Floor map creator

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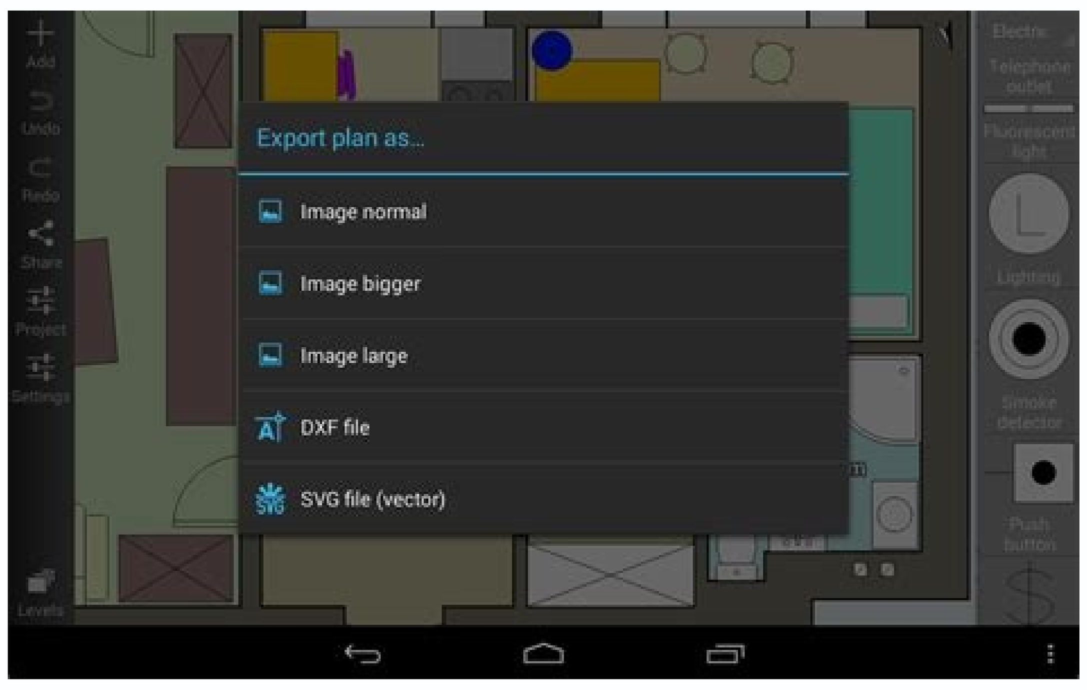

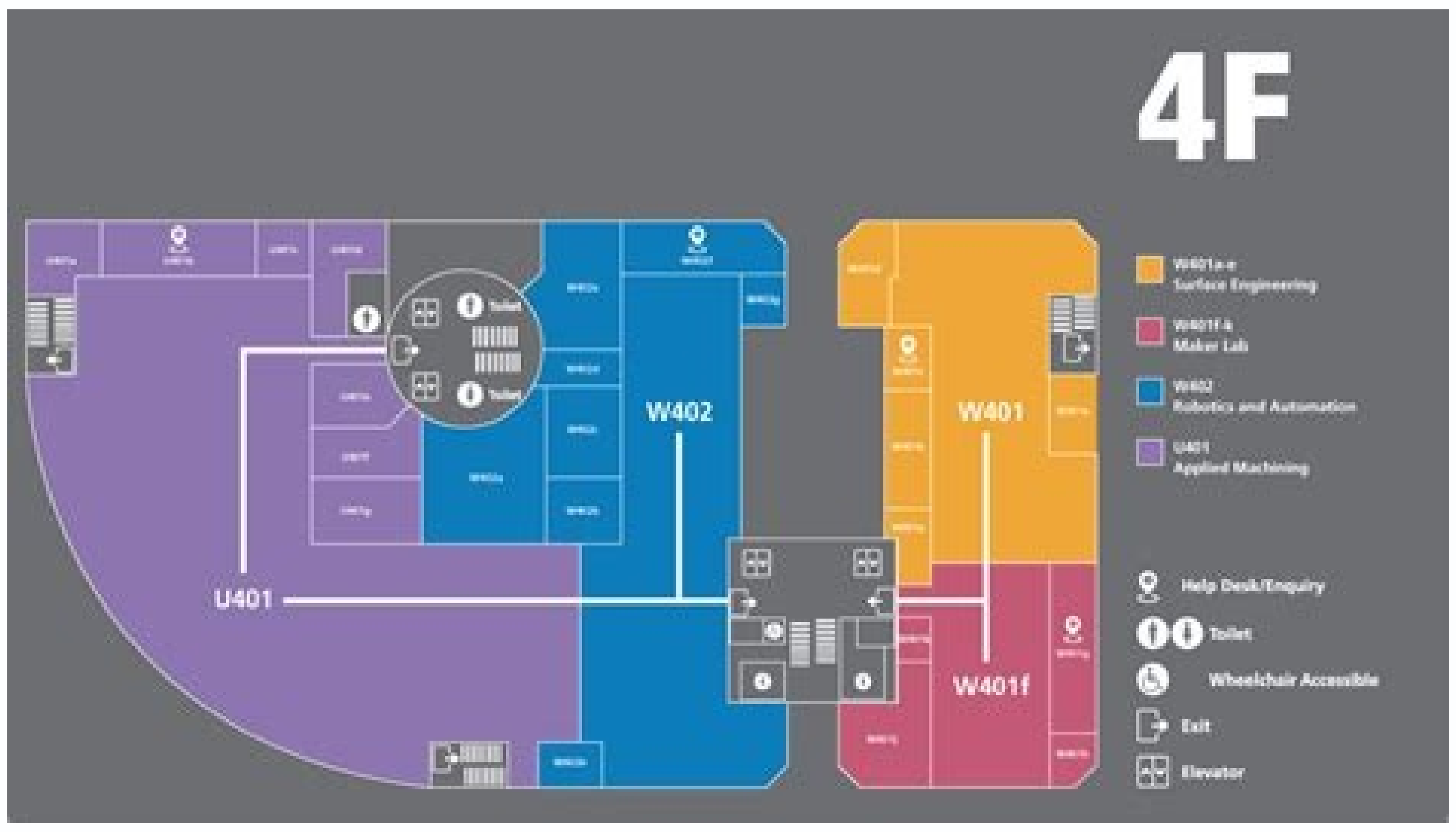

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Architectural diagram of a structure For integrated circuit diagrams, see Floorplan (microelectronics). For the financial term, see Retail floorplan. Sample main floor plan for a small family home Part of a series onGraphical projection Planar Parallel projection Orthographic projection Isometric projection Oblique projection Perspective projection Curvilinear perspective Reverse perspective Views Bird's-eye view Cross section Cutaway drawing Exploded view drawing Fisheye lens Multiviews Panorama Worm's-eye view Zoom lens Topics 3D projection Anamorphosis Axonometry Computer graphics Computer-aided design Descriptive geometry Engineering drawing Map projection Picture plane Plans (drawings) Projection (linear algebra) Projection plane Projective geometry Stereoscopy Technical drawing True length Vanishing point Video game graphics Viewing frustum vte In architecture and building engineering, a floor plan is a technical drawing to scale, showing a view from above, of the relationships between rooms, spaces, traffic patterns, and other physical features at one level of a structure. Dimensions are usually drawn between the walls to specify room sizes and wall lengths. Floor plans may also include details of fixtures like sinks, water heaters, furnaces, etc. Floor plans may include notes for construction to specify finishes, construction methods, or symbols for electrical items. It is also called a plan which is a measured plane typically projected at the floor height of 4 ft (1.2 m), as opposed to an elevation which is a measured plane projected from the side of a building, along its height, or a section or cross section where a building is cut along an axis to reveal the interior structure. Overview Similar to a map, the orientation of the view is downward from above, but unlike a conventional map, a plan is drawn at a particular vertical position (commonly at about four feet above the floor). Objects below this level are seen, objects at this level are shown 'cut' in plan-section, and objects above this vertical position within the structure are omitted or shown dashed. Plan view or planform is defined as a vertical orthographic projection of an object on a horizontal plane, like a map. The term may be used in general to describe any drawing showing the physical layout of objects. For example, it may denote the arrangement of the displayed objects at an exhibition, or the arrangement of exhibitor booths at a convention. Drawings are now reproduced using plotters and large format xerographic copiers. A reflected ceiling plan (RCP) shows a view of the room as if looking from above, through the ceiling, at a mirror installed one foot below the ceiling level, which shows the reflected image of the ceiling above. This convention maintains the same orientation of the floor and ceilings plans – looking down from above. RCPs are used by designers and architects to demonstrate lighting, visible mechanical features, and ceiling forms as part of the documents provided for construction. The art of constructing ground plans (ichnography; Gr. τὸ ἴχνος, íchnos, "track, trace" and γράφειν, gráphein, "to write";[1] pronounced ik-nog-rəfi) was first described by Vitruvius (i.2) and included the geometrical projection or horizontal section representing the plan of any building, taken at such a level as to show the outer walls, with the doorways, windows, fireplaces, etc., and the correct thickness of the walls; the position of piers, columns or pilasters, courtyards and other features which constitute the design,[2] as to scale. Floor plan topics Building blocks Floor plans use standard symbols to indicate features such as doors. This symbol shows the location of the door in a wall and which way the door opens. A floor plan is not a top view or birds eye view. It is a measured drawing to scale of the layout of a floor in a building. A top view or bird's eye view does not show an orthogonally projected plane cut at the typical four foot height above the floor level. A floor plan could show:[3] interior walls and hallways restrooms windows and doors appliances such as stoves, refrigerators, water heater etc. interior features such as fireplaces, saunas and whirlpools the use of all rooms Plan view A plan view is an orthographic projection of a three-dimensional object from the position of a horizontal plane through the object. In other words, a plan is a section viewed from the top. In such views, the portion of the object above the plane (section) is omitted to reveal what lies beyond. In the case of a floor plan, the roof and upper portion of the walls may typically be omitted. Whenever an interior design project is being approached, a floor plan is the typical starting point for any further design considerations and decisions. Roof plans are orthographic projections, but they are not sections as their viewing plane is outside of the object. A plan is a common method of depicting the internal arrangement of a three-dimensional object in two dimensions. It is often used in technical drawing and is traditionally crosshatched. The style of crosshatching indicates the type of material the section passes through. 3D floor plans A 3D floor plan can be defined as a virtual model of a building floor plan. It is often used to better convey architectural plans to individuals not familiar with floor plans. Despite the purpose of floor plans originally being to depict 3D layouts in a 2D manner, technological expansion has made rendering 3D models much more cost effective. 3D plans show a better depth of image and are often complemented by 3D furniture in the room. This allows a greater appreciation of scale than with traditional 2D floor plans. See also 3D printing 3D scanner Architect's scale Architectural drawing List of floor plan software House House plan Indoor positioning system (IPS) Room number References ^ T. F. HOAD. "ichnography." The Concise Oxford Dictionary of English Etymology. 1996. (Encyclopedia.com. 4 Jan. 2010) ^ One or more of the preceding sentences incorporates text from a publication now in the public domain: Chisholm, Hugh, ed. (1911). "Ichnography". Encyclopædia Britannica. Vol. 14 (11th ed.). Cambridge University Press. p. 243. ^ Site Plans, Elevations and Floor Plans Archived 2010-06-07 at the Wayback Machine A Community Guide San Jose. Accessed 11 February 2009. External links Media related to floor plans at Wikimedia Commons Renaissance Visual Thinking: Architectural Representation as Medium to Contemplate 'True Form', Federica Goffi-Hamilton Retrieved from " 2This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "3D floor plan" – news · newspapers · books · scholar · JSTOR (July 2016) (Learn how and when to remove this template message) A 3D floor plan, or 3D floorplan, is a virtual model of a building floor plan, depicted from a birds eye view, utilized within the building industry to better convey architectural plans. Usually built to scale, a 3D floor plan must include walls and a floor and typically includes exterior wall fenestrations, windows, and doorways. It does not include a ceiling so as not to obstruct the view. Other common attributes may be added, but are not required, such as cabinets, flooring, bathroom fixtures, paint color, wall tile, and other interior finishes. Furniture may be added to assist in communicating proper home staging and interior design.[1] Purpose 3D floor plans assist real estate marketers and architects in explaining floor plans to clients. Their simplicity allows individuals unfamiliar with conventional floor plans to understand difficult architectural concepts. This allows architects and homeowners to literally see design elements prior to construction and alter design elements during the design phase. 3D floorplans are often commissioned by architects, builders, hotels, universities, real estate agents, and property owners to assist in relating their floor plans to clients.[2] Construction A 3D floor plan is built utilizing 3D rendering software, the same type of software used to create major animated motion pictures. Through complex lighting,[3] staging, camera, and rendering techniques 3D floor plans appear to be real photographs rather than digital representations of the buildings after which they are modeled. It is also the presentation of building floor-plan in an advanced manner, bringing it to real life views.[4] Technology WebGL allows many companies to provide their users with unique 3D experiences right in their web browser. In addition, since 2014, WebVR helps make Virtual Reality experiences accessible to wider audiences. 3D floor plans can now be visited via Google Cardboard or various VR headsets. Due to the increasing popularity of VR content, many real estate professionals (real estate firms, developers, online platforms) are turning to 3D models of spaces to improve their marketing efforts.[5] See also Floor plan Plan (drawing) 3d rendering Virtual tour Home staging Computer-aided design WebVR WebGL References ^ "A Virtual Look Into Don Draper's Mad Men Apartment". 2016-03-31. Retrieved 2016-07-21. ^ "Now you can shop for luxury homes in virtual reality". Fortune. 2015-09-09. Retrieved 2016-07-21. ^ "How to enhance the atmosphere of 3d models with light baking? - Archilogic". 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Unsourced material may be challenged and removed.Find sources: "3D modeling" – news · newspapers · books · scholar · JSTOR (April 2010) (Learn how and when to remove this template message) Three-dimensional (3D)computer graphics Fundamentals Modeling Scanning Rendering Printing Primary uses 3D models Computer-aided design Graphic design Video games Visual effects Visualization Virtual engineering Virtual reality Virtual cinematography Related topics Computer-generated imagery (CGI) Animation computer skeletal 3D display Wire-frame model Texture mapping Motion capture Crowd simulation Global illumination Volume rendering vte In 3D computer graphics, 3D modeling is the process of developing a mathematical coordinate-based representation of any surface of an object (inanimate or living) in three dimensions via specialized software by manipulating edges, vertices, and polygons in a simulated 3D space.[1][2][3] Three-dimensional (3D) models represent a physical body using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc.[4] Being a collection of data (points and other information), 3D models can be created manually, algorithmically (procedural modeling), or by scanning.[5][6] Their surfaces may be further defined with texture mapping. 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Individual programs of this class, such as SketchUp, are called modeling applications.[8] History Three-dimensional model of a spectrograph[9] Rotating 3D video-game model 3D selfie models are generated from 2D pictures taken at the Fantasitron 3D photo booth at Madurodam 3D models are now widely used anywhere in 3D graphics and CAD but their history predates the widespread use of 3D graphics on personal computers.[10] In the past, many computer games used pre-rendered images of 3D models as sprites before computers could render them in real-time. The designer can then see the model in various directions and views, this can help the designer see if the object is created as intended to compared to their original vision. Seeing the design this way can help the designer or company figure out changes or improvements needed to the product.[11] Representation A modern render of the iconic Utah teapot model developed by Martin Newell (1975). 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In a shell model of a cube, the bottom and top surface of the cube must have a uniform thickness with no holes or cracks in the first and last layer printed. Polygonal meshes (and to a lesser extent subdivision surfaces) are by far the most common representation. Level sets are a useful representation for deforming surfaces which undergo many topological changes such as fluids. The process of transforming representations of objects, such as the middle point coordinate of a sphere and a point on its circumference into a polygon representation of a sphere, is called tessellation. This step is used in polygon-based rendering, where objects are broken down from abstract representations ("primitives") such as spheres, cones etc., to so-called meshes, which are nets of interconnected triangles. Meshes of triangles (instead of e.g. squares) are popular as they have proven to be easy to rasterize (the surface described by each triangle is planar, so the projection is always convex); .[12] Polygon representations are not used in all rendering techniques, and in these cases the tessellation step is not included in the transition from abstract representation to rendered scene. Process There are three popular ways to represent a model: Polygonal modeling – Points in 3D space, called vertices, are connected by line segments to form a polygon mesh. The vast majority of 3D models today are built as textured polygonal models, because they are flexible, 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 nonuniform rational B-spline (NURBS), splines, patches, and geometric primitives Digital sculpting – Still a fairly new method of modeling, 3D sculpting has become very popular in the few years it has been around.[13] 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, which is similar to voxel, 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. A 3D fantasy fish composed of organic surfaces generated using LAI4D. The modeling stage consists of shaping individual objects that are later used in the scene. There are a number of modeling techniques, including: Constructive solid geometry Implicit surfaces Subdivision surfaces Modeling can be performed by means of a dedicated program (e.g., Blender, Cinema 4D, LightWave, Maya, Modo, 3ds Max) or an application component (Shaper, Lofter in 3ds Max) or some scene description language (as in POV-Ray). In some cases, there is no strict distinction between these phases; in such cases modeling is just part of the scene creation process (this is the case, for example, with Caligari trueSpace and Realsoft 3D). 3D models can also be created using the technique of Photogrammetry with dedicated programs such as RealityCapture, Metashape and 3DF Zephyr. Cleanup and further processing can be performed with applications such as MeshLab, the GigaMesh Software Framework, netfabb or MeshMixer. Photogrammetry creates models using algorithms to interpret the shape and texture of real-world objects and environments based on photographs taken from many angles of the subject. Complex materials such as blowing sand, clouds, and liquid sprays are modeled with particle systems, and are a mass of 3D coordinates which have either points, polygons, texture splats, or sprites assigned to them. Human models Main article: Virtual actor The first widely available commercial application of human virtual models appeared in 1998 on the Lands' End web site. The human virtual models were created by the company My Virtual Mode Inc. and enabled users to create a model of themselves and try on 3D clothing.[14] There are several modern programs that allow for the creation of virtual human models (Poser being one example). 3D clothing Dynamic 3D clothing model made in Marvelous Designer The development of cloth simulation software such as Marvelous Designer, CLO3D and Optitex, has enabled artists and fashion designers to model dynamic 3D clothing on the computer.[15] Dynamic 3D clothing is used for virtual fashion catalogs, as well as for dressing 3D characters for video games, 3D animation movies, for digital doubles in movies[16] as well as for making clothes for avatars in virtual worlds such as SecondLife. Comparison with 2D methods 3D photorealistic effects are often achieved without wire-frame modeling and are sometimes indistinguishable in the final form. Some graphic art software includes filters that can be applied to 2D vector graphics or 2D raster graphics on transparent layers. Advantages of wireframe 3D modeling over exclusively 2D methods include: Flexibility, ability to change angles or animate images with quicker rendering of the changes; Ease of rendering, automatic calculation and rendering photorealistic effects rather than mentally visualizing or estimating; Accurate photorealism, less chance of human error in misplacing, overdoing, or forgetting to include a visual effect. Disadvantages compare to 2D photorealistic rendering may include a software learning curve and difficulty achieving certain photorealistic effects. Some photorealistic effects may be achieved with special rendering filters included in the 3D modeling software. For the best of both worlds, some artists use a combination of 3D modeling followed by editing the 2D computer-rendered images from the 3D model. 3D model market A large market for 3D models (as well as 3D-related content, such as textures, scripts, etc.) still exists - either for individual models or large collections. Several online marketplaces for 3D content allow individual artists to sell content that they have created, including TurboSquid, CGStudio, CreativeMarket, MyMiniFactory, Sketchfab, CGTrader and Cults. Often, the artists' goal is to get additional value out of assets they have previously created for projects. By doing so, artists can earn more money out of their old content, and companies can save money by buying pre-made models instead of paying an employee to create one from scratch. These marketplaces typically split the sale between themselves and the artist that created the asset, artists get 40% to 95% of the sales according to the marketplace. In most cases, the artist retains ownership of the 3d model while the customer only buys the right to use and present the model. Some artists sell their products directly in its own stores offering their products at a lower price by not using intermediaries. Over the last several years numerous marketplaces specializing in 3D rendering and printing models have emerged. Some of the 3D printing marketplaces are a combination of models sharing sites, with or without a built in e-com capability. Some of those platforms also offer 3D printing services on demand, software for model rendering and dynamic viewing of items. 3D printing file sharing and model rendering platforms include Shapeways, Sketchfab, Pinshape, Thingiverse, TurboSquid, CGTrader, Threeding, MyMiniFactory, and GrabCAD. 3D printing Main articles: 3D printing and Rapid prototyping The term 3D printing or three-dimensional printing is a form of additive manufacturing technology where a three-dimensional object is created from successive layers material.[17] Objects can be created without the need for complex expensive molds or assembly with multiple parts. 3D printing allows ideas to be prototyped and tested without having to go through a production process.[17][18] In recent years, there has been an upsurge in the number of companies offering personalized 3D printed models of objects that have been scanned, designed in CAD software, and then printed to the customer's requirements.[19] 3D models can be purchased from online marketplaces and printed by individual or companies using commercially available 3D printers, enabling the home-production of objects such as spare parts and even medical equipment.[20][21] Uses Steps of forensic facial reconstruction of a mummy made in Blender by the Brazilian 3D designer Cícero Moraes. Today, 3D modeling is used in various industries like film, animation and gaming, interior design and architecture.[22] They are also used in the medical industry to create interactive representations of anatomy.[23] The medical industry uses detailed models of organs; these may be created with multiple 2-D image slices from an MRI or CT scan. The movie industry uses them as characters and objects for animated and real-life motion pictures. The video game industry uses them as assets for computer and video games. The science sector uses them as highly detailed models of chemical compounds.[24] The architecture industry uses them to demonstrate proposed buildings and landscapes in lieu of traditional, physical architectural models. The archeology community is now creating 3D models of cultural heritage for research and visualization. The engineering community utilizes them as designs of new devices, vehicles and structures as well as a host of other uses. In recent decades the earth science community has started to construct 3D geological models as a standard practice. 3D models can also be the basis for physical devices that are built with 3D printers or CNC machines. In terms of video game development, 3D modeling is one stage in a longer development process. Simply put, the source of the geometry for the shape of an object can be: A designer, industrial engineer or artist using a 3D-CAD system An existing object, reverse engineered or copied using a 3-D shape digitizer or scanner Mathematical data stored in memory based on a numerical description or calculation of the object.[17] A wide number of 3D software are also used in constructing digital representation of mechanical models or parts before they are actually manufactured. CAD- and CAM-related software is used in such fields, and with this software, not only can you construct the parts, but also assemble them, and observe their functionality. 3D modeling is also used in the field of industrial design, wherein products are 3D modeled before representing them to the clients. In media and event industries, 3D modeling is used in stage and set design.[25] The OWL 2 translation of the vocabulary of X3D can be used to provide semantic descriptions for 3D models, which is suitable for indexing and retrieval of 3D models by features such as geometry, dimensions, material, texture, diffuse reflection, transmission spectra, transparency, reflectivity, opalescence, glazes, varnishes, and enamels (as opposed to unstructured textual descriptions or 2.5D virtual museums and exhibitions using Google Street View on Google Arts & Culture, for example).[26] The RDF representation of 3D models can be used in reasoning, which enables intelligent 3D applications which, for example, can automatically compare two 3D models by volume.[27] Testing a 3D solid model Further information: Solid modeling 3D solid models can be tested in different ways depending on what is needed by using simulation, mechanism design, and analysis. If a motor is designed and assembled correctly (this can be done differently depending on what 3D modeling program is being used), using the mechanism tool the user should be able to tell if the motor or machine is assembled correctly by how it operates. Different design will need to be tested in different ways. For example; a pool pump would have a simulation ran of the water running through the pump to see how the water flows through the pump. These tests verify if a product is developed correctly or if it needs to be modified to meet its requirements. See also List of 3D modeling software List of common 3D test models List of file formats#3D graphics 3D city model 3D computer graphics software 3D figure 3D printing 3D scanner 3D scanning Additive manufacturing file format Building information modeling Cloth modeling Computer facial animation Cornell box Digital geometry Edge loop Geological modeling Holography Industrial CT scanning Marching cubes Open CASCADE Polygon mesh Polygonal modeling Ray tracing (graphics) Scaling (geometry) SIGGRAPH Stanford bunny Triangle mesh Utah teapot Voxel B-rep References ^ "What is 3D Modeling & What's It Used For?". Concept Art Empire. 2018-04-27. Retrieved 2021-05-05. ^ "3D Modeling". Siemens Digital Industries Software. Retrieved 2021-07-14. ^ Marketing, TOPS (2020-04-27). "What is 3D Modeling? | How 3D Modeling is Used Today". TOPS. Retrieved 2021-07-14. ^ Slick, Justin (2020-09-24). "What Is 3D Modeling?". Lifewire. Retrieved 2022-02-03. ^ "How to scan with a phone: Here are our best tips". 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Find sources: "3D modeling" – news · newspapers · books · scholar · JSTOR (April 2010) (Learn how and when to remove this template message) Three-dimensional (3D)computer graphics Fundamentals Modeling Scanning Rendering Printing Primary uses 3D models Computer-aided design Graphic design Video games Visual effects Visualization Virtual engineering Virtual reality Virtual cinematography Related topics Computer-generated imagery (CGI) Animation computer skeletal 3D display Wire-frame model Texture mapping Motion capture Crowd simulation Global illumination Volume rendering vte 3D modeling In 3D computer graphics, 3D modeling is the process of developing a mathematical coordinate-based representation of any surface of an object (inanimate or living) in three dimensions via specialized software by manipulating edges, vertices, and polygons in a simulated 3D space.[1][2][3] Three-dimensional (3D) models represent a physical body using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc.[4] Being a collection of data (points and other information), 3D models can be created manually, algorithmically (procedural modeling), or by scanning.[5][6] Their surfaces may be further defined with texture mapping. 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The Utah teapot is one of the most common models used in 3D graphics education. Almost all 3D models can be divided into two categories: Solid - These models define the volume of the object they represent (like a rock). Solid models are mostly used for engineering and medical simulations, and are usually built with constructive solid geometry Shell or boundary - These models represent the surface, i.e. the boundary of the object, not its volume (like an infinitesimally thin eggshell). Almost all visual models used in games and film are shell models. Solid and shell modeling can create functionally identical objects. Differences between them are mostly variations in the way they are created and edited and conventions of use in various fields and differences in types of approximations between the model and reality. Shell models must be manifold (having no holes or cracks in the shell) to be meaningful as a real object. In a shell model of a cube, the bottom and top surface of the cube must have a uniform thickness with no holes or cracks in the first and last layer printed. Polygonal meshes (and to a lesser extent subdivision surfaces) are by far the most common representation. Level sets are a useful representation for deforming surfaces which undergo many topological changes such as fluids. The process of transforming representations of objects, such as the middle point coordinate of a sphere and a point on its circumference into a polygon representation of a sphere, is called tessellation. This step is used in polygon-based rendering, where objects are broken down from abstract representations ("primitives") such as spheres, cones etc., to so-called meshes, which are nets of interconnected triangles. Meshes of triangles (instead of e.g. squares) are popular as they have proven to be easy to rasterise (the surface described by each triangle is planar, so the projection is always convex).[12] Polygon representations are not used in all rendering techniques, and in these cases the tessellation step is not included in the transition from abstract representation to rendered scene. Process There are three popular ways to represent a model: Polygonal modeling – Points in 3D space, called vertices, are connected by line segments to form a polygon mesh. The vast majority of 3D models today are built as textured polygonal models, because they are flexible, 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 nonuniform rational B-spline (NURBS), splines, patches, and geometric primitives Digital sculpting – Still a fairly new method of modeling, 3D sculpting has become very popular in the few years it has been around.[13] 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, which is similar to voxel, 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. A 3D fantasy fish composed of organic surfaces generated using LAI4D. The modeling stage consists of shaping individual objects that are later used in the scene. There are a number of modeling techniques, including: Constructive solid geometry Implicit surfaces Subdivision surfaces Modeling can be performed by means of a dedicated program (e.g., Blender, Cinema 4D, LightWave, Maya, Modo, 3ds Max) or an application component (Shaper, Lofter in 3ds Max) or some scene description language (as in POV-Ray). In some cases, there is no strict distinction between these phases; in such cases modeling is just part of the scene creation process (this is the case, for example, with Caligari trueSpace and Realsoft 3D). 