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FUNDAMENTALS AND APPLICATIONS OF 3D TECHNOLOGY

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The term "3D modeling" encompasses the utilization of specialized software to craft a three-dimensional depiction of an object. This representation, known as a 3D model, has the ability to convey the dimensions, structure, and texture of the object, whether it be an existing product or a conceptual design yet to materialize in the physical world. To delve deeper into the concept of "what is 3D modeling?" read on.

Within the realm of the construction industry, 3D models of construction sites prove instrumental in the management of machinery. These representations incorporate the actual environment's points, lines, and surfaces, utilizing coordinate data to indicate the horizontal and vertical positions in relation to a reference point. The spatial linkages inherent in these representations allow for viewing from diverse perspectives.

Machine control employs an array of positioning sensors to provide input on parameters such as target grades and the position of a bucket or blade to machine operators. The 3D model serves as a tool for machine operators to verify the accuracy of their work. Workers can locate the replica's points in the field through GPS technology, and machine sensors can relay information about their positioning relative to the model's points.

These control techniques aid teams in translating the 3D model into reality by guiding equipment to precisely replicate the lines, points, and surfaces specified in the model. Beyond construction, 3D models find applications in project evaluations, design assessments, and environmental compliance analyses conducted by various teams. Particularly advantageous in pre-bidding scenarios, these models enable contractors to explore multiple designs and articulate their concepts effectively.

The roots of 3D modeling can be traced back to the 1960s, where it was initially confined to professionals in engineering and automation due to limited access and high costs of mathematical modeling software. The complexity of the modeling process and its exclusive reliance on mathematical models hindered broader engagement, particularly for artists.

The landscape changed with the introduction of Sketchpad by American engineer Ivan Sutherland in the early 1960s. Serving as one of the earliest graphical user interfaces, Sketchpad revolutionized the visualization and control of program functions. This innovation laid the foundation for computer graphics, operating systems, software interfaces, and subsequently influenced the entire 3D graphics industry.

Sutherland developed the first version of Sketchpad in 1961, running on the TX-2 computer at MIT. His doctoral thesis, "Sketchpad: A Man-Machine Graphical Communication System," published in 1963, marked a milestone in 3D modeling. Following this success, Sutherland and David Evans established the first department of computer technologies at the University of Utah, recruiting talented students, including Edwin Catmull, later the founder of Pixar Animation Studios.

In 1968, Evans & Sutherland, the first 3D graphics company, was founded, paving the way for the democratization of the 3D graphics industry. Sketchpad's influence extended to imaging software, including CAD and modeling programs.

The 1970s witnessed the rise of computer graphics companies, and the automated design and drafting system ADAM contributed to the proliferation of 3D software. The era of rendering, symbolized by Martin Newell's "Utah Teapot," characterized this period.

The 1980s marked the widespread adoption of 3D modeling, with IBM's launch of the first personal computer in 1981 and the emergence of CAD as a standard practice in various industries. UniSolids CAD software by Unigraphics and AutoCAD, a revolutionary 2D drafting software, played pivotal roles during this decade.

The 1990s witnessed the modernization of 3D modeling software, becoming a standard practice in designing products across industries. Falling prices made the software accessible to companies, freelancers, and hobbyists. The introduction of freemium business models and free software like Blender increased the popularity of 3D modeling among users of all levels. Towards the end of the decade, software companies adapted to the emerging technology of 3D printing, leading to the development of dedicated applications.

Post-2000s, 3D modeling and CAD software continued to evolve positively, offering a diverse range of applications for different users and budgets. The development of cloud-based systems allowed global access to files and accounts from various devices. Today, there is a plethora of software options, and formal courses are available to educate users of all types on software usage.

3D replicas, a widely utilized technological form, find application across various industries. Numerous sectors leverage 3D modeling for a multitude of purposes. Some notable applications include:

Architectural Visualization for Building Planning:

Employing 3D modeling aids in the planning of structures through architectural visualization.

