. By default, Fastgraph uses a near clipping value of 1 and a far clipping value of 1000, but we can redefine these with fg_3Dsetzclip(). Its two parameters are floating point z values that respectively specify the near and far clipping planes. They must be greater than zero (recall that z values are positive in a left-handed 3D coordinate system), or if z-buffering is used, greater than or equal to 1. The far clipping plane must be greater than the near clipping plane.

3D Polygon Clipping

- However the most common case in 3D clipping is that we are clipping graphics objects made up of polygons
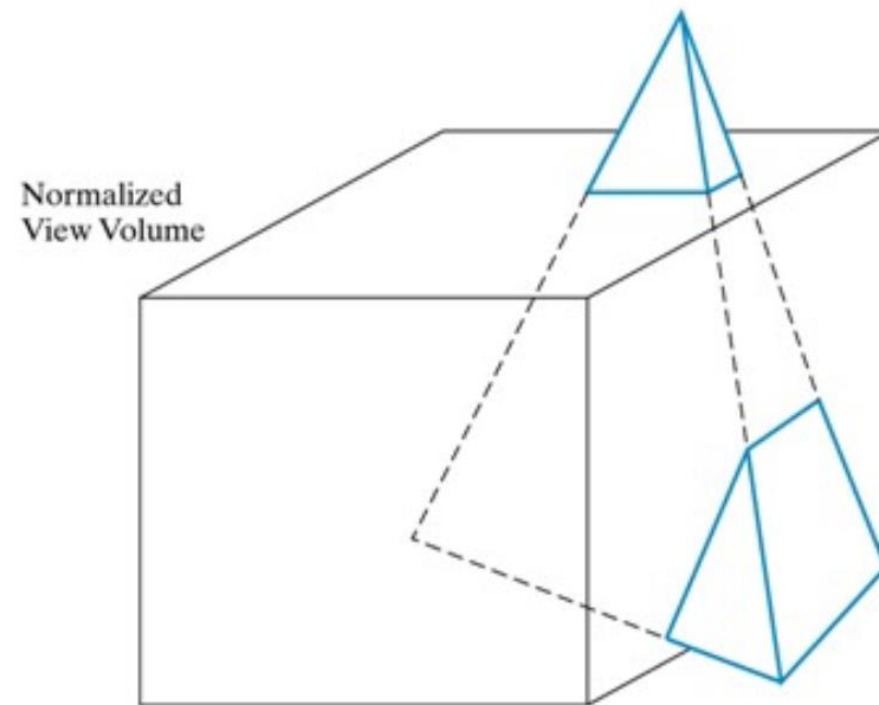
Color Theory

- Colour theory is both the science and art of using colour. It explains how humans perceive colour; and the visual effects of how colours mix, match or contrast with each other. Colour theory also involves the messages colours communicate; and the methods used to replicate colour.

- In colour theory, colours are organized on a colour wheel and grouped into 3 categories: primary colours, secondary colours and tertiary colours. More on that later.

Understanding colour

- Colour is perception. Our eyes see something (the sky, for example), and data sent from our eyes to our brains tells us it's a certain colour (blue). Objects reflect light in different combinations of wavelengths. Our brains pick up on those wavelength combinations and translate them into the phenomenon we call colour.

RGB: the additive colour mixing model

- Humans see colours in light waves. Mixing light—or the **additive colour mixing model**—allows you to create colours by mixing red, green and blue light sources of various intensities. The more light you add, the brighter the colour mix becomes. If you mix all three colours of light, you get pure, white light.