3D models can also be created using the technique of Photogrammetry with dedicated programs such as RealityCapture, Metashape and 3DF Zephyr. Cleanup and further processing can be performed with applications such as MeshLab, the GigaMesh Software Framework, netfabb or MeshMixer. Photogrammetry creates models using algorithms to interpret the shape and texture of real-world objects based on photographs taken from many angles of the subject. Complex materials such as blowing sand, clouds, and liquid sprays are modeled with particle systems, and are a mass of 3D coordinates which have either points, polygons, texture splats, or sprites assigned to them. Human models Main article: Virtual actor The first widely available commercial application of human virtual models appeared in 1998 on the Lands' End web site. The human virtual models were created by the company My Virtual Mode Inc. and enabled users to create a model of themselves and try on 3D clothing.[14] There are several modern programs that allow for the creation of virtual human models (Poser being one example). 3D clothing Dynamic 3D clothing model made in Marvelous Designer The development of cloth simulation software such as Marvelous Designer, CLO3D and Optitex, has enabled artists and fashion designers to model dynamic 3D clothing on the computer.[15] Dynamic 3D clothing is used for virtual fashion catalogs, as well as for dressing 3D characters for video games, 3D animation movies, for digital doubles in movies[16] as well as for making clothes for avatars in virtual worlds such as SecondLife. Comparison with 2D methods 3D photorealistic effects are often achieved without wire-frame modeling and are sometimes indistinguishable in the final form. Some graphic art software includes filters that can be applied to 2D vector graphics or 2D raster graphics on transparent layers. Advantages of wireframe 3D modeling over exclusively 2D methods include: Flexibility, ability to change angles or animate images with quicker rendering of the changes; Ease of rendering, automatic calculation and rendering photorealistic effects rather than mentally visualizing or estimating; Accurate photorealism, less chance of human error in misplacing, overdoing, or forgetting to include a visual effect. Disadvantages compare to 2D photorealistic rendering may include a software learning curve and difficulty achieving certain photorealistic effects. Some photorealistic effects may be achieved with special rendering filters included in the 3D modeling software. For the best of both worlds, some artists use a combination of 3D modeling followed by editing the 2D computer-rendered images from the 3D model. 3D model market A large market for 3D models (as well as 3D-related content, such as textures, scripts, etc.) still exists - either for individual models or large collections. Several online marketplaces for 3D content allow individual artists to sell content that they have created, including TurboSquid, CGStudio, CreativeMarket, MyMiniFactory, Sketchfab, CGTrader and Cults. Often, the artists' goal is to get additional value out of assets they have previously created for projects. By doing so, artists can earn more money out of their old content, and companies can save money by buying pre-made models instead of paying an employee to create one from scratch. These marketplaces typically split the sale between themselves and the artist that created the asset, artists get 40% to 95% of the sales according to the marketplace. In most cases, the artist retains ownership of the 3d model while the customer only buys the right to use and present the model. Some artists sell their products directly in its own stores offering their products at a lower price by not using intermediaries. Over the last several years numerous marketplaces specializing in 3D rendering and printing models have emerged. Some of the 3D printing marketplaces are a combination of models sharing sites, with or without a built in e-com capability. Some of those platforms also offer 3D printing services on demand, software for model rendering and dynamic viewing of items. 3D printing file sharing and model rendering platforms include Shapeways, Sketchfab, Pinshape, Thingiverse, TurboSquid, CGTrader, Threeding, MyMiniFactory, and GrabCAD. 3D printing Main articles: 3D printing and Rapid prototyping The term 3D printing or three-dimensional printing is a form of additive manufacturing technology where a three-dimensional object is created from successive layers material.[17] Objects can be created without the need for complex expensive molds or assembly with multiple parts. 3D printing allows ideas to be prototyped and tested without having to go through a production process.[17][18] In recent years, there has been an upsurge in the number of companies offering personalized 3D printed models of objects that have been scanned, designed in CAD software, and then printed to the customer's requirements.[19] 3D models can be purchased from online marketplaces and printed by individual or companies using commercially available 3D printers, enabling the home-production of objects such as spare parts and even medical equipment.[20][21] Uses Steps of forensic facial reconstruction of a mummy made in Blender by the Brazilian 3D designer Cícero Moraes. Today, 3D modeling is used in various industries like film, animation and gaming, interior design and architecture.[22] They are also used in the medical industry to create interactive representations of anatomy.[23] The medical industry uses detailed models of organs; these may be created with multiple 2-D image slices from an MRI or CT scan. The movie industry uses them as characters and objects for animated and real-life motion pictures. The video game industry uses them as assets for computer and video games. The science sector uses them as highly detailed models of chemical compounds.[24] The architecture industry uses them to demonstrate proposed buildings and landscapes in lieu of traditional, physical architectural models. The archeology community is now creating 3D models of cultural heritage for research and visualization. The engineering community utilizes them as designs of new devices, vehicles and structures as well as a host of other uses. In recent decades the earth science community has started to construct 3D geological models as a standard practice. 3D models can also be the basis for physical devices that are built with 3D printers or CNC machines. In terms of video game development, 3D modeling is one stage in a longer development process. Simply put, the source of the geometry for the shape of an object can be: A designer, industrial engineer or artist using a 3D-CAD system An existing object, reverse engineered or copied using a 3-D shape digitizer or scanner Mathematical data stored in memory based on a numerical description or calculation of the object.[17] A wide number of 3D software are also used in constructing digital representation of mechanical models or parts before they are actually manufactured. CAD- and CAM-related software is used in such fields, and with this software, not only can you construct the parts, but also assemble them, and observe their functionality. 3D modeling is also used in the field of industrial design, wherein products are 3D modeled before representing them to the clients. In media and event industries, 3D modeling is used in stage and set design.[25] The OWL 2 translation of the vocabulary of X3D can be used to provide semantic descriptions for 3D models, which is suitable for indexing and retrieval of 3D models by features such as geometry, dimensions, material, texture, diffuse reflection, transmission spectra, transparency, reflectivity, opalescence, glazes, varnishes, and enamels (as opposed to unstructured textual descriptions or 2.5D virtual museums and exhibitions using Google Street View on Google Arts & Culture, for example).[26] The RDF representation of 3D models can be used in reasoning, which enables intelligent 3D applications which, for example, can automatically compare two 3D models by volume.[27] Testing a 3D solid model Further information: Solid modeling 3D solid models can be tested in different ways depending on what is needed by using simulation, mechanism design, and analysis. If a motor is designed and assembled correctly (this can be done differently depending on what 3D modeling program is being used), using the mechanism tool the user should be able to tell if the motor or machine is assembled correctly by how it operates. Different design will need to be tested in different ways. For example; a pool pump would have a simulation ran of the water running through the pump to see how the water flows through the pump. These tests verify if a product is developed correctly or if it needs to be modified to meet its requirements. See also List of 3D modeling software List of common 3D test models List of file formats#3D graphics 3D city model 3D computer graphics software 3D figure 3D printing 3D scanner 3D scanning Additive manufacturing file format Building information modeling Cloth modeling Computer facial animation Cornell box Digital geometry Edge loop Geological modeling Holography Industrial CT scanning Marching cubes Open CASCADE Polygon mesh Polygonal modeling Ray tracing (graphics) Scaling (geometry) SIGGRAPH Stanford bunny Triangle mesh Utah teapot Voxel B-rep References ^ "What is 3D Modeling & What's It Used For?". Concept Art Empire. 2018-04-27. Retrieved 2021-05-05. ^ "3D Modeling". Siemens Digital Industries Software. Retrieved 2021-07-14. ^ Marketing, TOPS (2020-04-27). "What is 3D Modeling? | How 3D Modeling is Used Today". TOPS. Retrieved 2021-07-14. ^ Slick, Justin (2020-09-24). "What Is 3D Modeling?". Lifewire. Retrieved 2022-02-03. ^ "How to scan with a phone: Here are our best tips". 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International Journal of Heritage in the Digital Era. 3 (3): 579–596. doi:10.1260/2047-4970.3.3.579. External links Look up modeler in Wiktionary, the free dictionary. Media related to 3D modeling at Wikimedia Commons Retrieved from " 5The 3D model of Berlin allows viewers to look at the city as it is now, as it once was, and as the city it might turn into in the future. A 3D city model is digital model of urban areas that represent terrain surfaces, sites, buildings, vegetation, infrastructure and landscape elements in three-dimensional scale as well as related objects (e.g., city furniture) belonging to urban areas. Their components are described and represented by corresponding two- and three-dimensional spatial data and geo-referenced data. 3D city models support presentation, exploration, analysis, and management tasks in a large number of different application domains. In particular, 3D city models allow "for visually integrating heterogeneous geoinformation within a single framework and, therefore, create and manage complex urban information spaces."[1][2] Storage To store 3D city models, both file-based and database approaches are used. There is no single, unique representation schema due to the heterogeneity and diversity of 3D city model contents. Encoding of components The components of 3D city models are encoded by common file and exchange formats for 2D raster-based GIS data (e.g., GeoTIFF), 2D vector-based GIS data (e.g., AutoCAD DXF), 3D models (e.g., .3DS, .OBJ), and 3D scenes (e.g., Collada, Keyhole Markup Language) such as supported by CAD, GIS, and computer graphics tools and systems. All components of a 3D city model have to be transformed into a common geographic coordinate system. Databases A database for 3D city models stores its components in a hierarchically structured, multi-scale way, which allows for a stable and reliable data management and facilitates complex GIS modeling and analysis tasks. For example, the 3D City Database is a free 3D geo-database to store, represent, and manage virtual 3D city models on top of a standard spatial relational database.[3] A database is required if 3D city models have to be continuously managed. 3D city model databases form a key element in 3D spatial data infrastructures that require support for storing, managing, maintenance, and distribution of 3D city model contents.[4] Their implementation requires support of a multitude of formats (e.g., based on FME multi formats). As common application, geodata download portals can be set up for 3D city model contents (e.g., virtualcityWarehouse).[5] CityGML The Open Geospatial Consortium (OGC) defines an explicit XML-based exchange format for 3D city models, CityGML, which supports not only geometric descriptions of 3D city model components but also the specification of semantics and topology information.[6] CityJSON CityJSON is a JSON-based format for storing 3D city models.[7] It mostly follows the CityGML data model, but aims to be developer- and user-friendly by avoiding most of the complexities of its usual GML encoding. Due to its simple encoding and the use of JSON, it is also suitable for web applications.[8] Construction Level of detail 3D city models are typically constructed at various levels of detail (LOD) to provide notions of multiple resolutions and at different levels of abstraction. Other metrics such as the level of spatio-semantic coherence and resolution of the texture can be considered a part of the LOD. For example, CityGML defines five LODs for building models: LOD 0: 2.5D footprints LOD 1: Buildings represented by block models (usually extruded footprints) LOD 2: Building models with standard roof structures LOD 3: Detailed (architectural) building models LOD 4: LOD 3 building models supplemented with interior features. There exist also approaches to generalize a given detailed 3D city model by means of automated generalization.[9] For example, a hierarchical road network (e.g., OpenStreetMap) can be used to group 3D city model components into "cells"; each cell is abstracted by aggregating and merging contained components. GIS data GIS data provide the base information to build a 3D city model such as by digital terrain models, road networks, land use maps, and related geo-referenced data. GIS data also includes cadastral data that can be converted into simple 3D models as, for example, in the case of extruded building footprints. Core components of 3D city models form digital terrain models (DTM) represented, for example, by TINs or grids. CAD data Typical sources of data for 3D city model also include CAD models of buildings, sites, and infrastructure elements. They provide a high level of detail, possible not required by 3D city model applications, but can be incorporated either by exporting their geometry or as encapsulated objects. BIM data Building information models represent another category of geo-spatial data that can be integrated into a 3D city model providing the highest level of detail for building components. Integration at visualization level Complex 3D city models typically are based on different sources of geodata such as geodata from GIS, building and site models from CAD and BIM. It is one of their core properties to establish a common reference frame for heterogeneous geo-spatial and geo-referenced data, i.e., the data need not to be merged or fused based on one common data model or schema. The integration is possible by sharing a common geo-coordinate system at the visualization level.[10] Building reconstruction The simplest form of building model construction consist in extruding the footprint polygons of buildings, e.g., taken from the cadaster, by pre-compute average heights. In practice, 3D models of buildings of urban regions are generated based on capturing and analyzing 3D point clouds (e.g., sampled by terrestrial or aerial laser scanning) or by photogrammetric approaches. To achieve a high percentage of geometrically and topologically correct 3D building models, digital terrain surfaces and 2D footprint polygons are required by automated building reconstruction tools such as BREC.[11] One key challenge is to find building parts with their corresponding roof geometry. "Since fully automatic image understanding is very hard to solve, semi-automatic components are usually required to at least support the recognition of very complex buildings by a human operator."[12] Statistical approaches are common for roof reconstruction based on airborne laser scanning point clouds. [13][14] Fully automated processes exist to generate LOD1 and LOD2 building models for large regions. For example, the Bavarian Office for Surveying and Spatial Information is responsible for about 8 million building models at LOD1 and LOD2.[15] Visualization The visualization of 3D city models represents a core functionality required for interactive applications and systems based on 3D city models. Real-time rendering Providing high quality visualization of massive 3D city models in a scalable, fast, and cost efficient manner is still a challenging task due to the complexity in terms of 3D geometry and textures of 3D city models. Real-time rendering provides a large number of specialized 3D rendering techniques for 3D city models. Examples of specialized real-time 3D rendering include: Real-time 3D rendering of road networks on high resolution terrain models.[16] Real-time 3D rendering of water surfaces with cartography-oriented design.[17] Real-time 3D rendering of day and night sky phenomena.[18] Real-time 3D rendering of grid-based terrain models.[19] Real-time 3D rendering using different levels of abstraction, ranging between 2D map views and 3D views.[20] Real-time 3D rendering of multiperspective views on 3D city models.[21][22] Real-time rendering algorithms and data structures are listed by the virtual terrain project.[23] Service-based rendering Service-oriented architectures (SOA) for visualizing 3D city models offer a separation of concerns into management and rendering and their interactive provision by client applications. For SOA-based approaches, 3D portrayal services[24] are required, whose main functionality represents the portrayal in the sense of 3D rendering and visualization.[25] SOA-based approaches can be distinguished into two main categories, currently discussed in the Open Geospatial Consortium: Web 3D service (W3DS): This type of service handles geodata access and mapping to computer graphics primitives such as scene graphs with textured 3D geometry models as well as their delivery to the requesting client applications. The client applications are responsible for the 3D rendering of delivered scene graphs, i.e., they are responsible for the interactive display using their own 3D graphics hardware. Web view service (WVS): This type of service encapsulates the 3D rendering process for 3D city models at the server side. The server generates views of the 3D scene or intermediate, image-based representations (e.g., virtual panoramas or G-buffer cube maps[26]), which are streamed and uploaded to requesting client applications. The client applications are responsible for re-construction the 3D scene based on the intermediate representations. Client applications do not have to process 3D graphics data, but to provide management for loading, caching, and displaying the image-based representations of 3D scenes and do not have to process the original (and possibly large) 3D city model. Map-based visualization A map-based technique, the "smart map" approach, aims at providing "massive, virtual 3D city models on different platforms namely web browsers, smartphones or tablets, by means of an interactive map assembled from artificial oblique image tiles."[27] The map tiles are synthesized by an automatic 3D rendering process of the 3D city model; the map tiles, generated for different levels-of-detail, are stored on the server. This way, the 3D rendering is completely performed on the server's side, simplifying access and usage of 3D city models. The 3D rendering process can apply advanced rendering techniques (e.g., global illumination and shadow calculation, illustrative rendering), but does not require client devices to have advanced 3D graphics hardware. Most importantly, the map-based approach allows for distributing and using complex 3D city models with having to stream the underlying data to client devices - only the pre-generated map tiles are sent. This way, "(a) The complexity of the 3D city model data is decoupled from data transfer complexity (b) the implementation of client applications is simplified significantly as 3D rendering is encapsulated on server side (c) 3D city models can be easily deployed for and used by a large number of concurrent users, leading to a high degree of scalability of the overall approach."[27] Applications 3D city models can be used for a multitude of purposes in a growing number of different application domains. Examples: Navigation systems: 3D navigation maps have become omnipresent both in automotive and pedestrian navigation systems, which include 3D city models, in particular, terrain models and 3D building models, to enhance the visual depiction and to simplify the recognition of locations.[28] Urban planning and architecture: To set up, analyze, and disseminate urban planning concepts and projects, 3D city models serve as communication and participation medium.[29] 3D city models provide means for project communication, better acceptance of development projects through visualization, and therefore avoid monetary loss through project delays; they also help to prevent planning errors.[30] Spatial data infrastructures (SDIs): 3D city models extend spatial data infrastructures and support the management, storage, and usage of 3D models within SDIs; they require not only tools and processes for the initial construction and storage of 3D city models but also have to provide efficient data management and data distribution to support workflows and applications.[31] GIS: GIS support 3D geodata and provide computational algorithms to construct, transform, validate, and analyze 3D city model components. Emergency management: For emergency, risk, and disaster management systems, 3D city models provide the computational framework. In particular, they serve to simulate fire, floodings, and explosions For example, the DETORBA project aims at simulating and analyzing effects of explosion in urban areas at high precision to support prediction of effects for the structural integrity and soundness of the urban infrastructure and safety preparations of rescue forces.[32] Spatial analysis: 3D city models provide the computational framework for 3D spatial analysis and simulation. For example, they can be used to compute solar potential for 3D roof surfaces of cities,[33] visibility analysis within the urban space,[34] noise simulation,[35] thermographic inspections of buildings[36][37] Geodesign: In geodesign, virtual 3D models of the environment (e.g., landscape models or urban models) facilitate exploration and presentation as well as analysis and simulation. Gaming: 3D city models can be used to obtain base data for virtual 3D scenes used in online and video games. Cultural heritage: 3D city model tools and systems are applied for modeling, design, exploration, and analysis tasks in the scope of cultural heritage. For example, archeological data can be embedded in 3D city models.[38] City information systems: 3D city models represent the framework for interactive 3D city information systems and 3D city maps. For example, municipalities apply 3D city models as centralized information platform for location marketing. [39] Property management: 3D city model technology can extend systems and applications used in real-estate and property management. Intelligent transportation systems: 3D city models can be applied to intelligent transportation systems.[40] Augmented reality: 3D city models can be used as reference frame for augmented reality applications.[41] See also City map References ^ "J. Döllner, K. Baumann, H. 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OGC 3D Portrayal IE 3D portrayal interoperability experiment of the Open Geospatial Consortium. 3D City Model of Berlin Example of a massive 3D city models for an urban area. 3D City Model of Roman Cologne Example of a 3D city model for cultural heritage applications. Retrieved from " 6Scanning of an object or environment to collect data on its shape It has been suggested that Volumetric capture be merged into this article. (Discuss) Proposed since April 2022. Making a 3D-model of a Viking belt buckle using a hand held VIUscan 3D laser scanner. Three-dimensional (3D)computer graphics Fundamentals Modeling Scanning Rendering Printing Primary uses 3D models Computer-aided design Graphic design Video games Visual effects Visualization Virtual engineering Virtual reality Virtual cinematography Related topics Computer-generated imagery (CGI) Animation computer skeletal 3D display Wire-frame model Texture mapping Motion capture Crowd simulation Global illumination Volume rendering vte 3D scanning is the process of analyzing a real-world object or environment to collect data on its shape and possibly its appearance (e.g. color). The collected data can then be used to construct digital 3D models. A 3D scanner can be based on many different technologies, each with its own limitations, advantages and costs. Many limitations in the kind of objects that can be digitised are still present. For example, optical technology may encounter many difficulties with dark, shiny, reflective or transparent objects. For example, industrial computed tomography scanning, structured-light 3D scanners, LiDAR and Time Of Flight 3D Scanners can be used to construct digital 3D models, without destructive testing. Collected 3D data is useful for a wide variety of applications. These devices are used extensively by the entertainment industry in the production of movies and video games, including virtual reality. Other common applications of this technology include augmented reality,[1] motion capture,[2][3] gesture recognition,[4] robotic mapping,[5] industrial design, orthotics and prosthetics,[6] reverse engineering and prototyping, quality control/inspection and the digitization of cultural artifacts.[7] Functionality The purpose of a 3D scanner is usually to create a 3D model. This 3D model consists of a polygon mesh or point cloud of geometric samples on the surface of the subject. These points can then be used to extrapolate the shape of the subject (a process called reconstruction). If colour information is collected at each point, then the colours or textures on the surface of the subject can also be determined. 3D scanners share several traits with cameras. Like most cameras, they have a cone-like field of view, and like cameras, they can only collect information about surfaces that are not obscured. While a camera collects colour information about surfaces within its field of view, a 3D scanner collects distance information about surfaces within its field of view. The "picture" produced by a 3D scanner describes the distance to a surface at each point in the picture. This allows the three dimensional position of each point in the picture to be identified. In some situations, a single scan will not produce a complete model of the subject. Multiple scans, from different directions are usually helpful to obtain information about all sides of the subject. These scans have to be brought into a common reference system, a process that is usually called alignment or registration, and then merged to create a complete 3D model. This whole process, going from the single range map to the whole model, is usually known as the 3D scanning pipeline.[8][9][10][11][12] Technology There are a variety of technologies for digitally acquiring the shape of a 3D object. The techniques work with most or all sensor types including optical, acoustic, laser scanning,[13] radar, thermal,[14] and seismic.