Real Estate Sector for 3D Tours:

The real estate sector utilizes 3D modeling to provide immersive 3D tours, enhancing property exploration.

Entertainment Industry for Games and Movies:

3D modeling plays a crucial role in the creation of video games and movies, contributing to realistic visual experiences.

Academic Research:

Academic research extensively utilizes 3D modeling for various applications, contributing to diverse fields of study.

In the construction industry, where new techniques are continually emerging, 3D models serve multiple functions. Below are some ways in which 3D models are applied in construction:

Enhanced Machine Control:

3D modeling facilitates precise, efficient, and cost-effective machine control. Machine operators, guided by on-board computers and GPS devices, can visualize the job site on a screen within the cab. Sensors and a GPS system guide the machine based on the measurements from the 3D model.

Site Layout Communication:

3D models prove beneficial for communicating site layout, including the placement of utility equipment and landscaping elements. Electricians, for instance, can use 3D models to quickly and accurately set up electrical connections, while mapping other utilities provides crews with confidence about equipment placement.

Progress Reports and As-Builts:

3D models are instrumental in conveying project progress and generating as-builts, revised drawings submitted upon project completion. Regular updates to the 3D model throughout an assignment allow for a dynamic representation of the evolving site. Post-project, the 3D model becomes a valuable resource for ongoing facility maintenance, operations, and asset management.

For example, let's look at the stages of developing a model that will not be used in game development or studios.

In the field of three-dimensional computer graphics, four main stages can be distinguished, which are necessary to obtain the finished product: 1. Modeling - creating objects that will be present in the scene. 2. Material Usage - defining surface properties of objects to simulate various real-world characteristics (color, texture, transparency, brightness, etc.). 3. Lighting - adding and placing light sources similar to what is done in a theater studio or on a film set. 4. Visualization - generating images based on models, materials, and lighting.

If the project involves creating animation, modeled characters can act as animated elements. Additionally, it's possible to change the position of objects in the scene, alter their sizes, shapes, or materials. Animation of the camera can also be created, resulting in a sequence of shots depicting the created scene from various angles.

Modeling based on primitives. Primitives are basic parametric shapes such as cubes, spheres, and pyramids. When visualized, objects like spheres are transformed into polygons, but the resulting surface appears much smoother. The smoothing effect is achieved through special shading algorithms.

Objects based on sections are named by analogy with the method used in shipbuilding, involving "stretching" a surface onto arbitrary sections. Sections or flat forms are two-dimensional objects. When creating three-dimensional objects, several forms are arranged along a certain path.

Modeling based on Boolean operations. Boolean objects are created by adding, subtracting, and intersecting overlapping surfaces.

Surface modeling is based on creating arbitrary surfaces. Various mathematical models are used in creating surfaces, leading to different modeling techniques. Polygonal meshes, editable grids - complex models created from multiple polygonal surfaces smoothed during visualization. Polygonal modeling involves manipulating vertices, edges, and faces directly.

Patches are built based on splines (smooth curves) and can be modified using control points. The spline elements are arranged along the edges of the surface being created. Non-uniform rational B-splines (NURBS) - a technology designed for creating smooth shapes and models. It is based on a special mathematical apparatus. Unlike patch modeling, control points in NURBS modeling can influence any local area of the surface.

Surface modeling based on spline grids. A set of splines, a kind of framework, is created, based on which the surface is formed.

At this stage, the surfaces of models are given the appearance of real materials. Only then will the models look as realistic as possible. They will acquire the appearance of wood, metal, plastic, etc. The surface may become reflective or transparent. For this purpose, in any 3D modeling program, there are material editors with ready-made sets of materials or tools to develop custom materials. In 3ds Max, the Material Editor is one of the most important modules of the program.

Color is one of the simplest material properties. However, even color usage has many aspects. Color can be primary, defining the coverage of the entire object, ambient, affecting the influence of ambient lighting, specular, defining the color of the brightest spots on the shiny surface, etc.