- TVs, screens and projectors use red, green and blue (RGB) as their primary colours, and then mix them together to create other colours.
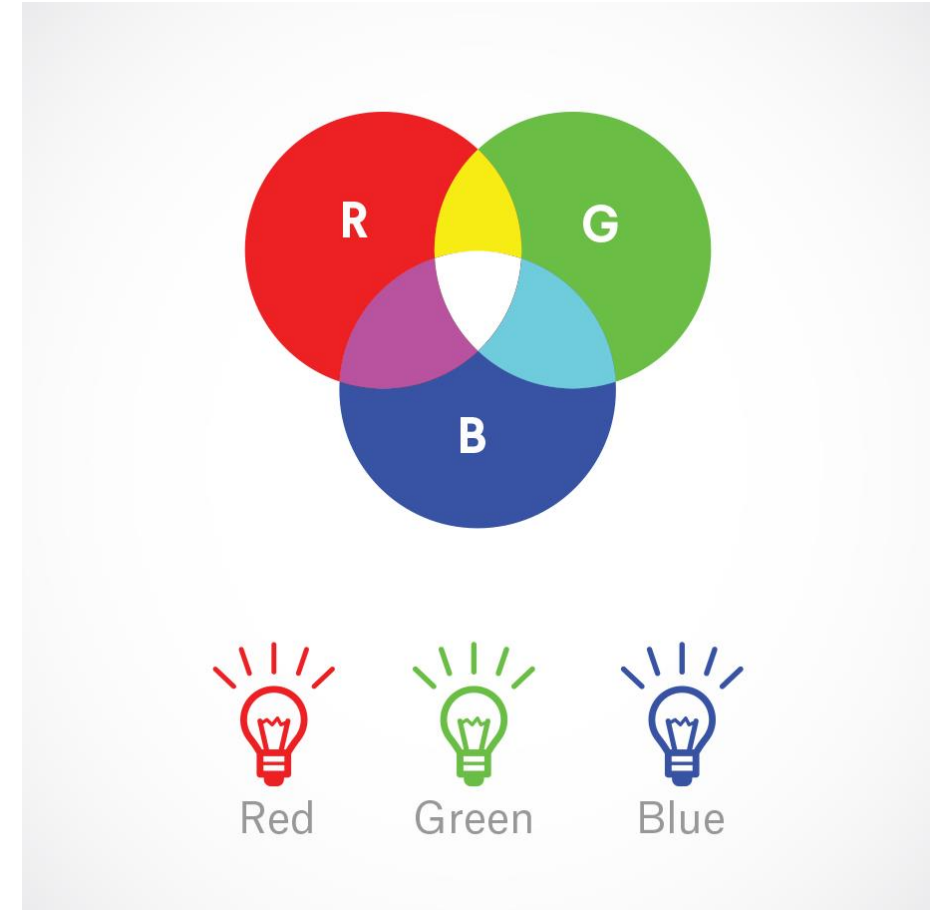
Simple 3D modeling

- In <u>3D computer graphics</u>, **3D modeling** is the process of developing a mathematical representation of any *surface* of an object (either inanimate or living) in <u>three dimensions</u> via <u>specialized software</u>. The product is called a **3D model**. Someone who works with 3D models may be referred to as a **3D artist**. It can be displayed as a two-dimensional image through a process called *3D rendering* or used in a <u>computer simulation</u> of physical phenomena. The model can also be physically created using <u>3D printing</u> devices.

- Models may be created automatically or manually. The manual modeling process of preparing geometric data for 3D computer graphics is similar to <u>plastic arts</u> such as <u>sculpting</u>.

There are three popular ways to represent a model:

<u>Polygonal modeling</u> – Points in 3D space, called *vertices*, are connected by line segments to form a <u>polygon mesh</u>. The vast majority of 3D models today are built as textured polygonal models, because they are flexible and because computers can render them so quickly. However, polygons are planar and can only approximate curved surfaces using many polygons.

Curve modeling – Surfaces are defined by curves, which are influenced by weighted control points. The curve follows (but does not necessarily interpolate) the points. Increasing the weight for a point will pull the curve closer to that point. Curve types include <u>nonuniform rational B-spline</u> (NURBS), splines, patches, and <u>geometric primitives</u>

Digital sculpting – Still a fairly new method of modeling, 3D sculpting has become very popular in the few years it has been around.[citation needed]There are currently three types of digital sculpting: Displacement, which is the most widely used among applications at this moment, uses a dense model (often generated by subdivision surfaces of a polygon control mesh) and stores new locations for the vertex positions through use of an image map that stores the adjusted locations. Volumetric, loosely based on voxels, has similar capabilities as displacement but does not suffer from polygon stretching when there are not enough polygons in a region to achieve a deformation. Dynamic tessellation is similar to voxel but divides the surface using triangulation to maintain a smooth surface and allow finer details. These methods allow for very artistic exploration as the model will have a new topology created over it once the models form and possibly details have been sculpted. The new mesh will usually have the original high resolution mesh information transferred into displacement data or normal map data if for a game engine.