[15][16] A well established classification[17] divides them into two types: contact and non-contact. Non-contact solutions can be further divided into two main categories, active and passive. There are a variety of technologies that fall under each of these categories. Contact A Coordinate Measuring Machine (CMM) with scanning head. 3D scanning of a fin whale skeleton in the Natural History Museum of Slovenia (August 2013) Contact 3D scanners work by physically probing (touching) the part and recording the position of the sensor as the probe moves around the part. There are two main types of contact 3D scanners: Coordinate measuring machines (CMMs) which traditionally have 3 perpendicular moving axis with a touch probe mounted on the Z axis. As the touch probe moves around the part, sensors on each axis record the position to generate XYZ coordinates. Modern CMMs are 5 axis systems, with the two extra axes provided by pivoting sensor heads. CMMs are the most accurate form of 3D measurement achieving micron precision. The greatest advantage of a CMM after accuracy is that it can be run in autonomous (CNC) mode or as a manual probing system. The disadvantage of CMMs is that their upfront cost and the technical knowledge required to operate them. Articulated Arms which generally have multiple segments with polar sensors on each joint. As per the CMM, as the articulated arm moves around the part sensors record their position and the location of the end of the arm is calculated using complex math and the wrist rotation angle and hinge angle of each joint. While not usually as accurate as CMMs, articulated arms still achieve high accuracy and are cheaper and slightly easier to use. They do not usually have CNC options. Both modern CMMs and Articulated Arms can also be fitted with non-contact laser scanners instead of touch probes. Non-contact active Active scanners emit some kind of radiation or light and detect its reflection or radiation passing through object in order to probe an object or environment. Possible types of emissions used include light, ultrasound or x-ray. Time-of-flight This lidar scanner may be used to scan buildings, rock formations, etc., to produce a 3D model. The lidar can aim its laser beam in a wide range: its head rotates horizontally, a mirror flips vertically. The laser beam is used to measure the distance to the first object on its path. The time-of-flight 3D laser scanner is an active scanner that uses laser light to probe the subject. At the heart of this type of scanner is a time-of-flight laser range finder. The laser range finder finds the distance of a surface by timing the round-trip time of a pulse of light. A laser is used to emit a pulse of light and the amount of time before the reflected light is seen by a detector is measured. Since the speed of light c {\displaystyle c} is known, the round-trip time determines the travel distance of the light, which is twice the distance between the scanner and the surface. If t {\displaystyle t} is the round-trip time, then distance is equal to c · t / 2 {\displaystyle \textstyle c\!\cdot \!t/2} . The accuracy of a time-of-flight 3D laser scanner depends on how precisely we can measure the t {\displaystyle t} time: 3.3 picoseconds (approx.) is the time taken for light to travel 1 millimetre. The laser range finder only detects the distance of one point in its direction of view. Thus, the scanner scans its entire field of view one point at a time by changing the range finder's direction of view to scan different points. The view direction of the laser range finder can be changed either by rotating the range finder itself, or by using a system of rotating mirrors. The latter method is commonly used because mirrors are much lighter and can thus be rotated much faster and with greater accuracy. Typical time-of-flight 3D laser scanners can measure the distance of 10,000~100,000 points every second. Time-of-flight devices are also available in a 2D configuration. This is referred to as a time-of-flight camera.[18] Triangulation Principle of a laser triangulation sensor. Two object positions are shown. Triangulation based 3D laser scanners are also active scanners that use laser light to probe the environment. With respect to time-of-flight 3D laser scanner the triangulation laser shines a laser on the subject and exploits a camera to look for the location of the laser dot. Depending on how far away the laser strikes a surface, the laser dot appears at different places in the camera's field of view. This technique is called triangulation because the laser dot, the camera and the laser emitter form a triangle. The length of one side of the triangle, the distance between the camera and the laser emitter is known. The angle of the laser emitter corner is also known. The angle of the camera corner can be determined by looking at the location of the laser dot in the camera's field of view. These three pieces of information fully determine the shape and size of the triangle and give the location of the laser dot corner of the triangle.[19] In most cases a laser stripe, instead of a single laser dot, is swept across the object to speed up the acquisition process. The National Research Council of Canada was among the first institutes to develop the triangulation based laser scanning technology in 1978. [20] Strengths and weaknesses Time-of-flight and triangulation range finders each have strengths and weaknesses that make them suitable for different situations. The advantage of time-of-flight range finders is that they are capable of operating over very long distances, on the order of kilometres. These scanners are thus suitable for scanning large structures like buildings or geographic features. The disadvantage of time-of-flight range finders is their accuracy. Due to the high speed of light, timing the round-trip time is difficult and the accuracy of the distance measurement is relatively low, on the order of millimetres. Triangulation range finders are exactly the opposite. They have a limited range of some meters, but their accuracy is relatively high. The accuracy of triangulation range finders is on the order of tens of micrometers. Time-of-flight scanners' accuracy can be lost when the laser hits the edge of an object because the information that is sent back to the scanner is from two different locations for one laser pulse. The coordinate relative to the scanner's position for a point that has hit the edge of an object will be calculated based on an average and therefore will put the point in the wrong place. When using a high resolution scan on an object the chances of the beam hitting an edge are increased and the resulting data will show noise just behind the edges of the object. Scanners with a smaller beam width will help to solve this problem but will be limited by range as the beam width will increase over distance. Software can also help by determining that the first object to be hit by the laser beam should cancel out the second. At a rate of 10,000 sample points per second, low resolution scans can take less than a second, but high resolution scans, requiring millions of samples, can take minutes for some time-of-flight scanners. The problem this creates is distortion from motion. Since each point is sampled at a different time, any motion in the subject or the scanner will distort the collected data. Thus, it is usually necessary to mount both the subject and the scanner on stable platforms and minimise vibration. Using these scanners to scan objects in motion is very difficult. Recently, there has been research on compensating for distortion from small amounts of vibration[21] and distortions due to motion and/or rotation.[22] Short-range laser scanners can't usually encompass a depth of field more than 1 meter.[23] When scanning in one position for any length of time slight movement can occur in the scanner position due to changes in temperature. If the scanner is set on a tripod and there is strong sunlight on one side of the scanner then that side of the tripod will expand and slowly distort the scan data from one side to another. Some laser scanners have level compensators built into them to counteract any movement of the scanner during the scan process. Conoscopic holography In a conoscopic system, a laser beam is projected onto the surface and then the immediate reflection along the same ray-path are put through a conoscopic crystal and projected onto a CCD. The result is a diffraction pattern, that can be frequency analyzed to determine the distance to the measured surface. The main advantage with conoscopic holography is that only a single ray-path is needed for measuring, thus giving an opportunity to measure for instance the depth of a finely drilled hole.[24] Hand-held laser scanners Hand-held laser scanners create a 3D image through the triangulation mechanism described above: a laser dot or line is projected onto an object from a hand-held device and a sensor (typically a charge-coupled device or position sensitive device) measures the distance to the surface. Data is collected in relation to an internal coordinate system and therefore to collect data where the scanner is in motion the position of the scanner must be determined. The position can be determined by the scanner using reference features on the surface being scanned (typically adhesive reflective tabs, but natural features have been also used in research work)[25][26] or by using an external tracking method. External tracking often takes the form of a laser tracker (to provide the sensor position) with integrated camera (to determine the orientation of the scanner) or a photogrammetric solution using 3 or more cameras providing the complete six degrees of freedom of the scanner. Both techniques tend to use infrared light-emitting diodes attached to the scanner which are seen by the camera(s) through filters providing resilience to ambient lighting.[27] Data is collected by a computer and recorded as data points within three-dimensional space, with processing this can be converted into a triangulated mesh and then a computer-aided design model, often as non-uniform rational B-spline surfaces. Hand-held laser scanners can combine this data with passive, visible-light sensors — which capture surface textures and colors — to build (or "reverse engineer") a full 3D model. Structured light Main article: Structured-light 3D scanner Structured-light 3D scanners project a pattern of light on the subject and look at the deformation of the pattern on the subject. The pattern is projected onto the subject using either an LCD projector or other stable light source. A camera, offset slightly from the pattern projector, looks at the shape of the pattern and calculates the distance of every point in the field of view. Structured-light scanning is still a very active area of research with many research papers published each year. Perfect maps have also been proven useful as structured light patterns that solve the correspondence problem and allow for error detection and error correction.[24] [See Morano, R., et al. "Structured Light Using Pseudorandom Codes," IEEE Transactions on Pattern Analysis and Machine Intelligence. The advantage of structured-light 3D scanners is speed and precision. Instead of scanning one point at a time, structured light scanners scan multiple points or the entire field of view at once. Scanning an entire field of view in a fraction of a second reduces or eliminates the problem of distortion from motion. Some existing systems are capable of scanning moving objects in real-time. A real-time scanner using digital fringe projection and phase-shifting technique (certain kinds of structured light methods) was developed, to capture, reconstruct, and render high-density details of dynamically deformable objects (such as facial expressions) at 40 frames per second.[28] Recently, another scanner has been developed. Different patterns can be applied to this system, and the frame rate for capturing and data processing achieves 120 frames per second. It can also scan isolated surfaces, for example two moving hands.[29] By utilising the binary defocusing technique, speed breakthroughs have been made that could reach hundreds [30] to thousands of frames per second.[31] Modulated light Modulated light 3D scanners shine a continually changing light at the subject. Usually the light source simply cycles its amplitude in a sinusoidal pattern. A camera detects the reflected light and the amount the pattern is shifted by determines the distance the light travelled. Modulated light also allows the scanner to ignore light from sources other than a laser, so there is no interference. Volumetric techniques Medical Computed tomography (CT) is a medical imaging method which generates a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images, similarly magnetic resonance imaging is another medical imaging technique that provides much greater contrast between the different soft tissues of the body than computed tomography (CT) does, making it especially useful in neurological (brain), musculoskeletal, cardiovascular, and oncological (cancer) imaging. These techniques produce a discrete 3D volumetric representation that can be directly visualised, manipulated or converted to traditional 3D surface by mean of isosurface extraction algorithms. Industrial Although most common in medicine, industrial computed tomography, microtomography and MRI are also used in other fields for acquiring a digital representation of an object and its interior, such as non destructive materials testing, reverse engineering, or studying biological and paleontological specimens. Non-contact passive Passive 3D imaging solutions do not emit any kind of radiation themselves, but instead rely on detecting reflected ambient radiation. Most solutions of this type detect visible light because it is a readily available ambient radiation. Other types of radiation, such as infrared could also be used. Passive methods can be very cheap, because in most cases they do not need particular hardware but simple digital cameras. Stereoscopic systems usually employ two video cameras, slightly apart, looking at the same scene. By analysing the slight differences between the images seen by each camera, it is possible to determine the distance at each point in the images. This method is based on the same principles driving human stereoscopic vision[1]. Photometric systems usually use a single camera, but take multiple images under varying lighting conditions. These techniques attempt to invert the image formation model in order to recover the surface orientation at each pixel. Silhouette techniques use outlines created from a sequence of photographs around a three-dimensional object against a well contrasted background. These silhouettes are extruded and intersected to form the visual hull approximation of the object. With these approaches some concavities of an object (like the interior of a bowl) cannot be detected. Photogrammetric non-contact passive methods This section needs expansion. You can help by adding to it. (March 2020) Main article: Photogrammetry Images taken from multiple perspectives such as a fixed camera array can be taken of a subject for a photogrammetric reconstruction pipeline to generate a 3D mesh or point cloud. Photogrammetry provides reliable information about 3D shapes of physical objects based on analysis of photographic images. The resulting 3D data is typically provided as a 3D point cloud, 3D mesh or 3D points.[32] Modern photogrammetry software applications automatically analyze a large number of digital images for 3D reconstruction, however manual interaction may be required if the software cannot automatically determine the 3D positions of the camera in the images which is an essential step in the reconstruction pipeline. Various software packages are available including PhotoModeler, Geodetic Systems, Autodesk ReCap, RealityCapture and Agisoft Metashape (see comparison of photogrammetry software). Close range photogrammetry typically uses a handheld camera such as a DSLR with a fixed focal length lens to capture images of objects for 3D reconstruction.[33] Subjects include smaller objects such as a building facade, vehicles, sculptures, rocks, and shoes. Camera Arrays can be used to generate 3D point clouds or meshes of live objects such as people or pets by synchronizing multiple cameras to photograph a subject from multiple perspectives at the same time for 3D object reconstruction.[34] Wide angle photogrammetry can be used to capture the interior of buildings or enclosed spaces using a wide angle lens camera such as a 360 camera. Aerial photogrammetry uses aerial images acquired by satellite, commercial aircraft or UAV drone to collect images of buildings, structures and terrain for 3D reconstruction into a point cloud or mesh. Acquisition from acquired sensor data Semi-automatic building extraction from lidar data and high-resolution images is also a possibility. Again, this approach allows modelling without physically moving towards the location or object.[35] From airborne lidar data, digital surface model (DSM) can be generated and then the objects higher than the ground are automatically detected from the DSM. Based on general knowledge about buildings, geometric characteristics such as size, height and shape information are then used to separate the buildings from other objects. The extracted building outlines are then simplified using an orthogonal algorithm to obtain better cartographic quality. Watershed analysis can be conducted to extract the ridgelines of building roofs. The ridgelines as well as slope information are used to classify the buildings per type. The buildings are then reconstructed using three parametric building models (flat, gabled, hipped).[36] Acquisition from on-site sensors Lidar and other terrestrial laser scanning technology[37] offers the fastest, automated way to collect height or distance information. lidar or laser for height measurement of buildings is becoming very promising.[38] Commercial applications of both airborne lidar and ground laser scanning technology have proven to be fast and accurate methods for building height extraction. The building extraction task is needed to determine building locations, ground elevation, orientations, building size, rooftop heights, etc. Most buildings are described to sufficient details in terms of general polyhedra, i.e., their boundaries can be represented by a set of planar surfaces and straight lines. Further processing such as expressing building footprints as polygons is used for data storing in GIS databases. Using laser scans and images taken from ground level and a bird's-eye perspective, Fruh and Zakhor present an approach to automatically create textured 3D city models. This approach involves registering and merging the detailed facade models with a complementary airborne model. The airborne modeling process generates a half-meter resolution model with a bird's-eye view of the entire area, containing terrain profile and building tops. Ground-based modeling process results in a detailed model of the building facades. Using the DSM obtained from airborne laser scans, they localize the acquisition vehicle and register the ground-based facades to the airborne model by means of Monte Carlo localization (MCL). Finally, the two models are merged with different resolutions to obtain a 3D model. Using an airborne laser altimeter, Haala, Brenner and Anders combined height data with the existing ground plans of buildings. The ground plans of buildings had already been acquired either in analog form by maps and plans or digitally in a 2D GIS. The project was done in order to enable an automatic data capture by the integration of these different types of information. Afterwards virtual reality city models are generated in the project by texture processing, e.g. by mapping of terrestrial images. The project demonstrated the feasibility of rapid acquisition of 3D urban GIS. Ground plans proved are another very important source of information for 3D building reconstruction. Compared to results of automatic procedures, these ground plans proved more reliable since they contain aggregated information which has been made explicit by human interpretation. For this reason, ground plans, can considerably reduce costs in a reconstruction project. An example of existing ground plan data usable in building reconstruction is the Digital Cadastral map, which provides information on the distribution of property, including the borders of all agricultural areas and the ground plans of existing buildings. Additionally information as street names and the usage of buildings (e.g. garage, residential building, office block, industrial building, church) is provided in the form of text symbols. At the moment the Digital Cadastral map is built up as a database covering an area, mainly composed by digitizing preexisting maps or plans. Cost Terrestrial laser scan devices (pulse or phase devices) + processing software generally start at a price of €150,000. Some less precise devices (as the Trimble VX) cost around €75,000. Terrestrial lidar systems cost around €300,000. Systems using regular still cameras mounted on RC helicopters (Photogrammetry) are also possible, and cost around €25,000. Systems that use still cameras with balloons are even cheaper (around €2,500), but require additional manual processing. As the manual processing takes around 1 month of labor for every day of taking pictures, this is still an expensive solution in the long run. Obtaining satellite images is also an expensive endeavor. High resolution stereo images (0.5 m resolution) cost around €11,000. Image satellites include Quikbird, Ikonos. High resolution monoscopic images cost around €5,500. Somewhat lower resolution images (e.g. from the CORONA satellite; with a 2 m resolution) cost around €1,000 per 2 images. Note that Google Earth images are too low in resolution to make an accurate 3D model.[39] Reconstruction Main article: 3D reconstruction From point clouds The point clouds produced by 3D scanners and 3D imaging can be used directly for measurement and visualization in the architecture and construction world. From models Most applications, however, use instead polygonal 3D models, NURBS surface models, or editable feature-based CAD models (aka solid models). Polygon mesh models: In a polygonal representation of a shape, a curved surface is modeled as many small faceted flat surfaces (think of a sphere modeled as a disco ball). Polygon models—also called Mesh models, are useful for visualization, for some CAM (i.e., machining), but are generally "heavy" (i.e., very large data sets), and are relatively un-editable in this form. Reconstruction to polygonal model involves finding and connecting adjacent points with straight lines in order to create a continuous surface. Many applications, both free and nonfree, are available for this purpose (e.g. GigaMesh, MeshLab, PointCab, kubit PointCloud for AutoCAD, Reconstructor, imagemodel, PolyWorks, Rapidform, Geomagic, Imageware, Rhino 3D etc.). Surface models: The next level of sophistication in modeling involves using a quilt of curved surface patches to model the shape. These might be NURBS, TSplines or other curved representations of curved topology. Using NURBS, the spherical shape becomes a true mathematical sphere. Some applications offer patch layout by hand but the best in class offer both automated patch layout and manual layout. These patches have the advantage of being lighter and more manipulable when exported to CAD. Surface models are somewhat editable, but only in a sculptural sense of pushing and pulling to deform the surface. This representation lends itself well to modelling organic and artistic shapes. Providers of surface modellers include Rapidform, Geomagic, Rhino 3D, Maya, T Splines etc. Solid CAD models: From an engineering/manufacturing perspective, the ultimate representation of a digitized shape is the editable, parametric CAD model. In CAD, the sphere is described by parametric features which are easily edited by changing a value (e.g., centre point and radius). These CAD models describe not simply the envelope or shape of the object, but CAD models also embody the "design intent" (i.e., critical features and their relationship to other features). An example of design intent not evident in the shape alone might be a brake drum's lug bolts, which must be concentric with the hole in the centre of the drum. This knowledge would drive the sequence and method of creating the CAD model; a designer with an awareness of this relationship would not design the lug bolts referenced to the outside diameter, but instead, to the center. A modeler creating a CAD model will want to include both Shape and design intent in the complete CAD model. Vendors offer different approaches to getting to the parametric CAD model. Some export the NURBS surfaces and leave it to the CAD designer to complete the model in CAD (e.g., Geomagic, Imageware, Rhino 3D). Others use the scan data to create an editable and verifiable feature based model that is imported into CAD with full feature tree intact, yielding a complete, native CAD model, capturing both shape and design intent (e.g. Geomagic, Rapidform). For instance, the market offers various plug-ins for established CAD-programs, such as SolidWorks. Xtract3D, DezignWorks and Geomagic for SolidWorks allow manipulating a 3D scan directly inside SolidWorks. Still other CAD applications are robust enough to manipulate limited points or polygon models within the CAD environment (e.g., CATIA, AutoCAD, Revit). From a set of 2D slices 3D reconstruction of the brain and eyeballs from CT scanned DICOM images. In this image, areas with the density of bone or air were made transparent, and the slices stacked up in an approximate free-space alignment. The outer ring of material around the brain are the soft tissues of skin and muscle on the outside of the skull. A black box encloses the slices to provide the black background. Since these are simply 2D images stacked up, when viewed on edge the slices disappear since they have effectively zero thickness. Each DICOM scan represents about 5 mm of material averaged into a thin slice. CT, industrial CT, MRI, or micro-CT scanners do not produce point clouds but a set of 2D slices (each termed a "tomogram") which are then 'stacked together' to produce a 3D representation. There are several ways to do this depending on the output required: Volume rendering: Different parts of an object usually have different threshold values or greyscale densities. From this, a 3-dimensional model can be constructed and displayed on screen. Multiple models can be constructed from various thresholds, allowing different colours to represent each component of the object. Volume rendering is usually only used for visualisation of the scanned object. Image segmentation: Where different structures have similar threshold/greyscale values, it can become impossible to separate them simply by adjusting volume rendering parameters. The solution is called segmentation, a manual or automatic procedure that can remove the unwanted structures from the image. Image segmentation software usually allows export of the segmented structures in CAD or STL format for further manipulation. Image-based meshing: When using 3D image data for computational analysis (e.g. CFD and FEA), simply segmenting the data and meshing from CAD can become time-consuming, and virtually intractable for the complex topologies typical of image data. The solution is called image-based meshing, an automated process of generating an accurate and realistic geometrical description of the scan data. From laser scans Laser scanning describes the general method to sample or scan a surface using laser technology. Several areas of application exist that mainly differ in the power of the lasers that are used, and in the results of the scanning process. Low laser power is used when the scanned surface doesn't have to be influenced, e.g. when it only has to be digitized. Confocal or 3D laser scanning are methods to get information about the scanned surface. Another low-power application uses structured light projection systems for solar cell flatness metrology,[40] enabling stress calculation throughout in excess of 2000 wafers per hour.[41] The laser power used for laser scanning equipment in industrial applications is typically less than 1W. The power level is usually on the order of 200 mW or less but sometimes more. From photographs See also: Photogrammetry 3D data acquisition and object reconstruction can be performed using stereo image pairs. Stereo photogrammetry or photogrammetry based on a block of overlapped images is the primary approach for 3D mapping and object reconstruction using 2D images. Close-range photogrammetry has also matured to the level where cameras or digital cameras can be used to capture the close-look images of objects, e.g., buildings, and reconstruct them using the very same theory as the aerial photogrammetry. An example of software which could do this is Vexcel FotoG 5.[42][43] This software has now been replaced by Vexcel GeoSynth.[44] Another similar software program is Microsoft Photosynth.[45][46] A semi-automatic method for acquiring 3D topologically structured data from 2D aerial stereo images has been presented by Sisi Zlatanova.[47] The process involves the manual digitizing of a number of points necessary for automatically reconstructing the 3D objects. Each reconstructed object is validated by superimposition of its wire frame graphics in the stereo model. The topologically structured 3D data is stored in a database and are also used for visualization of the objects. Notable software used for 3D data acquisition using 2D images include e.g. Agisoft Metashape,[48] RealityCapture,[49] and ENSAIS Engineering College TIPHON (Traitement d'Image et PHOtogrammétrie Numérique).