In the process of creating materials, texture maps are widely used, which are either raster images of real objects or procedurally generated images. Several texture maps can be used in the process of creating a material.

Precise placement of material on the surface of an object is achieved through so-called mapping coordinates (UVW Map), where the raster image is interactively placed on the object's surface.

Skillful use of materials can save a lot of time and achieve excellent results. For example, windows or balcony grids can be modeled using polygons or other methods, or a material based on raster images can be applied to primitive objects like Box.Texture maps are successfully used to give a sense of relief and volume to the surface. Relief is achieved through differences in color brightness, similar to embossing.When creating materials, properties of the object such as reflection, refraction, and opacity are defined. Moreover, not only how the surface reacts to light can be set but also the necessary properties of reflected light and its intensity. Much of this is determined by mathematical algorithms that implement these effects.

Creating transparent objects using materials allows control over the properties of refracted light. Skillful use of materials allows achieving excellent results. This requires skills not only of an engineer but also of an artist.

Lighting. The best lighting should be almost subconscious: present but not intrusive.

It emphasizes the properties of the scene created through modeling and material usage. Lighting sets the mood for the entire scene. Specialists study lighting properties in architecture, but certain skills can be acquired through the study of artistic photography and cinematography.

Visualization.Visualization is the final stage of working on the modeled scene. At this stage, the computer converts the mathematical model of the scene into a form suitable for visual perception. This process is called rendering. In English, there is the word "visualization," but it has a broader meaning. Only during the rendering stage in 3ds Max do all the properties of object materials, light sources, and effects applied within the scene become visible.

The scenes created can be visualized with different degrees of accuracy. Various visualization mechanisms are used to achieve different qualities, but they are executed at different speeds. Additionally, the performance of the computer and the parameters of the graphics card play a significant role at this stage.

Ray Tracing and Photon Mapping.The most common method for generating realistic images is ray tracing. When building an image, a ray is sent in a specified direction to assess the incoming light energy from that direction. This energy is determined by the illumination of the first surface encountered by the ray.

Ray tracing provides good results and allows for reflection and refraction calculations. Despite its popularity and efficiency, there are several physical phenomena that it poorly represents or does not represent at all. For instance, effects such as diffused reflections (the color tone from a mahogany dresser on a white rug) and focused light (glints from water at the bottom of a pool).

Photon Mapping is an extension of the ray tracing method that offers solutions for such situations. By utilizing photon maps alongside ray tracing, the method efficiently simulates all types of direct and indirect lighting. Furthermore, Photon Mapping accounts for the influence of the medium through which light propagates. The algorithm of Photon Mapping operates as follows: photons are emitted from light sources, and then photon tracing occurs with subsequent information storage on the photon map.

In 3ds Max, both methods are used: ray tracing by default and a specialized mental ray renderer augmented with photon mapping. A few words about the terminology used in material descriptions for the mental ray renderer. In mental ray, a shader is generally referred to as an algorithm that calculates a specific surface property of an object. A complex combination of shaders describing various surface properties in mental ray is called phenomena.

Conclusion**.** In conclusion, the versatility of 3D models extends across a spectrum of industries, serving diverse purposes from architectural planning to immersive real estate experiences and entertainment production. The construction sector, in particular, benefits significantly from 3D modeling applications, with advancements in machine control enhancing accuracy and cost- effectiveness. The use of 3D models in site layout communication proves invaluable for coordinating utility placements and landscaping elements, optimizing efficiency in various construction processes. Furthermore, the integration of 3D models into progress reports and as-builts offers a dynamic and comprehensive approach to project documentation, ensuring that stakeholders have accurate representations throughout a project's lifecycle. As technology continues to evolve, the role of 3D modeling in various fields, especially in construction and beyond, is poised to expand, providing innovative solutions and contributing to the continual advancement of industries.

List of sources used

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