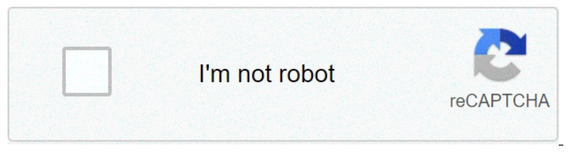


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# Meaning of collinear points

Not to be confused with colinear map or multicollinearity. Look up collinearity or collinear in Wiktionary, the free dictionary. In geometry, collinearity of a set of points is the property of their lying on a single line.[1] A set of points with this property is said to be collinear (sometimes spelled as colinear[2]). In greater generality, the term has been used for aligned objects, that is, things being "in a line" or "in a row". Points on a line In any geometry, the set of points on a line are said to be collinear. In Euclidean geometry this relation is intuitively visualized by points lying in a row on a "straight line". However, in most geometries (including Euclidean) a line is typically a primitive (undefined) object type, so such visualizations will not necessarily be appropriate. A model for the geometry offers an interpretation of how the points, lines and other object types relate to one another and a notion such as collinearity must be interpreted within the context of that model. For instance, in spherical geometry, where lines are represented in the standard model by great circles of a sphere, sets of collinear points lie on the same great circle. Such points do not lie on a "straight line" in the Euclidean sense, and are not thought of as being in a row. A mapping of a geometry to itself which sends lines to lines is called a collineation; it preserves the collinearity property. The linear maps (or linear functions) of vector spaces, viewed as geometric maps, map lines to lines; that is, they map collinear point sets to collinear point sets and so, are collineations. In projective geometry these linear mappings are called homographies and are just one type of collineation. Examples in Euclidean geometry Triangles In any triangle the following sets of points are collinear: The orthocenter, the circumcenter, the centroid, the Exeter point, the de Longchamps point, and the center of the nine-point circle are collinear, all falling on a line called the Euler line. The de Longchamps point also has other collinearities. Any vertex, the tangency of the opposite side with an excircle, and the Nagel point are collinear in a line called a splitter of the triangle. The midpoint of any side, the point that is equidistant from it along the triangle's boundary in either direction (so these two points bisect the perimeter), and the center of the Spieker circle are collinear in a line called a cleaver of the triangle. (The Spieker circle is the incircle of the medial triangle, and its center is the center of mass of the perimeter of the triangle.) Any vertex, the tangency of the opposite side with the incircle, and the Gergonne point are collinear. From any point on the circumcircle of a triangle, the nearest points on each of the three extended sides of the triangle are collinear in the Simson line of the point on the circumcircle. The lines connecting the feet of the altitudes intersect the opposite sides at collinear points.[3]:p.199 A triangle's incenter, the midpoint of an altitude, and the point of contact of the corresponding side with the excircle relative to that side are collinear.[4]:p.120,#78 Menelaus' theorem states that three points $P_1$, $P_2$, $P_3$ on the sides (some extended) of a triangle opposite vertices $A_1$, $A_2$, $A_3$ respectively are collinear if and only if the following products of segment lengths are equal:[3]:p. 147 $P_1A_2 \cdot P_2A_3 \cdot P_3A_1 = P_1A_3 \cdot P_2A_1 \cdot P_3A_2$. $P_1A_2\cdot P_2A_3\cdot P_3A_1=P_1A_3\cdot P_2A_1\cdot P_3A_2$. The incenter, the centroid, and the Spieker circle's center are collinear. The circumcenter, the Brocard midpoint, and the Lemoine point of a triangle are collinear.[5] Two perpendicular lines intersecting at the orthocenter of a triangle each intersect each of the triangle's extended sides. The midpoints on the three sides of these points of intersection are collinear in the Droz–Farny line. Quadrilaterals In a convex quadrilateral ABCD whose opposite sides intersect at E and F, the midpoints of AC, BD, and EF are collinear and the line through them is called the Newton line (sometimes known as the Newton-Gauss line[citation needed]). If the quadrilateral is a tangential quadrilateral, then its incenter also lies on this line.[6] In a convex quadrilateral, the quasiorthocenter H, the "area centroid" G, and the quasicircumcenter O are collinear in this order, and HG = 2GO.[7] (See Quadrilateral#Remarkable points and lines in a convex quadrilateral.) Other collinearities of a tangential quadrilateral are given in Tangential quadrilateral#Collinear points. In a cyclic quadrilateral, the circumcenter, the vertex centroid (the intersection of the two bimedians), and the anticenter are collinear.[8] In a cyclic quadrilateral, the area centroid, the vertex centroid, and the intersection of the diagonals are collinear.