[50] A method for semi-automatic building extraction together with a concept for storing building models alongside terrain and other topographic data in a topographical information system has been developed by Franz Rottensteiner. His approach was based on the integration of building parameter estimations into the photogrammetry process applying a hybrid modeling scheme. Buildings are decomposed into a set of simple primitives that are reconstructed individually and are then combined by Boolean operators. The internal data structure of both the primitives and the compound building models are based on the boundary representation methods[51][52] Multiple images are used in Zeng's approach to surface reconstruction from multiple images. A central idea is to explore the integration of both 3D stereo data and 2D calibrated images. This approach is motivated by the fact that only robust and accurate feature points that survived the geometry scrutiny of multiple images are reconstructed in space. The density insufficiency and the inevitable holes in the stereo data should then be filled in by using information from multiple images. The idea is thus to first construct small surface patches from stereo points, then to progressively propagate only reliable patches in their neighborhood from images into the whole surface using a best-first strategy. The problem thus reduces to searching for an optimal local surface patch going through a given set of stereo points from images. Multi-spectral images are also used for 3D building detection. The first and last pulse data and the normalized difference vegetation index are used in the process.[53] New measurement techniques are also employed to obtain measurements of and between objects from single images by using the projection, or the shadow as well as their combination. This technology is gaining attention given its fast processing time, and far lower cost than stereo measurements.[citation needed] Applications Space experiments 3D scanning technology has been used to scan space rocks for the European Space Agency.[54][55] Construction industry and civil engineering Robotic control: e.g. a laser scanner may function as the "eye" of a robot.[56][57] As-built drawings of bridges, industrial plants, and monuments Documentation of historical sites[58] Site modelling and lay outing Quality control Quantity surveys Payload monitoring [59] Freeway redesign Establishing a bench mark of pre-existing shape/state in order to detect structural changes resulting from exposure to extreme loadings such as earthquake, vessel/truck impact or fire. Create GIS (geographic information system) maps[60] and geomatics. Subsurface laser scanning in mines and karst voids.[61] Forensic documentation[62] Design process Increasing accuracy working with complex parts and shapes, Coordinating product design using parts from multiple sources, Updating old CD scans with those from more current technology, Replacing missing or older parts, Creating cost savings by allowing as-built design services, for example in automotive manufacturing plants, "Bringing the plant to the engineers" with web shared scans, and Saving travel costs. Entertainment 3D scanners are used by the entertainment industry to create digital 3D models for movies, video games and leisure purposes.[63] They are heavily utilized in virtual cinematography. In cases where a real-world equivalent of a model exists, it is much faster to scan the real-world object than to manually create a model using 3D modeling software. Frequently, artists sculpt physical models of what they want and scan them into digital form rather than directly creating digital models on a computer. 3D photography 3D selfie in 1:20 scale printed by Shapeways using gypsum-based printing, created by Madurodam miniature park from 2D pictures taken at its Fantasitron photo booth. Fantasitron 3D photo booth at Madurodam 3D scanners are evolving for the use of cameras to represent 3D objects in an accurate manner.[64] Companies are emerging since 2010 that create 3D portraits of people (3D figurines or 3D selfie). An augmented reality menu for the Madrid restaurant chain 80 Degrees[65] Law enforcement 3D laser scanning is used by the law enforcement agencies around the world. 3D models are used for on-site documentation of:[66] Crime scenes Bullet trajectories Bloodstain pattern analysis Accident reconstruction Bombings Plane crashes, and more Reverse engineering Reverse engineering of a mechanical component requires a precise digital model of the objects to be reproduced. Rather than a set of points a precise digital model can be represented by a polygon mesh, a set of flat or curved NURBS surfaces, or ideally for mechanical components, a CAD solid model. A 3D scanner can be used to digitise free-form or gradually changing shaped components as well as prismatic geometries whereas a coordinate measuring machine is usually used only to determine simple dimensions of a highly prismatic model. These data points are then processed to create a usable digital model, usually using specialized reverse engineering software. Real estate Land or buildings can be scanned into a 3D model, which allows buyers to tour and inspect the property remotely, anywhere, without having to be present at the property.[67] There is already at least one company providing 3D-scanned virtual real estate tours.[68] A typical virtual tour Archived 2017-04-27 at the Wayback Machine would consist of dollhouse view,[69] inside view, as well as a floor plan. Virtual/remote tourism The environment at a place of interest can be captured and converted into a 3D model. This model can then be explored by the public, either through a VR interface or a traditional "2D" interface. This allows the user to explore locations which are inconvenient for travel.[70] A group of history students at Vancouver iTech Preparatory Middle School created a Virtual Museum by 3D Scanning more than 100 artifacts.[71] Cultural heritage There have been many research projects undertaken via the scanning of historical sites and artifacts both for documentation and analysis purposes.[72] The combined use of 3D scanning and 3D printing technologies allows the replication of real objects without the use of traditional plaster casting techniques, that in many cases can be too invasive for being performed on precious or delicate cultural heritage artifacts.[73] In an example of a typical application scenario, a gargoyle model was digitally acquired using a 3D scanner and the produced 3D data was processed using MeshLab. The resulting digital 3D model was fed to a rapid prototyping machine to create a real resin replica of the original object. Creation of 3D models for Museums and Archaeological artifacts[74][75][76] Michelangelo In 1999, two different research groups started scanning Michelangelo's statues. Stanford University with a group led by Marc Levoy[77] used a custom laser triangulation scanner built by Cyberware to scan Michelangelo's statues in Florence, notably the David, the Prigioni and the four statues in The Medici Chapel. The scans produced a data point density of one sample per 0.25 mm, detailed enough to see Michelangelo's chisel marks. These detailed scans produced a large amount of data (up to 32 gigabytes) and processing the data from his scans took 5 months. Approximately in the same period a research group from IBM, led by H. Rushmeier and F. Bernardini scanned the Pietà of Florence acquiring both geometric and colour details. The digital model, result of the Stanford scanning campaign, was thoroughly used in the 2004 subsequent restoration of the statue.[78] Monticello In 2002, David Luebke, et al. scanned Thomas Jefferson's Monticello.[79] A commercial time of flight laser scanner, the DeltaSphere 3000, was used. The scanner data was later combined with colour data from digital photographs to create the Virtual Monticello, and the Jefferson's Cabinet exhibits in the New Orleans Museum of Art in 2003. The Virtual Monticello exhibit simulated a window looking into Jefferson's Library. The exhibit consisted of a rear projection display on a wall and a pair of stereo glasses for the viewer. The glasses, combined with polarised projectors, provided a 3D effect. Position tracking hardware on the glasses allowed the display to adapt as the viewer moves around, creating the illusion that the display is actually a hole in the wall looking into Jefferson's Library. The Jefferson's Cabinet exhibit was a barrier stereogram (essentially a non-active hologram that appears different from different angles) of Jefferson's Cabinet. Cuneiform tablets The first 3D models of cuneiform tablets were acquired in Germany in 2000.[80] In 2003 the so-called Digital Hammurabi project acquired cuneiform tablets with a laser triangulation scanner using a regular grid pattern having a resolution of 0.025 mm (0.00098 in).[81] With the use of high-resolution 3D-scanners by the Heidelberg University for tablet acquisition in 2009 the development of the GigaMesh Software Framework began to visualize and extract cuneiform characters from 3D-models.[82] It was used to process ca. 2.000 3D-digitized tablets of the Hilprecht Collection in Jena to create an Open Access benchmark dataset[83] and an annotated collection[84] of 3D-models of tablets freely available under CC BY licenses.[85] Kasubi Tombs A 2009 CyArk 3D scanning project at Uganda's historic Kasubi Tombs, a UNESCO World Heritage Site, using a Leica HDS 4500, produced detailed architectural models of Muzibu Azaala Mpanga, the main building at the complex and tomb of the Kabakas (Kings) of Uganda. A fire on March 16, 2010, burned down much of the Muzibu Azaala Mpanga structure, and reconstruction work is likely to lean heavily upon the dataset produced by the 3D scan mission.[86] "Plastico di Roma antica" In 2005, Gabriele Guidi, et al. scanned the "Plastico di Roma antica",[87] a model of Rome created in the last century. Neither the triangulation method, nor the time of flight method satisfied the requirements of this project because the item to be scanned was both large and contained small details. They found though, that a modulated light scanner was able to provide both the ability to scan an object the size of the model and the accuracy that was needed. The modulated light scanner was supplemented by a triangulation scanner which was used to scan some parts of the model. Other projects The 3D Encounters Project at the Petrie Museum of Egyptian Archaeology aims to use 3D laser scanning to create a high quality 3D image library of artefacts and enable digital travelling exhibitions of fragile Egyptian artefacts, English Heritage has investigated the use of 3D laser scanning for a wide range of applications to gain archaeological and condition data, and the National Conservation Centre in Liverpool has also produced 3D laser scans on commission, including portable object and in situ scans of archaeological sites.[88] The Smithsonian Institution has a project called Smithsonian X 3D notable for the breadth of types of 3D objects they are attempting to scan. These include small objects such as insects and flowers, to human sized objects such as Amelia Earhart's Flight Suit to room sized objects such as the Gunboat Philadelphia to historic sites such as Liang Bua in Indonesia. Also of note the data from these scans is being made available to the public for free and downloadable in several data formats. Medical CAD/CAM 3D scanners are used to capture the 3D shape of a patient in orthotics and dentistry. It gradually supplants tedious plaster cast. CAD/CAM software are then used to design and manufacture the orthosis, prosthesis or dental implants. Many Chairside dental CAD/CAM systems and Dental Laboratory CAD/CAM systems use 3D Scanner technologies to capture the 3D surface of a dental preparation (either in vivo or in vitro), in order to produce a restoration digitally using CAD software and ultimately produce the final restoration using a CAM technology (such as a CNC milling machine, or 3D printer). The chairside systems are designed to facilitate the 3D scanning of a preparation in vivo and produce the restoration (such as a Crown, Onlay, Inlay or Veneer). Creation of 3D models for Anatomy and Biology education[89][90] and cadaver models for educational neurosurgical simulations.[91] Quality assurance and industrial metrology The digitalisation of real-world objects is of vital importance in various application domains. This method is especially applied in industrial quality assurance to measure the geometric dimension accuracy. Industrial processes such as assembly are complex, highly automated and typically based on CAD (computer-aided design) data. The problem is that the same degree of automation is also required for quality assurance. It is, for example, a very complex task to assemble a modern car, since it consists of many parts that must fit together at the very end of the production line. The optimal performance of this process is guaranteed by quality assurance systems. Especially the geometry of the metal parts must be checked in order to assure that they have the correct dimensions, fit together and finally work reliably. Within highly automated processes, the resulting geometric measures are transferred to machines that manufacture the desired objects. Due to mechanical uncertainties and abrasions, the result may differ from its digital nominal. In order to automatically capture and evaluate these deviations, the manufactured part must be digitised as well. For this purpose, 3D scanners are applied to generate point samples from the object's surface which are finally compared against the nominal data.[92] The process of comparing 3D data against a CAD model is referred to as CAD-Compare, and can be a useful technique for applications such as determining wear patterns on moulds and tooling, determining accuracy of final build, analysing gap and flush, or analysing highly complex sculpted surfaces. At present, laser triangulation scanners, structured light and contact scanning are the predominant technologies employed for industrial purposes, with contact scanning remaining the slowest, but overall most accurate option. Nevertheless, 3D scanning technology offers distinct advantages compared to traditional touch probe measurements. White-light or laser scanners accurately digitize objects all around, capturing fine details and freeform surfaces without reference points or spray. The entire surface is covered at record speed without the risk of damaging the part. Graphic comparison charts illustrate geometric deviations of full object level, providing deeper insights into potential causes.[93][94] Circumvention of shipping costs and international import/export tariffs 3D scanning can be used in conjunction with 3D printing technology to virtually teleport certain object across distances without the need of shipping them and in some cases incurring import/export tariffs. For example, a plastic object can be 3D-scanned in the United States, the files can be sent off to a 3D-printing facility over in Germany where the object is replicated, effectively teleporting the object across the globe. In the future, as 3D scanning and 3D printing technologies become more and more prevalent, governments around the world will need to reconsider and rewrite trade agreements and international laws. Object reconstruction Main article: 3D reconstruction After the data has been collected, the acquired (and sometimes already processed) data from images or sensors needs to be reconstructed. This may be done in the same program or in some cases, the 3D data needs to be exported and imported into another program for further refining, and/or to add additional data. Such additional data could be gps-location data, ... Also, after the reconstruction, the data might be directly implemented into a local (GIS) map[95][96] or a worldwide map such as Google Earth. Software Several software packages are used in which the acquired (and sometimes already processed) data from images or sensors is imported. Notable software packages include:[97] Qlone 3DF Zephyr Canoma Leica Photogrammetry Suite MeshLab MountainsMap SEM (microscopy applications only) PhotoModeler SketchUp tomviz See also 3D computer graphics software 3D printing 3D reconstruction 3D selfie Angle-sensitive pixel Depth map Digitization Epipolar geometry Full body scanner Image reconstruction Light-field camera Photogrammetry Range imaging Remote sensing Structured-light 3D scanner Thingiverse References

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Retrieved 2009-09-09. ^ 3D data implementation to GIS maps ^ Reconstruction software Retrieved from " 7Process of converting 3D scenes into 2D images For rendering of 3D scalar fields, see Volume rendering. This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "3D rendering" – news · newspapers · books · scholar · JSTOR (September 2018) (Learn how and when to remove this template message) Three-dimensional (3D)computer graphics Fundamentals Modeling Scanning Rendering Printing Primary uses 3D models Computer-aided design Graphic design Video games Visual effects Visualization Virtual engineering Virtual reality Virtual cinematography Related topics Computer-generated imagery (CGI) Animation computer skeletal 3D display Wire-frame model Texture mapping Motion capture Crowd simulation Global illumination Volume rendering vte 3D rendering is the 3D computer graphics process of converting 3D models into 2D images on a computer. 3D renders may include photorealistic effects or non-photorealistic styles. Rendering methods A photorealistic 3D render of 6 computer fans using radiosity rendering, DOF and procedural materials Rendering is the final process of creating the actual 2D image or animation from the prepared scene. This can be compared to taking a photo or filming the scene after the setup is finished in real life.[1] Several different, and often specialized, rendering methods have been developed. These range from the distinctly non-realistic wireframe rendering through polygon-based rendering, to more advanced techniques such as: scanline rendering, ray tracing, or radiosity. Rendering may take from fractions of a second to days for a single image/frame. In general, different methods are better suited for either photorealistic rendering, or real-time rendering.[2] Real-time Main article: Real-time computer graphics A screenshot from Second Life, a 2003 online virtual world which renders frames in real-time Rendering for interactive media, such as games and simulations, is calculated and displayed in real time, at rates of approximately 20 to 120 frames per second. In real-time rendering, the goal is to show as much information as possible as the eye can process in a fraction of a second (a.k.a. "in one frame": In the case of a 30 frame-per-second animation, a frame encompasses one 30th of a second). The primary goal is to achieve an as high as possible degree of photorealism at an acceptable minimum rendering speed (usually 24 frames per second, as that is the minimum the human eye needs to see to successfully create the illusion of movement). In fact, exploitations can be applied in the way the eye 'perceives' the world, and as a result, the final image presented is not necessarily that of the real world, but one close enough for the human eye to tolerate. Rendering software may simulate such visual effects as lens flares, depth of field or motion blur. These are attempts to simulate visual phenomena resulting from the optical characteristics of cameras and of the human eye. These effects can lend an element of realism to a scene, even if the effect is merely a simulated artifact of a camera. This is the basic method employed in games, interactive worlds and VRML. The rapid increase in computer processing power has allowed a progressively higher degree of realism even for real-time rendering, including techniques such as HDR rendering. Real-time rendering is often polygonal and aided by the computer's GPU.[3] Non-real-time Computer-generated image (CGI) created by Gilles Tran Animations for non-interactive media, such as feature films and video, can take much more time to render.[4] Non-real-time rendering enables the leveraging of limited processing power in order to obtain higher image quality. Rendering times for individual frames may vary from a few seconds to several days for complex scenes. Rendered frames are stored on a hard disk, then transferred to other media such as motion picture film or optical disk. These frames are then displayed sequentially at high frame rates, typically 24, 25, or 30 frames per second (fps), to achieve the illusion of movement. When the goal is photo-realism, techniques such as ray tracing, path tracing, photon mapping or radiosity are employed. This is the basic method employed in digital media and artistic works. Techniques have been developed for the purpose of simulating other naturally occurring effects, such as the interaction of light with various forms of matter. Examples of such techniques include particle systems (which can simulate rain, smoke, or fire), volumetric sampling (to simulate fog, dust and other spatial atmospheric effects), caustics (to simulate light focusing by uneven light-refracting surfaces, such as the light ripples seen on the bottom of a swimming pool), and subsurface scattering (to simulate light reflecting inside the volumes of solid objects, such as human skin). The rendering process is computationally expensive, given the complex variety of physical processes being simulated. Computer processing power has increased rapidly over the years, allowing for a progressively higher degree of realistic rendering. Film studios that produce computer-generated animations typically make use of a render farm to generate images in a timely manner. However, falling hardware costs mean that it is entirely possible to create small amounts of 3D animation on a home computer system given the costs involved when using render farms.[5] The output of the renderer is often used as only one small part of a completed motion-picture scene. Many layers of material may be rendered separately and integrated into the final shot using compositing software. Reflection and shading models Models of reflection/scattering and shading are used to describe the appearance of a surface. Although these issues may seem like problems all on their own, they are studied almost exclusively within the context of rendering. Modern 3D computer graphics rely heavily on a simplified reflection model called the Phong reflection model (not to be confused with Phong shading). In the refraction of light, an important concept is the refractive index; in most 3D programming implementations, the term for this value is "index of refraction" (usually shortened to IOR). Shading can be broken down into two different techniques, which are often studied independently: Surface shading - how light spreads across a surface (mostly used in scanline rendering for real-time 3D rendering in video games) Reflection/scattering - how light interacts with a surface at a given point (mostly used in ray-traced renders for non-real-time photorealistic and artistic 3D rendering in both CGI still 3D images and CGI non-interactive 3D animations) Surface shading algorithms Popular surface shading algorithms in 3D computer graphics include: Flat shading: a technique that shades each polygon of an object based on the polygon's "normal" and the position and intensity of a light source Gouraud shading: invented by H. Gouraud in 1971; a fast and resource-conscious vertex shading technique used to simulate smoothly shaded surfaces Phong shading: invented by Bui Tuong Phong; used to simulate specular highlights and smooth shaded surfaces Reflection The Utah teapot with green lighting Reflection or scattering is the relationship between the incoming and outgoing illumination at a given point. Descriptions of scattering are usually given in terms of a bidirectional scattering distribution function or BSDF.[6] Shading Shading addresses how different types of scattering are distributed across the surface (i.e., which scattering function applies where). Descriptions of this kind are typically expressed with a program called a shader.[7] A simple example of shading is texture mapping, which uses an image to specify the diffuse color at each point on a surface, giving it more apparent detail. Some shading techniques include: Bump mapping: Invented by Jim Blinn, a normal-perturbation technique used to simulate wrinkled surfaces.[8] Cel shading: A technique used to imitate the look of hand-drawn animation. Transport Transport describes how illumination in a scene gets from one place to another. Visibility is a major component of light transport. Projection Perspective projection The shaded three-dimensional objects must be flattened so that the display device - namely a monitor - can display it in only two dimensions, this process is called 3D projection. This is done using projection and, for most applications, perspective projection. The basic idea behind perspective projection is that objects that are further away are made smaller in relation to those that are closer to the eye. Programs produce perspective by multiplying a dilation constant raised to the power of the negative of the distance from the observer. A dilation constant of one means that there is no perspective. High dilation constants can cause a "fish-eye" effect in which image distortion begins to occur. Orthographic projection is used mainly in CAD or CAM applications where scientific modeling requires precise measurements and preservation of the third dimension. Rendering engines Main article: List of 3D rendering software Render engines may come together or be integrated with 3D modeling software but there is standalone software as well. Some render engines are compatible with multiple 3D software, while some are exclusive to one. See also Architectural rendering Ambient occlusion Computer vision Geometry pipeline Geometry processing Graphics Graphics processing unit (GPU) Graphical output devices Image processing Industrial CT scanning Painter's algorithm Parallel rendering Reflection (computer graphics) SIGGRAPH Volume rendering Notes and references