Illumination model

- An **illumination model**, also called a lighting **model** and sometimes referred to as a shading **model**, is used to calculate the intensity of light that we should see at a given point on the surface of an object.

- **Illumination model**, also known as Shading model or Lightning model, is used to calculate the intensity of light that is reflected at a given point on surface. There are three factors on which lightning effect depends on:

- **Light Source :**

Light source is the light emitting source. There are three types of light sources:

    1. **Point Sources** – The source that emit rays in all directions (A bulb in a room).

    2. **Parallel Sources** – Can be considered as a point source which is far from the surface (The sun).

    3. **Distributed Sources** – Rays originate from a finite area (A tubelight).

Their position, electromagnetic spectrum and shape determine the lightning effect.

- **Surface :**

When light falls on a surface part of it is reflected and part of it is absorbed. Now the surface structure decides the amount of reflection and absorption of light. The position of the surface and positions of all the nearby surfaces also determine the lightning effect.

- **Observer :**

The observer's position and sensor spectrum sensitivities also affect the lightning effect.

Ambient Illumination :

Assume you are standing on a road, facing a building with glass exterior and sun rays are falling on that building reflecting back from it and the falling on the object under observation. This would be **Ambient Illumination**. In simple words, Ambient Illumination is the one where source of light is indirect.

The reflected intensity I_{amb} of any point on the surface is:

$$I_{amb} = K_a I_a$$

Where, I_a : ambient light intensity

K_a : surface ambient reflectivity, value of K_a varies from 0 to 1

Diffuse Reflection :

Diffuse reflection occurs on the surfaces which are rough or grainy. In this reflection the brightness of a point depends upon the angle made by the light source and the surface.

The reflected intensity I_{diff} of a point on the surface is:

$$I_{diff} = K_d\, I_p\, \cos(\theta) = K_d\, I_p\, (N \cdot L)$$

Where, I_p : the point light intensity
K_d : the surface diffuse reflectivity, value of K_d varies from 0 to 1
N : the surface normal
L : the light direction

Specular Reflection :

When light falls on any shiny or glossy surface most of it is reflected back, such reflection is known as Specular Reflection.

Phong Model is an empirical model for Specular Reflection which provides us with the formula for calculation the reflected intensity I_{spec}:

$$I_{spec} = W(\theta) \, I_l \, \cos^n(\Phi)$$

where, $W(\theta) : K_s$
L : direction of light source
N : normal to the surface
R : direction of reflected ray
V : direction of observer
Θ : Angle between L and R
Φ : angle between R and V

Shading Algorithm

Shading Algorithms for 3-d Computer Graphics. … Two of the most famous **algorithms** are **Gouraud Shading Algorithm** and **Phong Shading Algorithm**. These **algorithms** handle location of light source, location of the camera, and surface reflection properties in different manners and produce different results.