[9] In a tangential trapezoid, the tangencies of the incircle with the two bases are collinear with the incenter. In a tangential trapezoid, the midpoints of the legs are collinear with the incenter. Hexagons Pascal's theorem (also known as the Hexagrammum Mysticum Theorem) states that if an arbitrary six points are chosen on a conic section (i.e., ellipse, parabola or hyperbola) and joined by line segments in any order to form a hexagon, then the three pairs of opposite sides of the hexagon (extended if necessary) meet in three points which lie on a straight line, called the Pascal line of the hexagon. The converse is also true: the Braikenridge–Maclaurin theorem states that if the three intersection points of the three pairs of lines through opposite sides of a hexagon lie on a line, then the six vertices of the hexagon lie on a conic, which may be degenerate as in Pappus's hexagon theorem. Conic sections By Monge's theorem, for any three circles in a plane, none of which is completely inside one of the others, the three intersection points of the three pairs of lines, each externally tangent to two of the circles, are collinear. In an ellipse, the center, the two foci, and the two vertices with the smallest radius of curvature are collinear, and the center and the two foci, and the two vertices are collinear. In a hyperbola, the center, the two foci, and the two vertices are collinear. Cones The center of mass of a conic solid of uniform density lies one-quarter of the way from the center of the base to the vertex, on the straight line joining the two. Tetrahedrons The centroid of a tetrahedron is the midpoint between its Monge point and circumcenter. These points define the Euler line of the tetrahedron that is analogous to the Euler line of a triangle. The center of the tetrahedron's twelve-point sphere also lies on the Euler line. Algebra Collinearity of points whose coordinates are given In coordinate geometry, in n-dimensional space, a set of three or more distinct points are collinear if and only if, the matrix of the coordinates of these vectors is of rank 1 or less. For example, given three points $X = (x1, x2, \ldots, xn)$, $Y = (y1, y2, \ldots, yn)$, and $Z = (z1, z2, \ldots, zn)$, if the matrix $[\, x\,1\ x\,2\ \ldots\ x\,n\ y\,1\ y\,2\ \ldots\ y\,n\ z\,1\ z\,2\ \ldots\ z\,n\,]$ {\displaystyle {\begin{bmatrix}x_{1}&x_{2}&\dots &x_{n}\\y_{1}&y_{2}&\dots &y_{n}\\z_{1}&z_{2}&\dots &z_{n}\end{bmatrix}}} is of rank 1 or less, the points are collinear. Equivalently, for every subset of three points $X = (x1, x2, \ldots, xn)$, $Y = (y1, y2, \ldots, yn)$, and $Z = (z1, z2, \ldots, zn)$, if the matrix $[\, 1\ x\,1\ x\,2\ \ldots\ x\,n\ 1\ y\,1\ y\,2\ \ldots\ y\,n\ 1\ z\,1\ z\,2\ \ldots\ z\,n\,]$ {\displaystyle {\begin{bmatrix}1&x_{1}&x_{2}&\dots &x_{n}\\1&y_{1}&y_{2}&\dots &y_{n}\\1&z_{1}&z_{2}&\dots &z_{n}\end{bmatrix}}} is of rank 2 or less, the points are collinear. In particular, for three points in the plane (n = 2), the above matrix is square and the points are collinear if and only if its determinant is zero; since that $3 \times 3$ determinant is plus or minus twice the area of a triangle with those three points as vertices, this is equivalent to the statement that the three points are collinear if and only if the triangle with those points as vertices has zero area. Collinearity of points whose pairwise distances are given A set of at least three distinct points is called straight, meaning all the points are collinear, if and only if, for every three of those points A, B, and C, the following determinant of a Cayley–Menger determinant is zero (with d(AB) meaning the distance between A and B, etc.): $\det \begin{bmatrix} 0 & d(AB)^2 & d(AC)^2 & 1 \\ d(AB)^2 & 0 & d(BC)^2 & 1 \\ d(AC)^2 & d(BC)^2 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix} = 0$. {\displaystyle \det {\begin{bmatrix}0&d(AB)^{2}&d(AC)^{2}&1\\d(AB)^{2}&0&d(BC)^{2}&1\\d(AC)^{2}&d(BC)^{2}&0&1\\1&1&1&0\end{bmatrix}}=0.} This determinant is, by Heron's formula, equal to −16 times the square of the area of a triangle with side lengths d(AB), d(BC), and d(AC); so checking if this determinant equals zero is equivalent to checking whether the triangle with vertices A, B, and C has zero area (so the vertices are collinear). Equivalently, a set of at least three distinct points are collinear if and only if, for every three of those points A, B, and C with d(AC) greater than or equal to each of d(AB) and d(BC), the triangle inequality $d(AC) \leq d(AB) + d(BC)$ holds with equality. Number theory Two numbers m and n are not coprime—that is, they share a common factor other than 1—if and only if for a rectangle plotted on a square lattice with vertices at (0, 0), (m, 0), (m, n), and (0, n), at least one interior point is collinear with (0, 0) and (m, n). Concurrency (plane dual) In various plane geometries the notion of interchanging the roles of "points" and "lines" while preserving the relationship between them is called plane duality. Given a set of collinear points, by plane duality we obtain a set of lines all of which meet at a common point. The property that this set of lines has (meeting