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External links How Stuff Works - 3D Graphics History of Computer Graphics series of articles (Wayback Machine copy) Retrieved from " 8Display device For more information on 3D television, see 3D television. A 3D display is a display device capable of conveying depth to the viewer through the visual system. Many 3D displays are stereoscopic displays, which produce a basic 3D effect by means of stereopsis, but can cause eye strain and visual fatigue. Newer 3D displays such as holographic and light field displays produce a more realistic 3D effect and are easier to view for long periods of time. 3D displays can be near-eye displays like in VR headsets, or they can be in a device further away from the eyes like a 3D-enabled mobile device or 3D movie theater. As of 2021, the most common type of 3D display is a stereoscopic display, which is the type of display used in almost all virtual reality equipment. The term “3D display” can also be used to refer to a volumetric display which may generate content that can be viewed from all angles. One company that produces volumetric displays is Voxon Photonics. History The first 3D display was created by Sir Charles Wheatstone in 1832.[1] It was a stereoscopic display that had rudimentary ability for representing depth. Stereoscopic displays Main article: Stereoscopy Stereoscopic displays are commonly referred to as “stereo displays,” “stereo 3D displays,” “stereoscopic 3D displays,” or sometimes erroneously as just “3D displays.” The basic technique of stereo displays is to present offset images that are displayed separately to the left and right eye. Both of these 2D offset images are then combined in the brain to give the perception of 3D depth. Although the term "3D" is ubiquitously used, it is important to note that the presentation of dual 2D images is distinctly different from displaying a light field, and is also different from displaying an image in three-dimensional space. The most notable difference to real 3D displays is that the observer's head and eyes movements will not increase information about the 3D objects being displayed. For example, holographic displays do not have such limitations. It is an overstatement of capability to refer to dual 2D images as being "3D". The accurate term "stereoscopic" is more cumbersome than the common misnomer "3D", which has been entrenched after many decades of unquestioned misuse. Although most stereoscopic displays do not qualify as real 3D displays, all real 3D displays are often referred to as also stereoscopic displays because they meet the lower criteria of being stereoscopic as well. Based on the principles of stereopsis, described by Sir Charles Wheatstone in the 1830s, stereoscopic technology provides a different image to the viewer's left and right eyes. The following are some of the technical details and methodologies employed in some of the more notable stereoscopic systems that have been developed. Side-by-side images "The early bird catches the worm" Stereograph published in 1900 by North-Western View Co. of Baraboo, Wisconsin, digitally restored. Traditional stereoscopic photography consists of creating a 3D illusion starting from a pair of 2D images, a stereogram. The easiest way to enhance depth perception in the brain is to provide the eyes of the viewer with two different images, representing two perspectives of the same object, with a minor deviation exactly equal to the perspectives that both eyes naturally receive in binocular vision. If eyestrain and distortion are to be avoided, each of the two 2D images preferably should be presented to each eye of the viewer so that any object at infinite distance seen by the viewer should be perceived by that eye while it is oriented straight ahead, the viewer's eyes being neither crossed nor diverging. When the picture contains no object at infinite distance, such as a horizon or a cloud, the pictures should be spaced correspondingly closer together. The side-by-side method is extremely simple to create, but it can be difficult or uncomfortable to view without optical aids. Stereoscope and stereographic cards Main article: Stereoscope A stereoscope is a device for viewing stereographic cards, which are cards that contain two separate images that are printed side by side to create the illusion of a three-dimensional image. Transparency viewers Main article: Slide viewer § Stereo slide viewer A View-Master Model E of the 1950s Pairs of stereo views printed on a transparent base are viewed by transmitted light. One advantage of transparency viewing is the opportunity for a wider, more realistic dynamic range than is practical with prints on an opaque base; another is that a wider field of view may be presented since the images, being illuminated from the rear, may be placed much closer to the lenses. The practice of viewing film-based stereoscopic transparencies dates to at least as early as 1931, when Tru-Vue began to market sets of stereo views on strips of 35 mm film that were fed through a hand-held Bakelite viewer. In 1939, a modified and miniaturized variation of this technology, employing cardboard disks containing seven pairs of small Kodachrome color film transparencies, was introduced as the View-Master. Head-mounted displays Main articles: Head-mounted display and Virtual retinal display The user typically wears a helmet or glasses with two small LCD or OLED displays with magnifying lenses, one for each eye. The technology can be used to show stereo films, images or games. Head-mounted displays may also be coupled with head-tracking devices, allowing the user to "look around" the virtual world by moving their head, eliminating the need for a separate controller. Owing to rapid advancements in computer graphics and the continuing miniaturization of video and other equipment these devices are beginning to become available at more reasonable cost. Head-mounted or wearable glasses may be used to view a see-through image imposed upon the real world view, creating what is called augmented reality. This is done by reflecting the video images through partially reflective mirrors. The real world can be seen through the partial mirror. A recent development in holographic-waveguide or "waveguide-based optics" allows a stereoscopic images to be superimposed on real world without the uses of bulky reflective mirror.[2][3] Head-mounted projection displays Head-mounted projection displays (HMPD) is similar to head-mounted displays but with images projected to and displayed on a retroreflective screen, The advantage of this technology over head-mounted display is that the focusing and vergence issues didn't require fixing with corrective eye lenses. For image generation, Pico-projectors are used instead of LCD or OLED screens.[4][5] Anaglyph Main article: Anaglyph 3D The archetypal 3D glasses, with modern red and cyan color filters, similar to the red/green and red/blue lenses used to view early anaglyph films. In an anaglyph, the two images are superimposed in an additive light setting through two filters, one red and one cyan. In a subtractive light setting, the two images are printed in the same complementary colors on white paper. Glasses with colored filters in each eye separate the appropriate image by canceling the filter color out and rendering the complementary color black. A compensating technique, commonly known as Anachrome, uses a slightly more transparent cyan filter in the patented glasses associated with the technique. Process reconfigures the typical anaglyph image to have less parallax. An alternative to the usual red and cyan filter system of anaglyph is ColorCode 3-D, a patented anaglyph system which was invented in order to present an anaglyph image in conjunction with the NTSC television standard, in which the red channel is often compromised. ColorCode uses the complementary colors of yellow and dark blue on-screen, and the colors of the glasses' lenses are amber and dark blue. Polarization systems Resembling sunglasses, RealD circular polarized glasses are now the standard for theatrical releases and theme park attractions. Main article: Polarized 3D system To present a stereoscopic picture, two images are projected superimposed onto the same screen through different polarizing filters. The viewer wears eyeglasses which also contain a pair of polarizing filters oriented differently (clockwise/counterclockwise with circular polarization or at 90 degree angles, usually 45 and 135 degrees,[6] with linear polarization). As each filter passes only that light which is similarly polarized and blocks the light polarized differently, each eye sees a different image. This is used to produce a three-dimensional effect by projecting the same scene into both eyes, but depicted from slightly different perspectives. Additionally, since both lenses have the same color, people with one dominant eye, where one eye is used more, are able to see the colors properly, previously negated by the separation of the two colors. Circular polarization has an advantage over linear polarization, in that the viewer does not need to have their head upright and aligned with the screen for the polarization to work properly. With linear polarization, turning the glasses sideways causes the filters to go out of alignment with the screen filters causing the image to fade and for each eye to see the opposite frame more easily. For circular polarization, the polarizing effect works regardless of how the viewer's head is aligned with the screen such as tilted sideways, or even upside down. The left eye will still only see the image intended for it, and vice versa, without fading or crosstalk. Polarized light reflected from an ordinary motion picture screen typically loses most of its polarization. So an expensive silver screen or aluminized screen with negligible polarization loss has to be used. All types of polarization will result in a darkening of the displayed image and poorer contrast compared to non-3D images. Light from lamps is normally emitted as a random collection of polarizations, while a polarization filter only passes a fraction of the light. As a result, the screen image is darker. This darkening can be compensated by increasing the brightness of the projector light source. If the initial polarization filter is inserted between the lamp and the image generation element, the light intensity striking the image element is not any higher than normal without the polarizing filter, and overall image contrast transmitted to the screen is not affected. Eclipse method A pair of LCD shutter glasses used to view XpanD 3D films. The thick frames conceal the electronics and batteries. Main article: Active shutter 3D system With the eclipse method, a shutter blocks light from each appropriate eye when the converse eye's image is projected on the screen. The display alternates between left and right images, and opens and closes the shutters in the glasses or viewer in synchronization with the images on the screen. This was the basis of the Teleview system which was used briefly in 1922.[7][8] A variation on the eclipse method is used in LCD shutter glasses. Glasses containing liquid crystal that will let light through in synchronization with the images on the cinema, television or computer screen, using the concept of alternate-frame sequencing. This is the method used by nVidia, XpanD 3D, and earlier IMAX systems. A drawback of this method is the need for each person viewing to wear expensive, electronic glasses that must be synchronized with the display system using a wireless signal or attached wire. The shutter-glasses are heavier than most polarized glasses, though lighter models are no heavier than some sunglasses or deluxe polarized glasses.[9] However these systems do not require a silver screen for projected images. Liquid crystal light valves work by rotating light between two polarizing filters. Due to these internal polarizers, LCD shutter-glasses darken the display image of any LCD, plasma, or projector image source, which has the result that images appear dimmer and contrast is lower than for normal non-3D viewing. This is not necessarily a usage problem; for some types of displays which are already very bright with poor grayish black levels, LCD shutter glasses may actually improve the image quality. Interference filter technology Main article: Anaglyph 3D § Interference filter systems Dolby 3D uses specific wavelengths of red, green, and blue for the right eye, and different wavelengths of red, green, and blue for the left eye. Eyeglasses which filter out the very specific wavelengths allow the wearer to see a 3D image. This technology eliminates the expensive silver screens required for polarized systems such as RealD, which is the most common 3D display system in theaters. It does, however, require much more expensive glasses than the polarized systems. It is also known as spectral comb filtering or wavelength multiplex visualization The recently introduced Omega 3D/Panavision 3D system also uses this technology, though with a wider spectrum and more "teeth" to the "comb" (5 for each eye in the Omega/Panavision system). The use of more spectral bands per eye eliminates the need to color process the image, required by the Dolby system. Evenly dividing the visible spectrum between the eyes gives the viewer a more relaxed "feel" as the light energy and color balance is nearly 50-50. Like the Dolby system, the Omega system can be used with white or silver screens. But it can be used with either film or digital projectors, unlike the Dolby filters that are only used on a digital system with a color correcting processor provided by Dolby. The Omega/Panavision system also claims that their glasses are cheaper to manufacture than those used by Dolby.[10] In June 2012, the Omega 3D/Panavision 3D system was discontinued by DPVO Theatrical, who marketed it on behalf of Panavision, citing "challenging global economic and 3D market conditions".[citation needed] Although DPVO dissolved its business operations, Omega Optical continues promoting and selling 3D systems to non-theatrical markets. Omega Optical’s 3D system contains projection filters and 3D glasses. In addition to the passive stereoscopic 3D system, Omega Optical has produced enhanced anaglyph 3D glasses. The Omega’s red/cyan anaglyph glasses use complex metal oxide thin film coatings and high quality annealed glass optics. Autostereoscopy Main article: Autostereoscopy The Nintendo 3DS uses parallax barrier autostereoscopy to display a 3D image. In this method, glasses are not necessary to see the stereoscopic image. Lenticular lens and parallax barrier technologies involve imposing two (or more) images on the same sheet, in narrow, alternating strips, and using a screen that either blocks one of the two images' strips (in the case of parallax barriers) or uses equally narrow lenses to bend the strips of image and make it appear to fill the entire image (in the case of lenticular prints). To produce the stereoscopic effect, the person must be positioned so that one eye sees one of the two images and the other sees the other. The optical principles of multiview auto-stereoscopy have been known for over a century.[11] Both images are projected onto a high-gain, corrugated screen which reflects light at acute angles. In order to see the stereoscopic image, the viewer must sit within a very narrow angle that is nearly perpendicular to the screen, limiting the size of the audience. Lenticular was used for theatrical presentation of numerous shorts in Russia from 1940 to 1948[12] and in 1946 for the feature-length film Robinzon Kruzo[13] Though its use in theatrical presentations has been rather limited, lenticular has been widely used for a variety of novelty items and has even been used in amateur 3D photography.[14][15] Recent use includes the Fujifilm FinePix Real 3D with an autostereoscopic display that was released in 2009. Other examples for this technology include autostereoscopic LCD displays on monitors, notebooks, TVs, mobile phones and gaming devices, such as the Nintendo 3DS. Other Main article: Stereoscopy The Pulfrich effect is a psychophysical percept wherein lateral motion of an object in the field of view is interpreted by the visual cortex as having a depth component, due to a relative difference in signal timings between the two eyes. Prismatic glasses make cross-viewing easier as well as over/under-viewing possible, examples include the KMQ viewer. 3D displays Real 3D displays display an image in three full dimensions. The most notable difference from stereoscopic displays with only two 2D offset images is that the observer's head and eyes movement will increase information about the 3-dimensional objects being displayed. Volumetric display Main article: Volumetric display Volumetric 3D display Volumetric displays use some physical mechanism to display points of light within a volume. Such displays use voxels instead of pixels. Volumetric displays include multiplanar displays, which have multiple display planes stacked up, and rotating panel displays, where a rotating panel sweeps out a volume. Other technologies have been developed to project light dots in the air above a device. An infrared laser is focused on the destination in space, generating a small bubble of plasma which emits visible light. Newer and more advanced 3D displays Holographic displays Main articles: Holographic display and Computer-generated holography Holographic display is a display technology that has the ability to provide all four eye mechanisms: binocular disparity, motion parallax, accommodation and convergence. The 3D objects can be viewed without wearing any special glasses and no visual fatigue will be caused to human eyes. In 2013, a Silicon valley Company LEIA Inc started manufacturing holographic displays well suited for mobile devices (watches, smartphones or tablets) using a multi-directional backlight and allowing a wide full-parallax angle view to see 3D content without the need of glasses.[16] Their first product was part of a mobile phone (Red Hydrogen One) and later on in their own Android tablet.[citation needed] Integral imaging Main article: Integral imaging Integral imaging is an autostereoscopic or multiscopic 3D display, meaning that it displays a 3D image without the use of special glasses on the part of the viewer. It achieves this by placing an array of microlenses (similar to a lenticular lens) in front of the image, where each lens looks different depending on viewing angle. Thus rather than displaying a 2D image that looks the same from every direction, it reproduces a 4D light field, creating stereo images that exhibit parallax when the viewer moves. Compressive light field displays A new display technology called "compressive light field" is being developed. These prototype displays use layered LCD panels and compression algorithms at the time of display. Designs include dual[17] and multilayer[18][19][20] devices that are driven by algorithms such as computed tomography and non-negative matrix factorization and non-negative tensor factorization. Problems Each of these display technologies can be seen to have limitations, whether the location of the viewer, cumbersome or unsightly equipment or great cost. The display of artifact-free 3D images remains difficult.[citation needed] See also Autostereogram Wiggle stereoscopy

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This article is about motion pictures that give an illusion of three-dimensional depth. For other uses of 3D, see 3D (disambiguation). 3D films are motion pictures made to give an illusion of three-dimensional solidity, usually with the help of special glasses worn by viewers. They have existed in some form since 1915, but had been largely relegated to a niche in the motion picture industry because of the costly hardware and processes required to produce and display a 3D film, and the lack of a standardized format for all segments of the entertainment business. Nonetheless, 3D films were prominently featured in the 1950s in American cinema, and later experienced a worldwide resurgence in the 1980s and 1990s driven by IMAX high-end theaters and Disney-themed venues. 3D films became increasingly successful throughout the 2000s, peaking with the success of 3D presentations of Avatar in December 2009, after which 3D films again decreased in popularity.[1] Certain directors have also taken more experimental approaches to 3D filmmaking, most notably celebrated auteur Jean-Luc Godard in his film Goodbye to Language. History This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. (December 2009) (Learn how and when to remove this template message) Before film The basic components of 3D films were introduced separately between 1833 and 1839. Stroboscopic animation was developed by Joseph Plateau in 1832 and published in 1833 in the form of a stroboscopic disc,[2] which he later called the fantascope and became better known as the phénakisticope. Around the very same time (1832/1833), Charles Wheatstone developed the stereoscope, but he didn't really make it public before June 1838. The first practical forms of photography were introduced in January 1839 by Louis Daguerre and Henry Fox Talbot. A combination of these elements into animated stereoscopic photography may have been conceived early on, but for decades it did not become possible to capture motion in real-time photographic recordings due to the long exposure times necessary for the light-sensitive emulsions that were used. Charles Wheatstone got inventor Henry Fox Talbot to produce some calotype pairs for the stereoscope and received the first results in October 1840. Only a few more experimental stereoscopic photographs were made before David Brewster introduced his stereoscope with lenses in 1849. Wheatstone also approached Joseph Plateau with the suggestion to combine the stereoscope with stereoscopic photography. In 1849, Plateau published about this concept in an article about several improvements made to his fantascope and suggested a stop motion technique that would involve a series of photographs of purpose-made plaster statuettes in different poses.[3] The idea reached Jules Duboscq, an instrument maker who already marketed Plateau's Fantascope as well as the stereoscopes of Wheatstone and Brewster. In November 1852, Duboscq added the concept of his "Stéréoscope-fantascope, ou Bïoscope" to his stereoscope patent. Production of images proved very difficult, since the photographic sequence had to be carefully constructed from separate still images. The bioscope was no success and the only extant disc, without apparatus, is found in the Joseph Plateau collection of the University of Ghent. The disc contains 12 albumen image pairs of a machine in motion.[4] Most of the other early attempts to create motion pictures also aimed to include the stereoscopic effect. In November 1851, Antoine Claudet claimed to have created a stereoscope that showed people in motion.[5] The device initially only showed two phases, but during the next two years, Claudet worked on a camera that would record stereoscopic pairs for four different poses (patented in 1853).[6] Claudet found that the stereoscopic effect didn't work properly in this device, but believed the illusion of motion was successful.[7] Johann Nepomuk Czermak published an article about his Stereophoroskop. His first idea to create animated images in 3D involved sticking pins in a stroboscopic disc in a sequence that would show the pin moving further into the cardboard and back. He also designed a device that would feed the images from two stroboscopic discs into one lenticular stereoscope and a vertical predecessor of the zoetrope.[8] On 27 February 1860 Peter Hubert Desvignes received British patent no. 537 for 28 monocular and stereoscopic variations of cylindrical stroboscopic devices. This included a version that used an endless band of pictures running between two spools that was intermittently lit by an electric spark.[9] Desvignes' Mimoscope, received an Honourable Mention "for ingenuity of construction" at the 1862 International Exhibition in London.[10] It could "exhibit drawings, models, single or stereoscopic photographs, so as to animate animal movements, or that of machinery, showing various other illusions."[11] Desvignes "employed models, insects and other objects, instead of pictures, with perfect success." The horizontal slits (like in Czermak's Stereophorskop) allowed a much improved view, with both eyes, of the opposite pictures.[12] In 1861 American engineer Coleman Sellers II received US patent No. 35,317 for the kinematoscope, a device that exhibited "stereoscopic pictures as to make them represent objects in motion". In his application he stated: "This has frequently been done with plane pictures but has never been, with stereoscopic pictures". He used three sets of stereoscopic photographs in a sequence with some duplicates to regulate the flow of a simple repetitive motion, but also described a system for very large series of pictures of complicated motion.[13][14] On 11 August 1877, the Daily Alta newspaper announced a project by Eadweard Muybridge and Leland Stanford to produce sequences of photographs of a running horse with 12 stereoscopic cameras. Muybridge had much experience with stereo photography and had already made instantaneous pictures of Stanford's horse Occident running at full speed. He eventually managed to shoot the proposed sequences of running horses in June 1878, with stereoscopic cameras. In 1898, Muybridge claimed that he had soon after placed the pictures in two synchronized zoetropes and placed mirrors as in Wheatstone's stereoscope resulting in "a very satisfactory reproduction of an apparently solid miniature horse trotting, and of another galloping".[15] Thomas Edison demonstrated his phonograph on 29 November 1877, after previous announcements of the device for recording and replaying sound had been published earlier in the year. An article in Scientific American concluded "It is already possible, by ingenious optical contrivances, to throw stereoscopic photographs of people on screens in full view of an audience. Add the talking phonograph to counterfeit their voices and it would be difficult to carry the illusion of real presence much further". Wordsworth Donisthorpe announced in the 24 January 1878 edition of Nature that he would advance that conception: "By combining the phonograph with the kinesigraph I will undertake not only to produce a talking picture of Mr. Gladstone which, with motionless lips and unchanged expression shall positively recite his latest anti-Turkish speech in his own voice and tone. Not only this, but the life size photograph itself shall move and gesticulate precisely as he did when making the speech, the words and gestures corresponding as in real life."[16] A Dr. Phipson repeated this idea in a French photography magazine, but renamed the device "Kinétiscope" to reflect the viewing purpose rather than the recording option. This was picked up in the United States and discussed in an interview with Edison later in the year.[17] Neither Donisthorpe or Edison's later moving picture results were stereoscopic. Early patents and tests In the late 1890s, British film pioneer William Friese-Greene filed a patent for a 3D film process. In his patent, two films were projected side by side on screen. The viewer looked through a stereoscope to converge the two images. Because of the obtrusive mechanics behind this method, theatrical use was not practical.[18] Frederic Eugene Ives patented his stereo camera rig in 1900. The camera had two lenses coupled together 1+3/4 inches (4.45 centimeters) apart.[19] On June 10, 1915, Edwin S. Porter and William E. Waddell presented tests to an audience at the Astor Theater in New York City.[20] In red-green anaglyph, the audience was presented three reels of tests, which included rural scenes, test shots of Marie Doro, a segment of John Mason playing a number of passages from Jim the Penman (a film released by Famous Players-Lasky that year, but not in 3D), Oriental dancers, and a reel of footage of Niagara Falls.[21] However, according to Adolph Zukor in his 1953 autobiography The Public Is Never Wrong: My 50 Years in the Motion Picture Industry, nothing was produced in this process after these tests. 1909–1915: Alabastra and Kinoplastikon In 1909 the German film market suffered much from overproduction and too much competition. German film tycoon Oskar Messter had initially gained much financial success with the Tonbild synchronized sound films of his Biophon system since 1903, but the films were losing money by the end of the decade and Messter would soon stop Tonbild production in 1913. Producers and exhibitors were looking into new film attractions and invested for instance in colorful imagery. The development of stereoscopic cinema seemed a logical step to lure visitors back into the movie theaters. In 1909, German civil engineer August Engelsmann patented a process that projected filmed performances within a physical decor on an actual stage. Soon after, Messter obtained patents for a very similar process, probably by agreement with Engelsmann, and started marketing it as "Alabastra". Performers were brightly dressed and brightly lit while filmed against a black background, mostly miming their singing or musical skills or dancing to the circa four-minute pre-recorded phonographs. The film recordings would be projected from below, to appear as circa 30 inch figures on a glass pane in front of a small stage, in a setup very similar to the Pepper's ghost illusion that offered a popular stage trick technique since the 1860s. The glass pane was not visible to the audience and the projected figures seemed able to move around freely across the stage in their virtual tangible and lifelike appearance. The brightness of the figures was necessary to avoid see-through spots and made them resemble alabaster sculptures. To adapt to this appearance, several films featured Pierrot or other white clowns, while some films were probably hand-coloured. Although Alabastra was well received by the press, Messter produced few titles, hardly promoted them and abandoned it altogether a few years later. He believed the system to be uneconomical due to its need for special theatres instead of the widely available movie screens, and he didn't like that it seemed only suitable for stage productions and not for "natural" films. Nonetheless, there were numerous imitators in Germany and Messter and Engelsmann still teamed with American swindler Frank J. Goldsoll set up a short-lived variant named "Fantomo" in 1914.[22] Rather in agreement with Messter or not, Karl Juhasz and Franz Haushofer opened a Kinoplastikon theater in Vienna in 1911. Their patented system was very similar to Alabastra, but projected life-size figures from the wings of the stage. With much higher ticket prices than standard cinema, it was targeted at middle-class audiences to fill the gap between low-brow films and high-class theatre. Audiences reacted enthusiastically and by 1913 there reportedly were 250 theatres outside Austria, in France, Italy, United Kingdom, Russia and North America. However, the first Kinoplastikon in Paris started in January 1914 and the premiere in New York took place in the Hippodrome in March 1915. In 1913, Walter R. Booth directed 10 films for the U.K. Kinoplastikon, presumably in collaboration with Cecil Hepworth. Theodore Brown, the licensee in the U.K. also patented a variant with front and back projection and reflected decor, and Goldsoll applied for a very similar patent only 10 days later.