Computer graphics deals with realistic rendering of 3-d objects. There are many rendering algorithms used. Two of the most famous algorithms are Gouraud Shading Algorithm and Phong Shading Algorithm. These algorithms handle location of light source, location of the camera, and surface reflection properties in different manners and produce different results. Their computational complexities are also very different; Phong Shading being very complex compared to Gouraud Shading. The rendering problem is analyzed using 3-d geometry to see how location of light source, location of the observer, and the surface reflection properties play their role. The equations for the two shading algorithms is derived, the computational complexities of the algorithms are compared, and an adaptive shading scheme is presented that chooses between computationally complex Phong Shading algorithm to render the parts of a 3-d object where it is really needed. For other parts of the 3-d object, computationally simple Gouraud Shading is used. This type of adaptive shading scheme has been in existence for some time. However, the algorithms for selection between two rendering methods are not very robust.
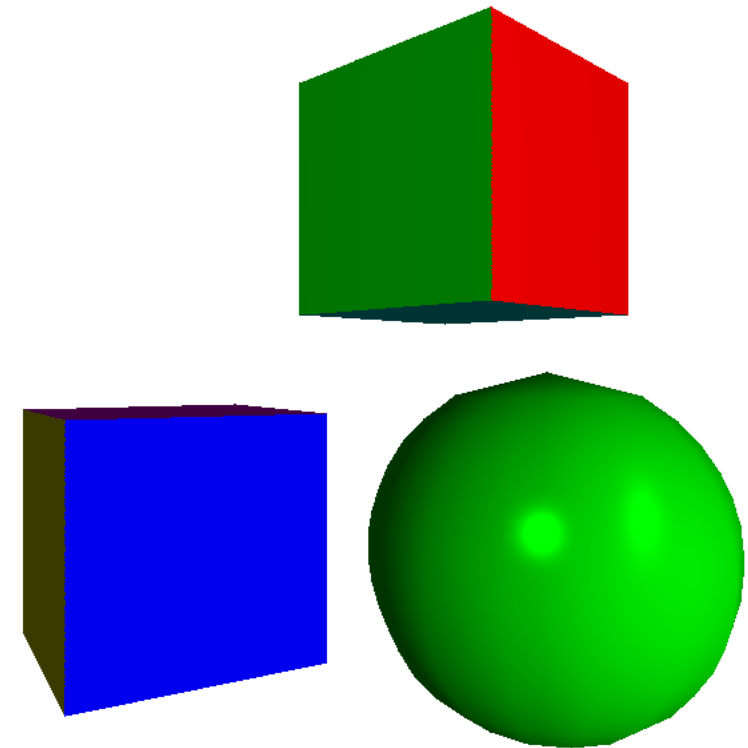
Gouraud shading

How can we do better? The easiest way, for which we have most of the infrastructure in place, is to compute lighting not at the center of the triangle, but at its three vertices; these lighting values between 0.00.0 and 1.01.0 can then be linearly interpolated first across the edges and then across the surface of the triangle to color every pixel with a smoothly varying shade. This is, in fact, exactly what we were doing in the **Drawing shaded triangles** chapter; the only difference is that we're computing the intensity values at each vertex using a lighting model, instead of assigning fixed values.
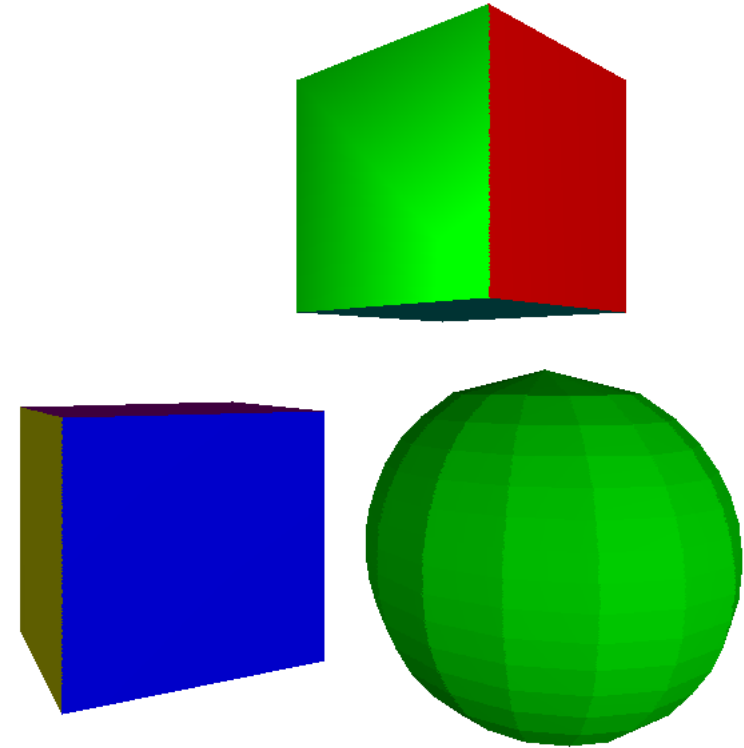
Phong shading

The limitations of Gouraud Shading can be easily overcome, but as usual, there's a tradeoff between quality and resource usage.

Flat Shading involved a single lighting calculation per triangle. Gouraud Shading requires three lighting calculations per triangle, plus the interpolation of a single attribute, the illumination, across the triangle. The next step in this quality and per-pixel cost increase is to calculate lighting at every pixel of the triangle.