at a common point) is called concurrency, and the lines are said to be concurrent lines. Thus, concurrency is the plane dual notion to collinearity. Collinearity graph Given a partial geometry P, where two points determine at most one line, a collinearity graph of P is a graph whose vertices are the points of P, where two vertices are adjacent if and only if they determine a line in P. Usage in statistics and econometrics Main article: Multicollinearity In statistics, collinearity refers to a linear relationship between two explanatory variables. Two variables are perfectly collinear if there is an exact linear relationship between the two, so the correlation between them is equal to 1 or −1. That is, $X_1$ {\displaystyle X_{1}} and $X_2$ {\displaystyle X_{2}} are perfectly collinear if there exist parameters $\lambda_0$ {\displaystyle \lambda _{0}} and $\lambda_1$ {\displaystyle \lambda _{1}} such that, for all observations i, we have $X_{2i}=\lambda _{0}+\lambda _{1}X_{1i}.$ {\displaystyle X_{2i}=\lambda _{0}+\lambda _{1}X_{1i}.} This means that if the various observations (X1i, X2i ) are plotted in the (X1, X2) plane, these points are collinear in the sense defined earlier in this article. Perfect multicollinearity refers to a situation in which k (k ≥ 2) explanatory variables in a multiple regression model are perfectly linearly related, according to $X_{ki}=\lambda _{0}+\lambda _{1}X_{1i}+\lambda _{2}X_{2i}+\cdots +\lambda _{k-1}X_{(k-1),i}$ {\displaystyle X_{ki}=\lambda _{0}+\lambda _{1}X_{1i}+\lambda _{2}X_{2i}+\cdots +\lambda _{k-1}X_{(k-1),i}} for all observations i. In practice, we rarely face perfect multicollinearity in a data set. More commonly, the issue of multicollinearity arises when there is a "strong linear relationship" among two or more independent variables, meaning that $X_{ki}=\lambda _{0}+\lambda _{1}X_{1i}+\lambda _{2}X_{2i}+\cdots +\lambda _{k-1}X_{(k-1)}+\varepsilon _{i}$ {\displaystyle X_{ki}=\lambda _{0}+\lambda _{1}X_{1i}+\lambda _{2}X_{2i}+\cdots +\lambda _{k-1}X_{(k-1)}+\varepsilon _{i}} where the variance of $\varepsilon_i$ {\displaystyle \varepsilon _{i}} is relatively small. The concept of lateral collinearity expands on this traditional view, and refers to collinearity between explanatory and criteria (i.e., explained) variables.[10] Usage in other areas Antenna arrays An antenna mast with four collinear directional arrays. In telecommunications, a collinear (or co-linear) antenna array is an array of dipole antennas mounted in such a manner that the corresponding elements of each antenna are parallel and aligned, that is they are located along a common line or axis. Photography The collinearity equations are a set of two equations, used in photogrammetry and computer stereo vision, to relate coordinates in an image (sensor) plane (in two dimensions) to object coordinates (in three dimensions). In the photography setting, the equations are derived by considering the central projection of a point of the object through the optical centre of the camera to the image in the image (sensor) plane. The three points, object point, image point and optical centre, are always collinear. Another way to say this is that the line segments joining the object points with their image points are all concurrent at the optical centre.[11] See also Pappus's hexagon theorem No-three-in-line problem Incidence (geometry)#Collinearity Coplanarity Notes ^ The concept applies in any geometry Dembowski (1968, pg. 26), but is often only defined within the discussion of a specific geometry Coxeter (1969, pg. 178), Brannan, Esplen & Gray (1998, pg.106) ^ Colinear (Merriam-Webster dictionary) ^ a b Johnson, Roger A., Advanced Euclidean Geometry, Dover Publ., 2007 (orig. 1929). ^ Altshiller-Court, Nathan. College Geometry, Dover Publications, 1980. ^ Scott, J. A. 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Journal of the Association for Information Systems. 13 (7): 546–580. ^ It's more mathematically natural to refer to these equations as concurrency equations, but photogrammetry literature does not use that terminology. References Brannan, David A.; Esplen, Matthew F.; Gray, Jeremy J. (1998), Geometry, Cambridge: Cambridge University Press, ISBN 0-521-59787-0 Coxeter, H. S. M. (1969), Introduction to Geometry, New York: John Wiley & Sons, ISBN 0-471-50458-0 Dembowski, Peter (1968), Finite geometries, Ergebnisse der Mathematik und ihrer Grenzgebiete, Band 44, Berlin, New York: Springer-Verlag, ISBN 3-540-61786-8, MR 0233275 Retrieved from " 2Form of computer-aided engineering This article is about computer modeling within an artistic medium. For scientific usage, see Computer simulation. 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 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. Outline The product is called a 3D model. Someone who works with 3D models may be referred to as a 3D artist or a 3D modeler. A 3D Model can also be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. 