[22] Further development and exploitation was probably haltered by World War I. Alabastra and Kinoplastikon were often advertised as stereoscopic and screenless. In reality the effect was heavily dependent on glass screen projection and the films were not stereoscopic, the shows seemed truly three-dimensional as the figures were clearly separate from the background and virtually appeared inside the real, three-dimensional stage area without any visible screen. Eventually, longer (multi-reel) films with story arcs proved to be the way out of the crisis in the movie market and supplanted the previously popular short films that mostly aimed to amuse people with tricks, gags or other brief variety and novelty attractions. Sound film, stereoscopic film and other novel techniques were relatively cumbersome to combine with multiple reels and were abandoned for a while. Early systems of stereoscopic filmmaking (pre-1952) Fairall in 1922 Fairall's 3D camera Audience wearing special glasses watch a 3D "stereoscopic film" at the Telekinema on the South Bank in London during the Festival of Britain 1951. The earliest confirmed 3D film shown to an out-of-house audience was The Power of Love, which premiered at the Ambassador Hotel Theater in Los Angeles on 27 September 1922.[23][24][25] The camera rig was a product of the film's producer, Harry K. Fairall, and cinematographer Robert F. Elder.[18] It was filmed dual-strip in black and white, and single strip color anaglyphic release prints were produced using a color film invented and patented by Harry K. Fairall. A single projector could be used to display the movie but anaglyph glasses were used for viewing. The camera system and special color release print film all received U.S. Patent No. 1,784,515 on Dec 9, 1930.[26][27] After a preview for exhibitors and press in New York City, the film dropped out of sight, apparently not booked by exhibitors, and is now considered lost. Early in December 1922, William Van Doren Kelley, inventor of the Prizma color system, cashed in on the growing interest in 3D films started by Fairall's demonstration and shot footage with a camera system of his own design. Kelley then struck a deal with Samuel "Roxy" Rothafel to premiere the first in his series of "Plasticon" shorts entitled Movies of the Future at the Rivoli Theater in New York City. Also in December 1922, Laurens Hammond (later inventor of the Hammond organ) premiered his Teleview system, which had been shown to the trade and press in October. Teleview was the first alternating-frame 3D system seen by the public. Using left-eye and right-eye prints and two interlocked projectors, left and right frames were alternately projected, each pair being shown three times to suppress flicker. Viewing devices attached to the armrests of the theater seats had rotary shutters that operated synchronously with the projector shutters, producing a clean and clear stereoscopic result. The only theater known to have installed Teleview was the Selwyn Theater in New York City, and only one show was ever presented with it: a group of short films, an exhibition of live 3D shadows, and M.A.R.S., the only Teleview feature. The show ran for several weeks, apparently doing good business as a novelty (M.A.R.S. itself got poor reviews), but Teleview was never seen again.[28] In 1922, Frederic Eugene Ives and Jacob Leventhal began releasing their first stereoscopic shorts made over a three-year period. The first film, entitled Plastigrams, was distributed nationally by Educational Pictures in the red-and-blue anaglyph format. Ives and Leventhal then went on to produce the following stereoscopic shorts in the "Stereoscopiks Series" released by Pathé Films in 1925: Zowie (April 10), Luna-cy! (May 18), The Run-Away Taxi (December 17) and Ouch (December 17).[29] On 22 September 1924, Luna-cy! was re-released in the De Forest Phonofilm sound-on-film system.[30] The late 1920s to early 1930s saw little interest in stereoscopic pictures. In Paris, Louis Lumière shot footage with his stereoscopic camera in September 1933. The following March he exhibited a remake of his 1895 short film L'Arrivée du Train, this time in anaglyphic 3D, at a meeting of the French Academy of Science.[31] In 1936, Leventhal and John Norling were hired based on their test footage to film MGM's Audioscopiks series. The prints were by Technicolor in the red-and-green anaglyph format, and were narrated by Pete Smith. The first film, Audioscopiks, premiered January 11, 1936, and The New Audioscopiks premiered January 15, 1938. Audioscopiks was nominated for the Academy Award in the category Best Short Subject, Novelty in 1936. With the success of the two Audioscopiks films, MGM produced one more short in anaglyph 3D, another Pete Smith Specialty called Third Dimensional Murder (1941). Unlike its predecessors, this short was shot with a studio-built camera rig. Prints were by Technicolor in red-and-blue anaglyph. The short is notable for being one of the few live-action appearances of the Frankenstein Monster as conceived by Jack Pierce for Universal Studios outside of their company. While many of these films were printed by color systems, none of them was actually in color, and the use of the color printing was only to achieve an anaglyph effect.[32] Introduction of Polaroid While attending Harvard University, Edwin H. Land conceived the idea of reducing glare by polarizing light. He took a leave of absence from Harvard to set up a lab and by 1929 had invented and patented a polarizing sheet.[33] In 1932, he introduced Polaroid J Sheet as a commercial product.[34] While his original intention was to create a filter for reducing glare from car headlights, Land did not underestimate the utility of his newly dubbed Polaroid filters in stereoscopic presentations. In January 1936, Land gave the first demonstration of Polaroid filters in conjunction with 3D photography at the Waldorf-Astoria Hotel.[35][citation needed] The reaction was enthusiastic, and he followed it up with an installation at the New York Museum of Science.[citation needed] It is unknown what film was run for audiences at this installation. Using Polaroid filters meant an entirely new form of projection, however. Two prints, each carrying either the right or left eye view, had to be synced up in projection using an external selsyn motor. Furthermore, polarized light would be largely depolarized by a matte white screen, and only a silver screen or screen made of other reflective material would correctly reflect the separate images. Later that year, the feature, Nozze Vagabonde appeared in Italy, followed in Germany by Zum Greifen nah (You Can Nearly Touch It), and again in 1939 with Germany's Sechs Mädel rollen ins Wochenend (Six Girls Drive Into the Weekend). The Italian film was made with the Gualtierotti camera; the two German productions with the Zeiss camera and the Vierling shooting system. All of these films were the first exhibited using Polaroid filters. The Zeiss Company in Germany manufactured glasses on a commercial basis commencing in 1936; they were also independently made around the same time in Germany by E. Käsemann and by J. Mahler.[36] In 1939, John Norling shot In Tune With Tomorrow, the first commercial 3D film using Polaroid in the US[citation needed]. This short premiered at the 1939 New York World's Fair and was created specifically for the Chrysler Motors Pavilion. In it, a full 1939 Chrysler Plymouth is magically put together, set to music. Originally in black and white, the film was so popular that it was re-shot in color for the following year at the fair, under the title New Dimensions.[citation needed] In 1953, it was reissued by RKO as Motor Rhythm. Another early short that utilized the Polaroid 3D process was 1940's Magic Movies: Thrills For You produced by the Pennsylvania Railroad Co. for the Golden Gate International Exposition.[citation needed] Produced by John Norling, it was filmed by Jacob Leventhal using his own rig. It consisted of shots of various views that could be seen from the Pennsylvania Railroad's trains. In the 1940s, World War II prioritized military applications of stereoscopic photography and it once again went on the back burner in most producers' minds. The "golden era" (1952–1954) What aficionados consider the "golden era" of 3D began in late 1952 with the release of the first color stereoscopic feature, Bwana Devil, produced, written and directed by Arch Oboler. The film was shot in "Natural Vision", a process that was co-created and controlled by M. L. Gunzberg. Gunzberg, who built the rig with his brother, Julian, and two other associates, shopped it without success to various studios before Oboler used it for this feature, which went into production with the title, The Lions of Gulu.[37] The critically panned film was nevertheless highly successful with audiences due to the novelty of 3D, which increased Hollywood interest in 3D during a period that had seen declining box-office admissions.[38] As with practically all of the features made during this boom, Bwana Devil was projected dual-strip, with Polaroid filters. During the 1950s, the familiar disposable anaglyph glasses made of cardboard were mainly used for comic books, two shorts by exploitation specialist Dan Sonney, and three shorts produced by Lippert Productions. However, even the Lippert shorts were available in the dual-strip format alternatively. Because the features utilized two projectors, the capacity limit of film being loaded onto each projector (about 6,000 feet (1,800 m), or an hour's worth of film) meant that an intermission was necessary for every feature-length film. Quite often, intermission points were written into the script at a major plot point. During Christmas of 1952, producer Sol Lesser quickly premiered the dual-strip showcase called Stereo Techniques in Chicago.[39] Lesser acquired the rights to five dual-strip shorts. Two of them, Now is the Time (to Put On Your Glasses) and Around is Around, were directed by Norman McLaren in 1951 for the National Film Board of Canada. The other three films were produced in Britain for Festival of Britain in 1951 by Raymond Spottiswoode. These were A Solid Explanation, Royal River, and The Black Swan. James Mage was also an early pioneer in the 3D craze. Using his 16 mm 3D Bolex system, he premiered his Triorama program on February 10, 1953, with his four shorts: Sunday In Stereo, Indian Summer, American Life, and This is Bolex Stereo.[40] This show is considered lost. Another early 3D film during the boom was the Lippert Productions short, A Day in the Country, narrated by Joe Besser and composed mostly of test footage. Unlike all of the other Lippert shorts, which were available in both dual-strip and anaglyph, this production was released in anaglyph only. April 1953 saw two groundbreaking features in 3D: Columbia's Man in the Dark and Warner Bros. House of Wax, the first 3D feature with stereophonic sound. House of Wax, outside of Cinerama, was the first time many American audiences heard recorded stereophonic sound. It was also the film that typecast Vincent Price as a horror star as well as the "King of 3-D" after he became the actor to star in the most 3D features (the others were The Mad Magician, Dangerous Mission, and Son of Sinbad). The success of these two films proved that major studios now had a method of getting filmgoers back into theaters and away from television sets, which were causing a steady decline in attendance. The Walt Disney Studios entered 3D with its May 28, 1953 release of Melody, which accompanied the first 3D western, Columbia's Fort Ti at its Los Angeles opening. It was later shown at Disneyland's Fantasyland Theater in 1957 as part of a program with Disney's other short Working for Peanuts, entitled, 3-D Jamboree. The show was hosted by the Mouseketeers and was in color. Universal-International released their first 3D feature on May 27, 1953, It Came from Outer Space, with stereophonic sound. Following that was Paramount's first feature, Sangaree with Fernando Lamas and Arlene Dahl. Columbia released several 3D westerns produced by Sam Katzman and directed by William Castle. Castle would later specialize in various technical in-theater gimmicks for such Columbia and Allied Artists features as 13 Ghosts, House on Haunted Hill, and The Tingler. Columbia also produced the only slapstick comedies conceived for 3D. The Three Stooges starred in Spooks and Pardon My Backfire; dialect comic Harry Mimmo starred in Down the Hatch. Producer Jules White was optimistic about the possibilities of 3D as applied to slapstick (with pies and other projectiles aimed at the audience), but only two of his stereoscopic shorts were shown in 3D. Down the Hatch was released as a conventional, "flat" motion picture. (Columbia has since printed Down the Hatch in 3D for film festivals.) John Ireland, Joanne Dru and Macdonald Carey starred in the Jack Broder color production Hannah Lee, which premiered June 19, 1953. The film was directed by Ireland, who sued Broder for his salary. Broder counter-sued, claiming that Ireland went over production costs with the film.[citation needed] Another famous entry in the golden era of 3D was the 3 Dimensional Pictures production of Robot Monster. The film was allegedly scribbled in an hour by screenwriter Wyott Ordung and filmed in a period of two weeks on a shoestring budget.[citation needed] Despite these shortcomings and the fact that the crew had no previous experience with the newly built camera rig, luck was on the cinematographer's side, as many find the 3D photography in the film is well shot and aligned. Robot Monster also has a notable score by then up-and-coming composer Elmer Bernstein. The film was released June 24, 1953, and went out with the short Stardust in Your Eyes, which starred nightclub comedian, Slick Slavin.[citation needed] 20th Century Fox produced their only 3D feature, Inferno in 1953, starring Rhonda Fleming. Fleming, who also starred in Those Redheads From Seattle, and Jivaro, shares the spot for being the actress to appear in the most 3D features with Patricia Medina, who starred in Sangaree, Phantom of the Rue Morgue and Drums of Tahiti. Darryl F. Zanuck expressed little interest in stereoscopic systems, and at that point was preparing to premiere the new widescreen film system, CinemaScope. The first decline in the theatrical 3D craze started in August and September 1953. The factors causing this decline were: Two prints had to be projected simultaneously.[citation needed] The prints had to remain exactly alike after repair, or synchronization would be lost.[citation needed] It sometimes required two projectionists to keep sync working properly.[citation needed] When either prints or shutters became out of sync, even for a single frame, the picture became virtually unwatchable and accounted for headaches and eyestrain.[citation needed] The necessary silver projection screen was very directional and caused sideline seating to be unusable with both 3D and regular films, due to the angular darkening of these screens. Later films that opened in wider-seated venues often premiered flat for that reason (such as Kiss Me Kate at the Radio City Music Hall).[citation needed] A mandatory intermission was needed to properly prepare the theater's projectors for the showing of the second half of the film.[citation needed] Because projection booth operators were at many times careless, even at preview screenings of 3D films, trade and newspaper critics claimed that certain films were "hard on the eyes."[citation needed] Sol Lesser attempted to follow up Stereo Techniques with a new showcase, this time five shorts that he himself produced.[citation needed] The project was to be called The 3-D Follies and was to be distributed by RKO.[citation needed] Unfortunately, because of financial difficulties and the general loss of interest in 3D, Lesser canceled the project during the summer of 1953, making it the first 3D film to be aborted in production.[citation needed] Two of the three shorts were shot: Carmenesque, a burlesque number starring exotic dancer Lili St. Cyr, and Fun in the Sun, a sports short directed by famed art designer/director William Cameron Menzies, who also directed the 3D feature The Maze for Allied Artists. Although it was more expensive to install, the major competing realism process was wide-screen, but two-dimensional, anamorphic, first utilized by Fox with CinemaScope and its September premiere in The Robe. Anamorphic films needed only a single print, so synchronization was not an issue. Cinerama was also a competitor from the start and had better quality control than 3D because it was owned by one company that focused on quality control. However, most of the 3D features past the summer of 1953 were released in the flat widescreen formats ranging from 1.66:1 to 1.85:1. In early studio advertisements and articles about widescreen and 3D formats, widescreen systems were referred to as "3D", causing some confusion among scholars.[citation needed] There was no single instance of combining CinemaScope with 3D until 1960, with a film called September Storm, and even then, that was a blow-up from a non-anamorphic negative.[citation needed] September Storm also went out with the last dual-strip short, Space Attack, which was actually shot in 1954 under the title The Adventures of Sam Space. In December 1953, 3D made a comeback with the release of several important 3D films, including MGM's musical Kiss Me, Kate. Kate was the hill over which 3D had to pass to survive. MGM tested it in six theaters: three in 3D and three-flat.[citation needed] According to trade ads of the time, the 3D version was so well-received that the film quickly went into a wide stereoscopic release.[citation needed] However, most publications, including Kenneth Macgowan's classic film reference book Behind the Screen, state that the film did much better as a "regular" release. The film, adapted from the popular Cole Porter Broadway musical, starred the MGM songbird team of Howard Keel and Kathryn Grayson as the leads, supported by Ann Miller, Keenan Wynn, Bobby Van, James Whitmore, Kurt Kasznar and Tommy Rall. The film also prominently promoted its use of stereophonic sound. Several other features that helped put 3D back on the map that month were the John Wayne feature Hondo (distributed by Warner Bros.), Columbia's Miss Sadie Thompson with Rita Hayworth, and Paramount's Money From Home with Dean Martin and Jerry Lewis. Paramount also released the cartoon shorts Boo Moon with Casper, the Friendly Ghost and Popeye, Ace of Space with Popeye the Sailor. Paramount Pictures released a 3D Korean War film Cease Fire filmed on actual Korean locations in 1953.[41] Top Banana, based on the popular stage musical with Phil Silvers, was brought to the screen with the original cast. Although it was merely a filmed stage production, the idea was that every audience member would feel they would have the best seat in the house through color photography and 3D.[citation needed] Although the film was shot and edited in 3D, United Artists, the distributor, felt the production was uneconomical in stereoscopic form and released the film flat on January 27, 1954.[citation needed] It remains one of two "Golden era" 3D features, along with another United Artists feature, Southwest Passage (with John Ireland and Joanne Dru), that are currently considered lost (although flat versions survive). A string of successful films filmed in 3D followed the second wave, but many were widely or exclusively shown flat. Some highlights are: The French Line, starring Jane Russell and Gilbert Roland, a Howard Hughes/RKO production. The film became notorious for being released without an MPAA seal of approval after several suggestive lyrics were included, as well as one of Ms. Russell's particularly revealing costumes.[citation needed] Playing up her sex appeal, one tagline for the film was, "It'll knock both of your eyes out!" The film was later cut and approved by the MPAA for a general flat release, despite having a wide and profitable 3D release.[citation needed] Taza, Son of Cochise, a sequel to 1950s Broken Arrow, which starred Rock Hudson in the title role, Barbara Rush as the love interest, and Rex Reason (billed as Bart Roberts) as his renegade brother. Originally released flat through Universal-International. It was directed by the great stylist Douglas Sirk, and his striking visual sense made the film a huge success when it was "re-premiered" in 3D in 2006 at the Second 3D Expo in Hollywood. Two ape films: Phantom of the Rue Morgue, featuring Karl Malden and Patricia Medina, produced by Warner Bros. and based on Edgar Allan Poe's "The Murders in the Rue Morgue", and Gorilla at Large, a Panoramic Production starring Cameron Mitchell, distributed flat and 3D through Fox. Creature from the Black Lagoon, starring Richard Carlson and Julie Adams, directed by Jack Arnold. Although arguably the most famous 3D film, it was typically seen in 3D only in large urban theaters and shown flat in the many smaller neighborhood theaters.[42] It was the only 3D feature that spawned a 3D sequel, Revenge of the Creature, which was in turn followed by The Creature Walks Among Us, shot flat. Dial M for Murder, directed by Alfred Hitchcock and starring Ray Milland, Robert Cummings, and Grace Kelly, is considered by aficionados of 3D to be one of the best examples of the process. Although available in 3D in 1954, there are no known playdates in 3D,[citation needed] since Warner Bros. had just instated a simultaneous 3D/2D release policy. The film's screening in 3D in February 1980 at the York Theater in San Francisco did so well that Warner Bros. re-released the film in 3D in February 1982. The film is now available on 3D Blu-ray, marking the first time it was released on home video in its 3D presentation. Gog, the last episode in Ivan Tors' Office of Scientific Investigation (OSI) trilogy dealing with realistic science fiction (following The Magnetic Monster and Riders to the Stars). Most theaters showed it flat. The Diamond (released in the United States as The Diamond Wizard), a 1954 British crime film starring Dennis O'Keefe. The only stereoscopic feature shot in Britain, released flat in both the UK and US. Irwin Allen's Dangerous Mission released by RKO in 1954 featuring Allen's trademarks of an all-star cast facing a disaster (a forest fire). Bosley Crowther's New York Times review mentions that it was shown flat. Son of Sinbad, another RKO/Howard Hughes production, starring Dale Robertson, Lili St. Cyr, and Vincent Price. The film was shelved after Hughes ran into difficulty with The French Line, and was not released until 1955, at which time it went out flat, converted to the SuperScope process. 3D's final decline was in the late spring of 1954, for the same reasons as the previous lull, as well as the further success of widescreen formats with theater operators. Even though Polaroid had created a well-designed "Tell-Tale Filter Kit" for the purpose of recognizing and adjusting out of sync and phase 3D,[citation needed] exhibitors still felt uncomfortable with the system and turned their focus instead to processes such as CinemaScope. The last 3D feature to be released in that format during the "Golden era" was Revenge of the Creature, on February 23, 1955. Ironically, the film had a wide release in 3D and was well received at the box office.[43] Revival (1960–1984) in single strip format Stereoscopic films largely remained dormant for the first part of the 1960s, with those that were released usually being anaglyph exploitation films. One film of notoriety was the Beaver-Champion/Warner Bros. production, The Mask (1961). The film was shot in 2-D, but to enhance the bizarre qualities of the dream-world that is induced when the main character puts on a cursed tribal mask, these scenes went to anaglyph 3D. These scenes were printed by Technicolor on their first run in red/green anaglyph. Although 3D films appeared sparsely during the early 1960s, the true second wave of 3D cinema was set into motion by Arch Oboler, the producer who had started the craze of the 1950s. Using a new technology called Space-Vision 3D. The origin of "Space-Vision 3D" goes back to Colonel Robert Vincent Bernier, a forgotten innovator in the history of stereoscopic motion pictures. His Trioptiscope Space-Vision lens was the gold standard for the production and exhibition of 3-D films for nearly 30 years.[44] "Space-Vision 3D" stereoscopic films were printed with two images, one above the other, in a single academy ratio frame, on a single strip, and needed only one projector fitted with a special lens. This so-called "over and under" technique eliminated the need for dual projector set-ups, and produced widescreen, but darker, less vivid, polarized 3D images. Unlike earlier dual system, it could stay in perfect synchronization, unless improperly spliced in repair. Arch Oboler once again had the vision for the system that no one else would touch, and put it to use on his film entitled The Bubble, which starred Michael Cole, Deborah Walley, and Johnny Desmond. As with Bwana Devil, the critics panned The Bubble, but audiences flocked to see it, and it became financially sound enough to promote the use of the system to other studios, particularly independents, who did not have the money for expensive dual-strip prints of their productions. In 1970, Stereovision, a new entity founded by director/inventor Allan Silliphant and optical designer Chris Condon, developed a different 35 mm single-strip format, which printed two images squeezed side by side and used an anamorphic lens to widen the pictures through Polaroid filters. Louis K. Sher (Sherpix) and Stereovision released the softcore sex comedy The Stewardesses (self-rated X, but later re-rated R by the MPAA). The film cost US$100,000 to produce, and ran for months in several markets.[citation needed] eventually earning $27 million in North America, alone ($140 million in constant-2010 dollars) in fewer than 800 theaters, becoming the most profitable 3-Dimensional film to date, and in purely relative terms, one of the most profitable films ever. It was later released in 70 mm 3D. Some 36 films worldwide were made with Stereovision over 25 years, using either a widescreen (above-below), anamorphic (side by side) or 70 mm 3D formats.[citation needed] In 2009 The Stewardesses was remastered by Chris Condon and director Ed Meyer, releasing it in XpanD 3D, RealD Cinema and Dolby 3D. The quality of the 1970s 3D films was not much more inventive, as many were either softcore and even hardcore adult films, horror films, or a combination of both. Paul Morrisey's Flesh For Frankenstein (aka Andy Warhol's Frankenstein) was a superlative example of such a combination. Between 1981 and 1983 there was a new Hollywood 3D craze started by the spaghetti western Comin' at Ya!. When Parasite was released it was billed as the first horror film to come out in 3D in over 20 years. Horror films and reissues of 1950s 3D classics (such as Hitchcock's Dial M for Murder) dominated the 3D releases that followed. The second sequel in the Friday the 13th series, Friday the 13th Part III, was released very successfully. Apparently saying "part 3 in 3D" was considered too cumbersome so it was shortened in the titles of Jaws 3-D and Amityville 3-D, which emphasized the screen effects to the point of being annoying at times, especially when flashlights were shone into the eyes of the audience. The science fiction film Spacehunter: Adventures in the Forbidden Zone was the most expensive 3D film made up to that point with production costs about the same as Star Wars but not nearly the same box office success, causing the craze to fade quickly through spring 1983. Other sci-fi/fantasy films were released as well including Metalstorm: The Destruction of Jared-Syn and Treasure of the Four Crowns, which was widely criticized for poor editing and plot holes, but did feature some truly spectacular closeups. 3D releases after the second craze included The Man Who Wasn't There (1983), Silent Madness and the 1985 animated film Starchaser: The Legend of Orin, whose plot seemed to borrow heavily from Star Wars. Only Comin' At Ya!, Parasite, and Friday the 13th Part III have been officially released on VHS and/or DVD in 3D in the United States (although Amityville 3D has seen a 3D DVD release in the United Kingdom). Most of the 1980s 3D films and some of the classic 1950s films such as House of Wax were released on the now defunct Video Disc (VHD) format in Japan as part of a system that used shutter glasses. Most of these have been unofficially transferred to DVD and are available on the grey market through sites such as eBay. Stereoscopic movies were also popular in other parts of the world, such as My Dear Kutthichathan, a Malayalam film which was shot with stereoscopic 3D and released in 1984. Rebirth of 3D (1985–2003) In the mid-1980s, IMAX began producing non-fiction films for its nascent 3D business, starting with We Are Born of Stars (Roman Kroitor, 1985). A key point was that this production, as with all subsequent IMAX productions, emphasized mathematical correctness of the 3D rendition and thus largely eliminated the eye fatigue and pain that resulted from the approximate geometries of previous 3D incarnations. In addition, and in contrast to previous 35mm-based 3D presentations, the very large field of view provided by IMAX allowed a much broader 3D "stage", arguably as important in 3D film as it is theatre. The Walt Disney Company also began more prominent use of 3D films in special venues to impress audiences with Magic Journeys (1982) and Captain EO (Francis Ford Coppola, 1986, starring Michael Jackson) being notable examples. In the same year, the National Film Board of Canada production Transitions (Colin Low), created for Expo 86 in Vancouver, was the first IMAX presentation using polarized glasses. Echoes of the Sun (Roman Kroitor, 1990) was the first IMAX film to be presented using alternate-eye shutterglass technology, a development required because the dome screen precluded the use of polarized technology. From 1990 onward, numerous films were produced by all three parties to satisfy the demands of their various high-profile special attractions and IMAX's expanding 3D network. Films of special note during this period include the extremely successful Into the Deep (Graeme Ferguson, 1995) and the first IMAX 3D fiction film Wings of Courage (1996), by director Jean-Jacques Annaud, about the pilot Henri Guillaumet. Other stereoscopic films produced in this period include: The Last Buffalo (Stephen Low, 1990) Jim Henson's Muppet*Vision 3D (Jim Henson, 1991) Imagine (John Weiley, 1993) Honey, I Shrunk the Audience (Daniel Rustuccio, 1994) Into the Deep (Graeme Ferguson, 1995) Across the Sea of Time (Stephen Low, 1995) Wings of Courage (Jean-Jacques Annaud, 1996) L5, First City in Space (Graeme Ferguson, 1996) T2 3-D: Battle Across Time (James Cameron, 1996) Paint Misbehavin (Roman Kroitor and Peter Stephenson, 1997) IMAX Nutcracker (1997) The Hidden Dimension (1997) T-Rex: Back to the Cretaceous (Brett Leonard, 1998) Mark Twain's America (Stephen Low, 1998) Siegfried & Roy: The Magic Box (Brett Leonard, 1999) Galapagos (Al Giddings and David Clark, 1999) Encounter in the Third Dimension (Ben Stassen, 1999) Alien Adventure (Ben Stassen, 1999) Ultimate G's (2000) Cyberworld (Hugh Murray, 2000) Cirque du Soleil: Journey of Man (Keith Melton, 2000) Haunted Castle (Ben Stassen, 2001) Panda Vision (Ben Stassen, 2001) Space Station 3D (Toni Myers, 2002) SOS Planet (Ben Stassen, 2002) Ocean Wonderland (2003) Falling in Love Again (Munro Ferguson, 2003) Misadventures in 3D (Ben Stassen, 2003) By 2004, 54% of IMAX theaters (133 of 248) were capable of showing 3D films.[45] Shortly thereafter, higher quality computer animation, competition from DVDs and other media, digital projection, digital video capture, and the use of sophisticated IMAX 70mm film projectors, created an opportunity for another wave of 3D films.[46][47] Mainstream resurgence (2003–present) In 2003, Ghosts of the Abyss by James Cameron was released as the first full-length 3D IMAX feature filmed with the Reality Camera System. This camera system used the latest HD video cameras, not film, and was built for Cameron by Vince Pace, to his specifications. The same camera system was used to film Spy Kids 3-D: Game Over (2003), Aliens of the Deep IMAX (2005), and The Adventures of Sharkboy and Lavagirl in 3-D (2005). In 2004, Las Vegas Hilton released Star Trek: The Experience which included two films. One of the films, Borg Invasion 4-D (Ty Granoroli), was in 3D. In August of the same year, rap group Insane Clown Posse released their ninth studio album Hell's Pit. One of two versions of the album contained a DVD featuring a 3D short film for the track "Bowling Balls", shot in high-definition video.[48] Shooting of the film Hidden Universe 3D with IMAX camera.[49] In November 2004, The Polar Express was released as IMAX's first full-length, animated 3D feature. It was released in 3,584 theaters in 2D, and only 66 IMAX locations. The return from those few 3D theaters was about 25% of the total. The 3D version earned about 14 times as much per screen as the 2D version. This pattern continued and prompted a greatly intensified interest in 3D and 3D presentation of animated films. In June 2005, the Mann's Chinese 6 theatre in Hollywood became the first commercial film theatre to be equipped with the Digital 3D format. Both Singin' in the Rain and The Polar Express were tested in the Digital 3D format over the course of several months. In November 2005, Walt Disney Studio Entertainment released Chicken Little in digital 3D format. The Butler's in Love, a short film directed by David Arquette and starring Elizabeth Berkley and Thomas Jane[50] was released on June 23, 2008. The film was shot at the former Industrial Light & Magic studios using KernerFX's prototype Kernercam stereoscopic camera rig. Ben Walters suggested in 2009 that both filmmakers and film exhibitors regain interest in 3D film. There was more 3D exhibition equipment, and more dramatic films being shot in 3D format. One incentive is that the technology is more mature. Shooting in 3D format is less limited, and the result is more stable. Another incentive was the fact that while 2D ticket sales were in an overall state of decline, revenues from 3D tickets continued to grow at the time.[51] Through the entire history of 3D presentations, techniques to convert existing 2D images for 3D presentation have existed. Few have been effective or survived. The combination of digital and digitized source material with relatively cost-effective digital post-processing has spawned a new wave of conversion products. In June 2006, IMAX and Warner Bros. released Superman Returns including 20 minutes of 3D images converted from the 2D original digital footage. George Lucas announced that he would re-release his Star Wars films in 3D based on a conversion process from the company In-Three. Later on in 2011, it was announced that Lucas was working with the company Prime Focus on this conversion.[52] In late 2005, Steven Spielberg told the press he was involved in patenting a 3D cinema system that did not need glasses, based on plasma screens. A computer splits each film-frame, and then projects the two split images onto the screen at differing angles, to be picked up by tiny angled ridges on the screen.[citation needed] Animated films Open Season, and The Ant Bully, were released in analog 3D in 2006. Monster House and The Nightmare Before Christmas were released on XpanD 3D, RealD and Dolby 3D systems in 2006. On May 19, 2007 Scar3D opened at the Cannes Film Market. It was the first US-produced 3D full-length feature film to be completed in Real D 3D. It has been the #1 film at the box office in several countries around the world, including Russia where it opened in 3D on 295 screens. On January 19, 2008, U2 3D was released; it was the first live-action digital 3D film. In the same year others 3D films included Hannah Montana & Miley Cyrus: Best of Both Worlds Concert, Journey to the Center of the Earth, and Bolt. On January 16, 2009, Lionsgate released My Bloody Valentine 3D, the first horror film and first R-rated film to be projected in Real D 3D.[53] It was released to 1,033 3D screens, the most ever for this format, and 1,501 regular screens. Another R-rated film, The Final Destination, was released later that year in August on even more screens. It was the first of its series to be released in HD 3D. Major 3D films in 2009 included Coraline, Monsters vs. Aliens, Up, X Games 3D: The Movie, The Final Destination, Disney's A Christmas Carol, and Avatar.[54] Avatar has gone on to be one of the most expensive films of all time, with a budget at $237 million; it is also the highest-grossing film of all time. The main technologies used to exhibit these films, and many others released around the time and up to the present, are Real D 3D, Dolby 3D, XpanD 3D, MasterImage 3D, and IMAX 3D. March and April 2010 saw three major 3D releases clustered together, with Alice in Wonderland hitting US theaters on March 5, 2010, How to Train Your Dragon on March 26, 2010, and Clash of the Titans on April 2, 2010. On May 13 of the same year, China's first IMAX 3D film started shooting. The pre-production of the first 3D film shot in France, Derrière les murs, began in May 2010 and was released in mid-2011. On October 1, 2010 Scar3D was the first-ever stereoscopic 3D Video-on-demand film released through major cable broadcasters for 3D televisions in the United States. Released in the United States on May 21, 2010, Shrek Forever After by DreamWorks Animation (Paramount Pictures) used the Real D 3D system, also released in IMAX 3D. World 3-D Expositions In September 2003, Sabucat Productions organized the first World 3-D Exposition, celebrating the 50th anniversary of the original craze. The Expo was held at Grauman's Egyptian Theatre. During the two-week festival, over 30 of the 50 "golden era" stereoscopic features (as well as shorts) were screened, many coming from the collection of film historian and archivist Robert Furmanek, who had spent the previous 15 years painstakingly tracking down and preserving each film to its original glory. In attendance were many stars from each film, respectively, and some were moved to tears by the sold-out seating with audiences of film buffs from all over the world who came to remember their previous glories. In May 2006, the second World 3-D Exposition was announced for September of that year, presented by the 3-D Film Preservation Fund. Along with the favorites of the previous exposition were newly discovered features and shorts, and like the previous Expo, guests from each film. Expo II was announced as being the locale for the world premiere of several films never before seen in 3D, including The Diamond Wizard and the Universal short, Hawaiian Nights with Mamie Van Doren and Pinky Lee. Other "re-premieres" of films not seen since their original release in stereoscopic form included Cease Fire!, Taza, Son of Cochise, Wings of the Hawk, and Those Redheads From Seattle. Also shown were the long-lost shorts Carmenesque and A Day in the Country (both 1953) and William Van Doren Kelley's two Plasticon shorts (1922 and 1923). Audience decline In the wake of its initial popularity and corresponding increase in the number of screens, more films are being released in the 3D format. For instance, only 45% of the premiere weekend box office earnings of Kung Fu Panda 2 came from 3D screenings as opposed to 60% for Shrek Forever After in 2010.[55] In addition, the premiere of Cars 2 opening weekend gross consisted of only 37% from 3D theatres.[56] Harry Potter and the Deathly Hallows – Part 2 and Captain America: The First Avenger were major releases that achieved similar percentages: 43% and 40% respectively.[57] In view of this trend, there has been box office analysis concluding the implementation of 3D presentation is apparently backfiring by discouraging people from going to film theatres at all. As Brandon Gray of Box Office Mojo notes, "In each case, 3D's more-money-from-fewer-people approach has simply led to less money from even fewer people."[58] Parallel, the number of televisions sold with support for 3D television has dropped, let alone those sold with actual 3D goggles. According to the Motion Picture Association of America, despite a record total of 47 3D films being released in 2011, the overall domestic box office receipts were down 18% to $1.8 billion from $2.2 billion in 2010.[59] Although revenues as a whole increased during 2012, the bulk has so far come from 2D presentations as exemplified by little over 50% of filmgoers opting to see the likes of The Avengers and 32% choosing Brave in their 3D versions. Conflicting reasons are respectively offered by studios and exhibitors: whereas the former blame more expensive 3D ticket prices, the latter argue that the quality of films in general is at fault. However, despite the perceived decline of 3D in the U.S. market, studio chiefs are optimistic of better receipts internationally, where there still appears to be a strong appetite for the format.[60][61] Studios are also using 3D to generate additional income from films that are already commercially successful. Such re-releases usually involve a conversion from 2D. For example, Disney has reissued both The Lion King and Beauty and the Beast, with plans to add some of its other well-known titles.[62] Titanic has also been modified for 3D,[63] and there are also plans to similarly present all six Star Wars films.[64] Jeffrey Katzenberg, a producer of 3D films and one of the leading proponents of the format, blames oversaturation of the market with inferior films, especially ones photographed conventionally and then digitally processed in post-production. He claims that such films have led audiences to conclude that the format is not worth the often much higher ticket price.[65] Daniel Engber, a columnist for Slate, comes to a similar conclusion: "What happened to 3-D? It may have died from a case of acute septicemia—too much crap in the system."[66] Film critic Mark Kermode, a noted detractor of 3D, has surmised that there is an emerging policy of distributors to limit the availability of 2D versions, thus "railroading" the 3D format into cinemas whether the paying filmgoer likes it or not. This was especially prevalent during the release of Prometheus in 2012, where only 30% of prints for theatrical exhibition (at least in the UK) were in 2D.[67] His suspicions were later reinforced by a substantial number of complaints about Dredd from those who wished to see it in 2D but were denied the opportunity.[68] In July 2017, IMAX announced that they will begin to focus on screening more Hollywood tentpole movies in 2D (even if there's a 3D version) and have fewer 3D screenings of movies in North America, citing that moviegoers in North America prefer 2D films over 3D films.[69] Techniques Further information: Stereoscopy Stereoscopic motion pictures can be produced through a variety of different methods. Over the years the popularity of systems being widely employed in film theaters has waxed and waned. Though anaglyph was sometimes used prior to 1948, during the early "Golden Era" of 3D cinematography of the 1950s the polarization system was used for every single feature-length film in the United States, and all but one short film.[70] In the 21st century, polarization 3D systems have continued to dominate the scene, though during the 1960s and 1970s some classic films which were converted to anaglyph for theaters not equipped for polarization, and were even shown in 3D on television.[71] In the years following the mid-1980s, some films were made with short segments in anaglyph 3D. The following are some of the technical details and methodologies employed in some of the more notable 3D film systems that have been developed. Producing 3D films Live action Main article: Stereo photography techniques The standard for shooting live-action films in 3D involves using two cameras mounted so that their lenses are about as far apart from each other as the average pair of human eyes, recording two separate images for both the left eye and the right eye. In principle, two normal 2D cameras could be put side-to-side but this is problematic in many ways. The only real option is to invest in new stereoscopic cameras. Moreover, some cinematographic tricks that are simple with a 2D camera become impossible when filming in 3D. This means those otherwise cheap tricks need to be replaced by expensive CGI.[72] In 2008, Journey to the Center of the Earth became the first live-action feature film to be shot with the earliest Fusion Camera System released in Digital 3D and was later followed by several others. Avatar (2009) was shot in a 3D process that is based on how the human eye looks at an image. It was an improvement to the existing 3D camera system. Many 3D camera rigs still in use simply pair two cameras side by side, while newer rigs are paired with a beam splitter or both camera lenses built into one unit. While Digital Cinema cameras are not a requirement for 3D they are the predominant medium for most of what is photographed. Film options include IMAX 3D and Cine 160. Animation In the 1930s and 1940s Fleischer Studio made several cartoons with extensive stereoscopic 3D backgrounds, including several Popeye, Betty Boop, and Superman cartoons. In the early to mid-1950s, only half of the major Animation film studios operation experimented with creating traditional 3D animated short subjects. Walt Disney Studio produced two traditional animation short for stereoscopic 3D, for cinemas. Adventures in Music: Melody (1953), and the Donald Duck cartoon Working for Peanuts (1953). Warner Brothers only produced a single cartoon in 3D: Lumber Jack-Rabbit (1953) starring Bugs Bunny. Famous Studio produced two cartoons in 3D, the Popeye cartoon Popeye, the Ace of Space (1953), and the Casper the Friendly Ghost cartoon Boo Moon (1954). Walter Lantz Studio produced the Woody Woodpecker cartoon Hypnotic Hick (1953), which was distributed by Universal. From the late 1950s until the mid-2000s almost no animation was produced for 3D display in theaters. Although several films used 3D backgrounds. One exception is Starchaser: The Legend of Orin. CGI animated films can be rendered as stereoscopic 3D version by using two virtual cameras. Stop-motion animated 3D films are photographed with two cameras similar to live action 3D films. In 2004 The Polar Express was the first stereoscopic 3D computer-animated feature film. The 3D version was solely release in Imax theaters. In November 2005, Walt Disney Studio Entertainment released Chicken Little in digital 3D format, being Disney's first CGI-animated film in 3D. The film was converted from 2D into 3D in post production. nWave Pictures' Fly Me to the Moon (2008) was actually the first animated film created for 3D and released exclusively in 3D in digital theaters around the world. No other animation films have released solely in 3D since. The first 3D feature by DreamWorks Animation, Monsters vs Aliens, followed in 2009 and used a new digital rendering process called InTru3D, which was developed by Intel to create more realistic animated 3D images. InTru3D is not used to exhibit 3D films in theaters; they are shown in either RealD 3D or IMAX 3D. 2D to 3D conversion Main article: 2D to 3D conversion In the case of 2D CGI animated films that were generated from 3D models, it is possible to return to the models to generate a 3D version. For all other 2D films, different techniques must be employed. For example, for the 3D re-release of the 1993 film The Nightmare Before Christmas, Walt Disney Pictures scanned each original frame and manipulated them to produce left-eye and right-eye versions. Dozens of films have now been converted from 2D to 3D. There are several approaches used for 2D to 3D conversion, most notably depth-based methods.[73] However, conversion to 3D has problems. Information is unavailable as 2D does not have information for a perspective view. Some TVs have a 3D engine to convert 2D content to 3D. Usually, on high frame rate content (and on some slower processors even normal frame rate) the processor is not fast enough and lag is possible. This can lead to strange visual effects.[74] Displaying 3D films Further information: 3D television and 3D Display Anaglyph Main article: Anaglyph 3D The traditional 3D glasses, with modern red and cyan color filters, similar to the red/green and red/blue lenses used to view early anaglyph films. Anaglyph images were the earliest method of presenting theatrical 3D, and the one most commonly associated with stereoscopy by the public at large, mostly because of non-theatrical 3D media such as comic books and 3D television broadcasts, where polarization is not practical. They were made popular because of the ease of their production and exhibition. The first anaglyph film was invented in 1915 by Edwin S Porter. Though the earliest theatrical presentations were done with this system, most 3D films from the 1950s and 1980s were originally shown polarized.[75] In an anaglyph, the two images are superimposed in an additive light setting through two filters, one red and one cyan. In a subtractive light setting, the two images are printed in the same complementary colors on white paper. Glasses with colored filters in each eye separate the appropriate images by canceling the filter color out and rendering the complementary color black. Anaglyph images are much easier to view than either parallel sighting or crossed eye stereograms, although the latter types offer bright and accurate color rendering, particularly in the red component, which is muted, or desaturated with even the best color anaglyphs. A compensating technique, commonly known as Anachrome, uses a slightly more transparent cyan filter in the patented glasses associated with the technique. Process reconfigures the typical anaglyph image to have less parallax. An alternative to the usual red and cyan filter system of anaglyph is ColorCode 3-D, a patented anaglyph system which was invented in order to present an anaglyph image in conjunction with the NTSC television standard, in which the red channel is often compromised. ColorCode uses the complementary colors of yellow and dark blue on-screen, and the colors of the glasses' lenses are amber and dark blue. The polarization 3D system has been the standard for theatrical presentations since it was used for Bwana Devil in 1952,[75] though early Imax presentations were done using the eclipse system and in the 1960s and 1970s classic 3D films were sometimes converted to anaglyph for special presentations. The polarization system has better color fidelity and less ghosting than the anaglyph system. In the post-'50s era, anaglyph has been used instead of polarization in feature presentations where only part of the film is in 3D such as in the 3D segment of Freddy's Dead: The Final Nightmare and the 3D segments of Spy Kids 3-D: Game Over. Anaglyph is also used in printed materials and in 3D television broadcasts where polarization is not practical. 3D polarized televisions and other displays only became available from several manufacturers in 2008; these generate polarization on the receiving end. Polarization systems cardboard 3D linear polarized glasses from the 1980s similar to those used in the 1950s. Though some were plain white, they often had the name of the theatre and/or graphics from the film Main article: Polarized 3D system To present a stereoscopic motion picture, two images are projected superimposed onto the same screen through different polarizing filters. The viewer wears low-cost glasses which also contain a pair of polarizing filters oriented differently (clockwise/counterclockwise with circular polarization or at 90 degree angles, usually 45 and 135 degrees,[76] with linear polarization). As each filter passes only that light which is similarly polarized and blocks the light polarized differently, each eye sees a different image. This is used to produce a three-dimensional effect by projecting the same scene into both eyes, but depicted from slightly different perspectives. Since no head tracking is involved, the entire audience can view the stereoscopic images at the same time. Resembling sunglasses, RealD circular polarized glasses are now the standard for theatrical releases and theme park attractions. Circular polarization has an advantage over linear polarization, in that the viewer does not need to have their head upright and aligned with the screen for the polarization to work properly. With linear polarization, turning the glasses sideways causes the filters to go out of alignment with the screen filters causing the image to fade and for each eye to see the opposite frame more easily. For circular polarization, the polarizing effect works regardless of how the viewer's head is aligned with the screen such as tilted sideways, or even upside down. The left eye will still only see the image intended for it, and vice versa, without fading or crosstalk. Nonetheless, 3D cinema films are made to be viewed without head tilt, and any significant head tilt will result in incorrect parallax and prevent binocular fusion. In the case of RealD a circularly polarizing liquid crystal filter which can switch polarity 144 times per second is placed in front of the projector lens. Only one projector is needed, as the left and right eye images are displayed alternately. Sony features a new system called RealD XLS, which shows both circular polarized images simultaneously: A single 4K projector (4096×2160 resolution) displays both 2K images (2048×1080 resolution) on top of each other at the same time, a special lens attachment polarizes and projects the images.[77] Optical attachments can be added to traditional 35mm projectors to adapt them for projecting film in the "over-and-under" format, in which each pair of images is stacked within one frame of film. The two images are projected through different polarizers and superimposed on the screen. This is a very cost-effective way to convert a theater for 3-D as all that is needed are the attachments and a non-depolarizing screen surface, rather than a conversion to digital 3-D projection. Thomson Technicolor currently produces an adapter of this type.[78] A metallic screen is necessary for these systems as reflection from non-metallic surfaces destroys the polarization of the light. Polarized stereoscopic pictures have been around since 1936, when Edwin H. Land first applied it to motion pictures. The so-called "3-D movie craze" in the years 1952 through 1955 was almost entirely offered in theaters using linear polarizing projection and glasses. Only a minute amount of the total 3D films shown in the period used the anaglyph color filter method. Linear polarization was likewise used with consumer level stereo projectors. Polarization was also used during the 3D revival of the 1980s. In the 2000s, computer animation, competition from DVDs and other media, digital projection, and the use of sophisticated IMAX 70mm film projectors, have created an opportunity for a new wave of polarized 3D films.[46][47] All types of polarization will result in a darkening of the displayed image and poorer contrast compared to non-3D images. Light from lamps is normally emitted as a random collection of polarizations, while a polarization filter only passes a fraction of the light. As a result, the screen image is darker. This darkening can be compensated by increasing the brightness of the projector light source. If the initial polarization filter is inserted between the lamp and the image generation element, the light intensity striking the image element is not any higher than normal without the polarizing filter, and overall image contrast transmitted to the screen is not affected. Active shutter A pair of LCD shutter glasses used to view XpanD 3D films. The thick frames conceal the electronics and batteries. Main article: Active shutter 3D system In this technology, a mechanism is used to block light from each appropriate eye when the converse eye's image is projected on the screen. The technology originated with the Eclipse Method, in which the projector alternates between left and right images, and opens and closes the shutters in the glasses or viewer in synchronization with the images on the screen.[citation needed] This was the basis of the Teleview system which was used briefly in 1922.[28][79] A newer implementation of the Eclipse Method came with LCD shutter glasses. Glasses containing liquid crystal that will let light through in synchronization with the images on the cinema, television or computer screen, using the concept of alternate-frame sequencing. This is the method used by nVidia, XpanD 3D, and earlier IMAX systems. A drawback of this method is the need for each person viewing to wear expensive, electronic glasses that must be synchronized with the display system using a wireless signal or attached wire. The shutter-glasses are heavier than most polarized glasses, though lighter models are no heavier than some sunglasses or deluxe polarized glasses.[80] However these systems do not require a silver screen for projected images. Liquid crystal light valves work by rotating light between two polarizing filters. Due to these internal polarizers, LCD shutter-glasses darken the display image of any LCD, plasma, or projector image source, which has the result that images appear dimmer and contrast is lower than for normal non-3D viewing. This is not necessarily a usage problem; for some types of displays which are already very bright with poor grayish black levels, LCD shutter glasses may actually improve the image quality. Interference filter technology Main article: Anaglyph 3D § Interference filter systems Dolby 3D uses specific wavelengths of red, green, and blue for the right eye, and different wavelengths of red, green, and blue for the left eye. Glasses which filter out the very specific wavelengths allow the wearer to see a 3D image. This technology eliminates the expensive silver screens required for polarized systems such as RealD, which is the most common 3D display system in theaters. It does, however, require much more expensive glasses than the polarized systems. It is also known as spectral comb filtering or wavelength multiplex visualization The recently introduced Omega 3D/Panavision 3D system also uses this technology, though with a wider spectrum and more "teeth" to the "comb" (5 for each eye in the Omega/Panavision system). The use of more spectral bands per eye eliminates the need to color process the image, required by the Dolby system. Evenly dividing the visible spectrum between the eyes gives the viewer a more relaxed "feel" as the light energy and color balance is nearly 50-50. Like the Dolby system, the Omega system can be used with white or silver screens. But it can be used with either film or digital projectors, unlike the Dolby filters that are only used on a digital system with a color correcting processor provided by Dolby. The Omega/Panavision system also claims that their glasses are cheaper to manufacture than those used by Dolby.