3D Models may be created automatically or manually. The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting. The 3D model can be physically created using 3D printing devices that form 2D layers of the model with three-dimensional material, one layer at a time. Without a 3D model, a 3D print is not possible.[7] 3D modeling software is a class of 3D computer graphics software used to produce 3D models. 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. 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.[10][11] Representation A modern render of the iconic Utah teapot model developed by Martin Newell (1975). 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 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 and because computers can render them so quickly. However, polygons are planar and can only approximate curved surfaces using many polygons. Curve modeling – Surfaces are defined by curves, which are influenced by weighted control points. The curve follows (but does not necessarily interpolate) the points. Increasing the weight for a point will pull the curve closer to that point. Curve types include 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. [citation needed] There are currently three types of digital sculpting: Displacement, which is the most widely used among applications at this moment, uses a dense model (often generated by subdivision surfaces of a polygon control mesh) and stores new locations for the vertex positions through use of an image map that stores the adjusted locations. Volumetric, loosely based on voxels, has similar capabilities as displacement but does not suffer from polygon stretching when there are not enough polygons in a region to achieve a deformation. Dynamic tessellation,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., Cinema 4D, Maya, 3ds Max, Blender, LightWave, Modo) 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, 3DF Zephyr, and Meshroom. 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.[13] 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.[14] 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[15] 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 The first company to sell 3D models was Viewpoint (Orem, UT), founded by John Wright in 1988. John's first digitized 3D model was a car made in 1984 using Movie.byu on a HP 9000 computer. The first 3D model "Catalog" was made for Wallace Colvard in 1990 who was working for NBC to create the first football and helmet for a new super bowl 3d animation commercial called "Bud Bowl". Wallace called John and asked if Viewpoint had a 3d Football in their "catalog". Viewpoint didn't have a catalog, so John and his team quickly made the first catalog of 3D objects which included just a few 3D objects and "faxed" it to Wallace. Viewpoint's 3D model business grew to over $6 million in sales by 1998 and their models are still showing in thousands of movies (Total Recall, Independence Day, Antz, etc.) 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, 3DBaza, CGStudio, CreativeMarket, 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 specialized in 3D printing models have emerged. Some of the 3D printing marketplaces are 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, etc. 3D printing file sharing 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.[16] 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.[16][17] 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. 3D models can be purchased from online marketplaces and printed by individuals or companies using commercially available 3D printers, enabling the home-production of objects such as spare parts and even medical equipment.[18][19] 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.[20] They are also used in the medical industry to create interactive representations of anatomy.[21] 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.[22] The architecture industry uses them to demonstrate proposed buildings and landscapes in lieu of traditional, physical architectural models. 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: 1. A designer, industrial engineer or artist using a 3D-CAD system 2. An existing object, reverse engineered or copied using a 3-D shape digitizer or scanner 3. Mathematical data stored in memory based on an numerical description or calculation the object.[16] 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.[23][24] 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).[25] 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.[26] 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 need 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 This section is in list format, but may read better as prose. You can help by converting this section, if appropriate. Editing help is available. (November 2016) 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 Evolver 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 External links Look up modeler in Wiktionary, the free dictionary. Media related to 3D modeling at Wikimedia Commons 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. 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