[81] In June 2012 the Omega 3D/Panavision 3D system was discontinued by DPVO Theatrical, who marketed it on behalf of Panavision, citing "challenging global economic and 3D market conditions".[82] Although DPVO dissolved its business operations, Omega Optical continues promoting and selling 3D systems to non-theatrical markets. Omega Optical's 3D system contains projection filters and 3D glasses. In addition to the passive stereoscopic 3D system, Omega Optical has produced enhanced anaglyph 3D glasses. The Omega's red/cyan anaglyph glasses use complex metal oxide thin film coatings and high quality annealed glass optics. Autostereoscopy Main article: Autostereoscopy In this method, glasses are not necessary to see the stereoscopic image. Lenticular lens and parallax barrier technologies involve imposing two (or more) images on the same sheet, in narrow, alternating strips, and using a screen that either blocks one of the two images' strips (in the case of parallax barriers) or uses equally narrow lenses to bend the strips of image and make it appear to fill the entire image (in the case of lenticular prints). To produce the stereoscopic effect, the person must be positioned so that one eye sees one of the two images and the other sees the other. Both images are projected onto a high-gain, corrugated screen which reflects light at acute angles. In order to see the stereoscopic image, the viewer must sit within a very narrow angle that is nearly perpendicular to the screen, limiting the size of the audience. Lenticular was used for theatrical presentation of numerous shorts in Russia from 1940 to 1948[71] and in 1946 for the feature-length film Robinson Crusoe.[83] Though its use in theatrical presentations has been rather limited, lenticular has been widely used for a variety of novelty items and has even been used in amateur 3D photography.[84][85] Recent use includes the Fujifilm FinePix Real 3D with an autostereoscopic display that was released in 2009. Other examples for this technology include autostereoscopic LCD displays on monitors, notebooks, TVs, mobile phones and gaming devices, such as the Nintendo 3DS. Health effects Main article: Health effects of 3D Some viewers have complained of headaches and eyestrain after watching 3D films.[86] Motion sickness, in addition to other health concerns,[87] are more easily induced by 3D presentations. One published study shows that of those who watch 3D films, nearly 55% experience varying levels of headaches, nausea and disorientation.[88] There are two primary effects of 3D film that are unnatural for human vision: crosstalk between the eyes, caused by imperfect image separation, and the mismatch between convergence and accommodation, caused by the difference between an object's perceived position in front of, or behind the screen and the real origin of that light on the screen. It is believed that approximately 12% of people are unable to properly see 3D images, due to a variety of medical conditions.[89][90] According to another experiment up to 30% of people have very weak stereoscopic vision preventing them from depth perception based on stereo disparity. This nullifies or greatly decreases immersion effects of digital stereo to them.[91] It has recently been discovered that each of the rods and cones in animal eyes can measure the distance to the point on the object that is in focus at the particular rod or cone. Each rod or cone can act as a passive LIDAR (Light Detection And Ranging). The lens selects the point on the object for each pixel to which the distance is measured; that is, humans can see in 3D separately with each eye.[92] If the brain uses this ability in addition to the stereoscopic effect and other cues no stereoscopic system can present a true 3D picture to the brain. The French National Research Agency (ANR) has sponsored multidisciplinary research in order to understand the effects of 3D film viewing, its grammar, and its acceptance.[93] Criticism After Toy Story, there were 10 really bad CG movies because everybody thought the success of that film was CG and not great characters that were beautifully designed and heartwarming. Now, you've got people quickly converting movies from 2D to 3D, which is not what we did. They're expecting the same result, when in fact they will probably work against the adoption of 3D because they'll be putting out an inferior product.— Avatar director James Cameron[94] Most of the cues required to provide humans with relative depth information are already present in traditional 2D films. For example, closer objects occlude further ones, distant objects are desaturated and hazy relative to near ones, and the brain subconsciously "knows" the distance of many objects when the height is known (e.g. a human figure subtending only a small amount of the screen is more likely to be 2 m tall and far away than 10 cm tall and close). In fact, only two of these depth cues are not already present in 2D films: stereopsis (or parallax) and the focus of the eyeball (accommodation). 3D film-making addresses accurate presentation of stereopsis but not of accommodation, and therefore is insufficient in providing a complete 3D illusion. However, promising results from research aimed at overcoming this shortcoming were presented at the 2010 Stereoscopic Displays and Applications conference in San Jose, U.S.[95] Film critic Mark Kermode[96] argued that 3D adds "not that much" value to a film, and said that, while he liked Avatar, the many impressive things he saw in the film had nothing to do with 3D. Kermode has been an outspoken critic of 3D film describing the effect as a "nonsense" and recommends using two right or left lenses from the 3D glasses to cut out the "pointy, pointy 3D stereoscopic vision", although this technique still does not improve the huge brightness loss from a 3D film.[97] Versions of these "2-D glasses" are being marketed.[98] As pointed out in the article "Virtual Space – the movies of the future"[99][failed verification] in real life the 3D effect, or stereoscopic vision, depends on the distance between the eyes, which is only about 2+1⁄2 inches. The depth perception this affords is only noticeable near to the head – at about arms length. It is only useful for such tasks as threading a needle. It follows that in films portraying real life, where nothing is ever shown so close to the camera, the 3D effect is not noticeable and is soon forgotten as the film proceeds. Director Christopher Nolan has criticised the notion that traditional film does not allow depth perception, saying "I think it's a misnomer to call it 3D versus 2D. The whole point of cinematic imagery is it's three dimensional... You know 95% of our depth cues come from occlusion, resolution, color and so forth, so the idea of calling a 2D movie a '2D movie' is a little misleading."[100] Nolan also criticised that shooting on the required digital video does not offer a high enough quality image[101] and that 3D cameras cannot be equipped with prime (non-zoom) lenses.[100] Late film critic Roger Ebert repeatedly criticized 3D film as being "too dim", sometimes distracting or even nausea-inducing, and argued that it is an expensive technology that adds nothing of value to the film-going experience (since 2-D films already provide a sufficient illusion of 3D).[102] While Ebert was "not opposed to 3-D as an option", he opposed it as a replacement for traditional film, and preferred 2-D technologies such as MaxiVision48 that improve image area/resolution and frames per second.[102] Brightness concerns Most 3D systems will cut down the brightness of the picture considerably – the light loss can be as high as 88%. Some of this loss may be compensated by running the projector's bulb at higher power or using more powerful bulbs.[103] The 2D brightness cinema standard is 14 foot-lamberts (48 candela per square metre), as set by the SMPTE standard 196M. As of 2012[update], there is no official standard for 3D brightness. According to the industry de facto standard, however, the "acceptable brightness range" goes as low as 3.5 fL (12 cd/m2) – just 25% of the standard 2D brightness.[104] Among others, Christopher Nolan has criticized the huge brightness loss: "You're not that aware of it because once you're 'in that world,' your eye compensates, but having struggled for years to get theaters up to the proper brightness, we're not sticking polarized filters in everything."[105] In September 2012, the DCI standards body issued a "recommended practice" calling for a 3D projection brightness of 7 fL (24 cd/m2), with an acceptable range of 5–9 fL (17–31 cd/m2).[2] It is not known how many theaters actually achieve such light levels with current technology. Prototype laser projection systems have reached 14 fL (48 cd/m2) for 3D on a cinema screen.[3] Post-conversion Main article: 2D to 3D conversion Another major criticism is that many of the films in the 21st century to date were not filmed in 3D, but converted into 3-D after filming. Filmmakers who have criticized the quality of this process include James Cameron (whose film Avatar was created mostly in 3D from the ground up, with some portions of the film created in 2D,[106] and is largely credited with the revival of 3D) and Michael Bay.[94] However, Cameron has said that quality 2D to 3D conversions can be done if they take the time they need and the director is involved.[107] Cameron's Titanic was converted into 3D in 2012, taking 60 weeks and costing $18 million. In contrast, computer-animated films for which the original computer models are still available can be rendered in 3D easily, as the depth information is still available and does not need to be inferred or approximated. This has been done with Toy Story, among others.[108] See also Film portal Cinematography Digital cinema List of 3D films (1914–2004) List of 3D films (2005–present) 2D to 3D conversion Depth perception Stereoscopy Autostereoscopy 3D display 3D television 4D film Volumetric display 3-D Film Preservation Fund Motion capture Stereoscopic video game Surround sound 3D formats Digital 3D Disney Digital 3-D RealD 3D Dolby 3D XpanD 3D MasterImage 3D IMAX 3D 4DX References

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(April 2022) (Learn how and when to remove this template message) 4D venue complete with motion-enhanced seating and multisensory olfactory technology. 4D film is a high technology multisensory presentation system combining motion pictures with physical effects that are synchronized and occur in the theatre. Effects simulated in 4D films include motion, vibration, scent, rain, mist, bubbles, fog, smoke, wind, temperature changes, and strobe lights.[1][2] Advanced seats in 4D venues vibrate and move during these multisensory presentations. Other common effects include air jets and water sprays. Auditorium effects may include smoke, rain, lightning, bubbles, and scent. 4D films are exhibited in every major global market in stadium seating multiplexes and are exhibited in theatrical releases.[3] Multinational mobile 4D theatres include Cinetransformer venues.[4] And as of 2022, 4D films are exhibited in more than 65 countries globally.[5] 4D motion pictures are also exhibited in theme parks.[6] History The precursors of the modern 4D film presentation include Sensurround, which debuted in 1974 with the film Earthquake. Only a few films were presented in Sensurround, and it was supplanted by Dolby Stereo in 1977, which featured extended low frequencies and made subwoofers a common addition to a cinema .[7] Other notable efforts at pushing the boundaries of the film viewing experience included Fantasound, the first use of stereo sound, Cinemiracle, and Cinerama, both widescreen formats utilizing multiple projectors. The Sensorium is regarded as the world's first commercial 4D film and was first screened in 1984 at Six Flags Power Plant in Baltimore. It was produced in partnership with Landmark Entertainment.[8] 4DX, D-Box Technologies, and Mediamation all currently integrate 4D technology in global stadium seating multiplexes.[9] List of 4D presentation systems for film theatres The following is a list of 4D presentation systems developed for traditional film theatres. Format Date Developer 3D Format Motion Seat Effects Remarks Notes Source 4DX CJ 4D Plex Stereoscopic 3D yes motion, vibration, scent/olfactory, water sprays, wind/air, snow, fog, strobes, lightning, bubbles Cineworld, Cinépolis D-Box D-Box Technologies Stereoscopic 3D yes motion, vibration Cinemark MX4D MediaMation Stereoscopic 3D yes motion, water sprays, wind/air, snow, fog, strobes, lightning, bubbles Paramount, Showcase [10] 4D E-Motion Lumma Stereoscopic 3D yes motion, vibration, scent/olfactory, water sprays, air shots, wind, strobes, colour lights, fog, bubbles, snow (Not named by developer) Red Rover Stereoscopic 3D yes motion, water sprays, wind/air, scent/olfactory, fog, strobes, bubbles, Branded as Super 4D in Lotte Cinema installations. Selected filmography Title Year Release venue/Country Notes The Scent of Mystery 1960 Specially outfitted general-release theaters Scent/olfactory The Sensorium 1984 Six Flags Power Plant, Baltimore, MD The first 4D film Captain EO 1986 Epcot, Disneyland, Disneyland Paris and Tokyo Disneyland Closed in the mid-late 1990s and reopened in 2010 as a tribute to the late Michael Jackson. Muppet*Vision 3D 1991 Disney's Hollywood Studios Directed by Jim Henson Honey, I Shrunk the Audience 1994 Epcot, Disneyland, Disneyland Paris and Tokyo Disneyland Sponsored by Kodak, closed in all locations in May 2010 and was replaced with Captain EO. Terminator 2 3D: Battle Across Time 1996 Universal Studios Japan Directed by James Cameron Pirates 4D 1997 SeaWorld Ohio, Busch Gardens Williamsburg, Thorpe Park in the UK, Busch Gardens Tampa Bay Produced by Busch Entertainment, Directed by Keith Melton. The Amazing Adventures of Spider-Man 1999 Islands of Adventure, Universal Studios Japan, Water, smoke, strobe, and vibration. PandaDroom 2002 The Efteling, Netherlands Same film released in other parks without 4D effects SpongeBob SquarePants 4-D 2002, 2006 Six Flags over Texas, Moody Gardens, Shedd Aquarium, Adventure Dome, Six Flags Great Adventure, Movie Park Germany, Adventure Aquarium, Kings Dominion, (formerly at Paramount Parks), Indianapolis Zoo, Carowinds, Camden Aquarium (Camden, NJ), Flamingo Land Theme Park and Zoo and other locations Mickey's PhilharMagic 2003 Magic Kingdom, Hong Kong Disneyland, Tokyo Disneyland, and Disney California Adventure. In collaboration with Walt Disney Feature Animation Haunted Lighthouse[a] 2003 Flamingo Land Theme Park and Zoo and Shrek 4-D 2003 Universal Studios Florida, Universal Studios Japan and Universal Studios Singapore Released in an anaglyph version as Shrek 3-D on DVD Borg Invasion 2004 Star Trek: The Experience, at Las Vegas Hilton, USA Closed in 2008, to be reopened in Neonopolis, Las Vegas Fly Me to the Moon 2008 Six Flags over Texas Journey to the Center of the Earth 4-D Adventure 2008 Vibrant 5D, Raipur Stone Mountain Park, Hollywood Warner Bros. Movie World Fly High: The Legend of Black Man 2017 First Indian 4D Film; directed by Rahul Rathish Kumar Avatar in 4D 2009 South Korea, Hong Kong In 4DX. James Cameron, Director London Eye 4D Experience 2009 London Eye Beyond All Boundaries 2009 WWII Museum, New Orleans Produced by Tom Hanks ENERGIA The Spirit of the Earth 2009 Cité de l'énergie, Shawinigan (Quebec) Spectators are seated on a revolving platform. Features wind, snow, smoke, rain, vibration and lighting effects. Marvel Super Heroes 4D 2010 Madame Tussauds London, Trans Studio Bandung[11] Rabid Rider 2010 Cincinnati Zoo Star Tours—The Adventures Continue 2011 Disneyland, Disney's Hollywood Studios, Tokyo Disneyland, & Disneyland Paris Replaced/Replacing Star Tours in all locations. Was updated in late 2015 to add an adventure themed to Star Wars: The Force Awakens[12] Shalem 2011? Jerusalem Time Elevator, Jerusalem A 3000-year-old guide to Jerusalem's history at the Jerusalem Time Elevator, Jerusalem.[13] It includes moving and tilting seats on a moving stage, air conditioning and smell enhancements, along with a 'light and sound' show highlighting real artifacts. A similar system, 'The Time Mine', has been installed at the Timna Valley park near Eilat, and another at the main hall of the Herzl Museum in Jerusalem. Spy Kids: All the Time in the World 2011 United States, India, Canada and UK Smell was achieved by using scratch and sniff cards Transformers: The Ride 2011 Universal Studios Singapore, Universal Studios Hollywood, Universal Studios Florida The Bourne Legacy 2012 Multinational In 4DX Despicable Me: Minion Mayhem 2012 Universal Studios Florida, Universal Studios Japan, and Universal Studios Hollywood 4-minute motion simulator ride, starring Gru, Margo, Edith, Agnes and the Minions; setting is 1 year after the events of the original film in 2010. Tallgrass Prairie: Tides of Time 2012 Flint Hills Discovery Center, Manhattan, Kansas Features wind, snow, smoke, and lighting effects[14] Prometheus 2012 Cinépolis Galerias Guadalajara, Mexico In 4DX. Ridley Scott, Director Titanic 2012 Multinational 4DX re-release,[15] James Cameron, Director The Adventures of Tintin 2011 Nickelodeon Resorts, Paramount Parks, North Carolina Zoo, and Alton Towers 14-minute condensed version of the film. Iron Man 3 2013 Korona World Theatre Nagoya, Japan,[16] Seoul, South Korea Labeled as 4DX featuring strobe lights, tilting seats, blowing wind and fog and scent. Interstellar 2014 Multinational In 4DX. Christopher Nolan, Director Rio 2014 San Diego Zoo, Kentucky Kingdom, North Carolina Zoo, Cincinnati Zoo 12-minute condensed version of the film. Temple Run 7D 2014 India 9-minute ride to various Indian temples including Kedarnath, Badrinath, Gangotri, Rameshwaram, and Dwarka produced by Modern Techno Projects Private Ltd. Star Wars: The Force Awakens 2015 Multinational In 4DX. J.J. Abrams, Director Ice Age: No Time for Nuts 4D 2015 United States 4D-remastered version of the 2006 short film of the same name. Rogue One 2016 Multinational In 4DX Batman v Superman: Dawn of Justice 2016 Seoul, Korea and New York City, New York Labeled as 4DX including fog, wind, motion, rain, lightning, vibrations and scents. Pixels 2016 Taguig, Philippines Labeled as 4DX including models, arcade, explosives, and shoots. Mass Effect: New Earth 4D 2016 California's Great America 4+1⁄2-minute film, 60-foot screen with 4K resolution, live performers, wind, water, leg pokers, neck ticklers, 80-channel surround sound LEGO Nexo Knights 4D: The Book of Creativity[17] 2016 Legoland parks and Legoland Discovery Centre parks worldwide 12+1⁄2-minute 4D film of LEGO Nexo Knights shown at Legoland, along with The LEGO Movie 4D Produced by Alexander Lentjes[18] for M2Film and Merlin Entertainments Gravity 2018 Multinational 4DX re-release,[19] Alfonso Cuarón, Director Life of Pi 2018 Multinational 4DX re-release,[20] Ang Lee, Director 1917 2019 Multinational In 4DX.[21] Sam Mendes, Director, Produced by Amblin Partners Star Wars: The Rise of Skywalker 2019 Multinational In 4DX. J.J. Abrams, Director Gemini Man 2019 Multinational In 4DX. Ang Lee, Director The Lion King 2019 Multinational In 4DX. Jon Favreau, Director Inception 2020 Multinational 4DX re-release,[22] Christopher Nolan, Director The Matrix Resurrections 2021 Multinational In 4DX. Lana Wachowski, Director Canvas 4D Conference 21 2021 Multinational In 4DX. Dr. Laxmikanth Dorai, Entrepreneur and Inventor Top Gun: Maverick 2022 Multinational In 4DX. Tom Cruise, David Ellison, Producers Oppenheimer 2023 Multinational In 4DX. Christopher Nolan, Director[23] See also Film portal Attraction: Flight of Passage List of 4DX motion-enhanced films Tribeca Enterprises Walking simulator Notes ^ Also known as R. L. Stine's Haunted Lighthouse 4-D) References ^ Archived at Ghostarchive and the Wayback Machine: "4DX Cinemas Next Generation - Motion Seats, Wind, Fog, Lighting, Bubbles, Water & Scents". YouTube. ^ Archived at Ghostarchive and the Wayback Machine: "Smelly Screens & Moving Seats At The UK's First 4DX Cinema | Swipe". YouTube. ^ Vourlias, Christopher (2020-01-21). 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As of September 2019[update], CJ 4DPlex operates 678 4DX theaters in 65 countries through partnerships with more than 80 theaters, including Wanda Cinemas, Cineworld, Regal Cinemas, Cinépolis, Event Cinemas, Village Cinemas, and Nu Metro. The company recorded an annual growth rate of more than 50 percent from 2013 to 2018.[2] History South Korea The 4DX technology has made its commercial debut at the CGV Sangam theater in Seoul in 2009.[3] Following the success of Avatar, the technology expanded to more theaters in South Korea.[4] Mexico In June 2011, Mexico-based Cinépolis have invested $25 million and made an agreement with the CJ Group to bring the 4DX technology to its 11 locations in the country, with the first opening in a theater in Mexico City.[5] It marked the technology's debut in the Americas and outside the Asia region, and the technology expanded throughout Mexico since its debut. In 2019, the company announced that they would install the "4DX Screen" theater, a theater with an expanded multi-sided screen with the 4DX theaters, in the country in the summer season of 2020.[6] South America In 2012, Cinépolis has expanded its 4DX reach to South America, opening its first location at a theater in São Paulo, Brazil.[7] The company later premiered the 4DX theater in Colombia at the El Limonar Shopping Center in Cali in July 2013.[8][9] Cine Hoyts (now part of Cinépolis) opened the first 4DX theater in Chile in 2013.[10] United States At CinemaCon in March 2014, CJ 4DPlex announced that it had reached an agreement with AEG and Regal Cinemas to introduce the country's first 4DX auditorium at Regal Cinemas L.A. Live in downtown Los Angeles.[11] In 2018, CJ and Regal's new parent company Cineworld announced that it planned to expand 4DX to at least 79 Regal locations.[12] As of 2020, there is an approximate total of 32 locations throughout the United States, primarily from various Regal locations, one Marcus Theatres location in Gurnee, two Cinépolis locations, and CGV's second U.S. at The Source OC in Buena Park.[13][14][15] Canada Cineplex Entertainment premiered a 4DX auditorium at one of its Toronto locations on 4 November 2016.[16] It opened a second location in Calgary in August 2019.[17] Currently, there are six 4DX locations in Canada. India In India, only few 4DX screens are currently available - PVR Cinemas has ten in Surat, Ahmedabad, Indore, Noida, Hyderabad, Chennai, Bangalore, Kochi, Gurgaon and Mumbai and Cinépolis also has five screens in Thane, Navi Mumbai, Saket and New Delhi. The first 4DX theatre in Kerala was launched at the Lulu International Shopping Mall in Kochi on 20 December 2021 with the release of Spider-Man: No Way Home. Talking to press after signing the agreement, Ajay Bijli, CMD at PVR said, "In a small time since the launch in Noida, 4DX format has outperformed by far all other formats." Japan Since opening its first theater in partnership with Korona World Cinemas in April 2013, the theater chain has seen an increase in the installation of 4DX theaters. It operates 4DX theaters nationwide in partnership with large theater chains such as Aeon Cinemas and United Cinemas.[18] Europe (United Kingdom, France, Austria, Denmark and Romania) In 2015 4dx opened in Romania with a lot of hype since it was the first one.[19] In 2017, CJ 4DPLEX partnered with France's Pathé and Denmark's Nordisk Film Kino to open its first 4DX theater in Europe.[20] It quickened its expansion in Europe by signing partnerships with Austrian theater operator Hollywood Megaplex in February 2017 and Cineworld in the United Kingdom.[21] China CJ 4DPLEX started integrating 4DX within the Chinese market in cooperation with its parent company CJ CGV in 2006. In 2013, it signed contracts with UME, a local theater operator in China. In 2014, CJ 4DPLEX made partnerships with Woosang More, WoMai, Beijing Jinbo, and Golden Harvest. In December 2014, CJ 4DPLEX formed a partnership with Wanda Cinema, a Chinese theater operator.[22] Costa Rica In Costa Rica, the 4DX technology made its commercial debut at Cinépolis in 2014.[23] South Africa In 2015, CJ 4DPLEX and Nu Metro Cinemas entered a partnership to open 5 4DX theaters in South Africa, making its debut in the African continent.[24] It opened the first 4DX auditorium in December that year with the release of Star Wars: The Force Awakens at the V&A Waterfront theater.[25] Australia At CinemaCon 2017, 4DX signed a contract with Australian theater operator Village Cinemas to open its first 4DX theater within a year.[26] It opened at the Century City theater in Melbourne, Victoria on 27 October 2017 with the release of Thor: Ragnarok.[27] It was the first time that the company entered Oceania and the Australian continent, and it made the technology available to all six continents.[28][27] Box office performance In August 2019, 4DX reached 2.7 million moviegoers. The top three performing films for 4DX in August were Fast and Furious Presents: Hobbs & Shaw, The Lion King, and Aladdin. The local films The Bravest and One Piece: Stampede performed well in China and Japan.[29] As of 6 August 2019[update], the top five movie titles of 4DX global box office hits in the first half of 2019 were: Avengers: Endgame ($34,705K) Aladdin ($24,759K) Aquaman ($21,301K) The Lion King ($16,841K) Captain Marvel ($14,133K) In 2018, the company attracted a cumulative 24 million viewers a year, recording $290 million in box office revenue.[citation needed] In July 2019, the company attracted 3.07 million viewers and $38 million in ticket sales globally.[30] Variations 4DX VR The 4DX technology has expanded to virtual-reality, also known as 4DX VR, which utilizes a set of specific 4DX model seats consisting of VR headsets, similar to that of virtual reality amusement rides, and is described to be the "world's first VR theater".[31] First showcased at the AAE 2017 and later IAAPA Attractions Expo 2017, it plays exclusive virtual reality-produced films, short films, as well as games and movie trailers.[32][33] There are at least six versions of the 4DX VR technology brand: Disk for horizontal rotation, Ride which consists of four-to-eight seats on a 6-axis motion-platform, Racing for presentations focused on the racing genre, Sway and Twist in which seats enable twist and side movements, motion-chair which is a singular 4DX chair consisting of the VR headsets, and Sports for sports-focused presentations with specific bike, snowboard, and kayak designs.[32] 4DX Screen The 4DX Screen technology (formerly 4DX with ScreenX) combines the multi-screen projection, known as ScreenX, and the motion-seats in a theater. It was first introduced in 2018 and made its debut in CinemaCon 2018.[34] Both technologies are owned by CJ 4DPLEX. Awards 2014: 4DX won the I3DS (International 3-D and Advanced Imaging Society) "Cinema Innovation of the Year" award.[35] 2015: 4DX won the Edison Awards, Silver Prize for Media and Visual Communication Entertainment Category.[citation needed] 2017: 4DX was chosen as one of "The Most Innovative Companies of 2017" for the Live Events Category by the magazine Fast Company.[36] 2018: 4DX and ScreenX won the Edison Awards, Silver Prize for Media and Visual Communication Entertainment Category.[37][38] 2018: 4DX won the "Innovation Technology of the Year Award" at Big Cine Expo.[39] 2019: 4DX and ScreenX won the iResearch Award, Originative Cinema Technology Category.[40] 2019: 4DX was chosen as one of "The Most Innovative Companies of 2019" for the Live Events Category by Fast Company.[41] Films Further information: List of 4DX motion-enhanced films Gallery 4DX theater in Vietnam. 4DX at a Korona Cinemas theater in Anjō, Japan. 4DX at the Pathé Carré de Soie in Lyon, France. 4D Venue in Los Angeles, United States. 4DX theater at a shopping mall in Salvador, Brazil. 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